# The Potential for Using Composted Municipal Waste in Agriculture:

## The case of Accra, Ghana

A.H. Hofny-Collins
*Faculty of Natural Resources and Agricultural Sciences*
*Department of Urban and Rural Development*
*Uppsala*

**Doctoral thesis**
**Swedish University of Agricultural Sciences**
**Uppsala 2006**

**Acta Universitatis Agriculturae Sueciae**
2006:65

ISSN 1652-6880
ISBN 91-576-7114-1

Tryck: SLU Service/Repro, Uppsala 2006

# Abstract

Hofny-Collins, Anna. 2006. *The Potential for using Composted Municipal Waste in Agriculture: The case of Accra, Ghana.*
Doctoral Dissertation. ISSN: 1652-6880, ISBN: 91-576-7114-1.

This thesis addresses the relationship between urban waste and agriculture using an interdisciplinary systems approach. The environmental, economic, socio-cultural and political potential for using municipal waste compost (MWC) in urban and peri-urban agriculture in Accra, Ghana, was explored from different stakeholder perspectives and scales of enquiry. A pluralistic methodology was used in order to address different parts of the research and a critical reflection was made by the researcher on the carrying out of interdisciplinary research using these approaches.

Waste management and composting practices were studied, as was urban and peri-urban agricultural systems. A series of farmer participatory experiments were carried out with urban vegetable growers to test the effects of using MWC from two different composting plants in Accra alongside current farmers' practices. The perspectives of different stakeholders were also assessed through a combination of methods, including semi structured and informal interviews, participatory appraisal techniques, formal surveys, group discussions and workshops.

Compost quality assessments revealed that the compost from the small-scale James Town plant was of higher quality than that produced at the large-scale Teshie/Nungua plant. Compost applications had a positive effect on crop growth. However, vegetable producers primarily used chicken manure as a fertility input and compared to this, the compost was inferior, particularly in relation to crop establishment and in creating a higher water demand. The growers were happy with the crop performance from compost, but saw the watering issue as a potential problem. They agreed that compost would be an attractive alternative during the rainy season. They also liked the fact that they did not need to apply compost to each crop, as they did with chicken manure.

Whilst, growers would be willing to use and pay for MWC, both composts were too expensive to represent a viable alternative to other fertility inputs. However, given an appropriate blend of public-private-community partnerships and scales of operation which could harness opportunistic alignments between the needs of different actors, composting and its use in agriculture has potential in contributing towards sustainable development in the urban environment of Accra. With some modest policy support, the possibilities for improving quality and financial viability are considerable. Providing quality and price can meet the needs of growers, there is a market for MWC in Accra.

*Keywords:* systems thinking, participatory, farmer experimentation, adaptive management, urban agriculture, municipal waste compost, waste management, Accra, Ghana

**Author's address**: 103 Valkyrie Road, Westcliff-on-Sea, Essex, SS0 8AW, England
Email: hofnycollinsa@hotmail.com

# Acknowledgement

It seems like a lifetime since I stared this Ph.D. In fact, in my son's world it is; when I started he was only a few weeks old. He has never known anything different than having a mother who is working on writing her thesis. People refer to it as a journey, and I agree. It becomes a way of life, a way of thinking and being. I have many people to thank, people who have contributed directly or indirectly to the completion of this work and I am very grateful to them all.

First of all I would like to thank David Gibbon, for being a source of inspiration and for supervising my Ph.D. He was one of the key people who awoke my interest in farming systems research and sustainable development during my years as an undergraduate and instrumental in encouraging me to embark on Ph.D. studies. When I years later decided to do a Ph.D. he became my supervisor and has been nothing but supportive throughout, in spite of institutional changes and moves that has taken place. I appreciate that he continued supervising me when he moved to the UK as I do SLU for providing the financial arrangements to enable the supervision to be continued. Over the years David has been a supervisor, mentor and friend and I value him greatly.

I am also immensely grateful to Janice Jiggins for the encouragement and invaluable insights she offered me early on when developing my thoughts about the research and for hours spent reading and editing drafts in the latter stages. I consider myself very lucky to have had her input; her perceptive comments, critical feedback and unfaltering encouragement. She has been an inspiration and helped me to keep going at times when I came close to giving up. Thank you Janice!

I would also like to thank several people at HDRA in the UK, where I worked before I started the Ph.D. and where the Ph.D. topic was first conceived. During the early stages of conceptualisation, the support and guidance from both Phil Harris and Margi Lennartsson were very helpful. Later, during the implementation and early data analysis stages I had help from Sandra Bywater, Francis Rayns and Margi. Thank you all!

I would also like to acknowledge the financial support I received from SAREC that enabled the fieldwork in Ghana to take place. In Ghana there are several people I would like to extend my thanks to:

The vegetable growers for allowing me to share their situation and get a glimpse of their lives and for taking the risk to experiment even though they had such limited land at their disposal. They always made me feel welcome and I greatly enjoyed the time spent with them.

Addo Kwaku for making the on-farm trial a success and for inviting me to meet his family and friends and attend numerous family events. Always positive and happy and great company! To Sowah too for his dedication and reliability.

Bertha Gana at the Ministry of Agriculture for her generosity in welcoming me into her home and for your friendship and support.

Sodey, for competent, reliable work with the vegetable growers and for being a good friend. Without her the vegetable growers' experiments would not have been possible.

I also have a particular debt of gratitude to Pieter Wisse Klaassen (Growth) for helpful guidance and encouragement and for taking me under his wing. Both he and his wife Ann-Christine contributed to adding quality to my time spent in Ghana. Similar gratitude is extended to Dagmar Kunze (FAO).

Special thanks too to Marlene Belder (FAO) for generous advice and assistance in soil Sampling, Dr Alorvov (Ministry of Agriculture) for going out of his way to assist me in the poultry study, Mr Awuye (WMD) for always being accommodating, Patsy (DFID) for hospitality and informative chats on governance issues and Pay Drechsel (IBSRAM) for guidance and assistance in the early stages of my fieldwork.

I would also like to express my gratitude to:

Phil Brookes at Rothamsted Experimental Station, UK, for generous assistance with issues relating to trial design. Janet Riley at Rothamsted Experimental Station, UK, for devoting considerable time and effort on assisting me with statistical analysis. Gary Travell for spending hours helping me to scan and stitch maps and for offering IT support on numerous occasions.

At SLU I would like to thank my fellow Ph.D. students for stimulating discussions, constructive feedback and friendship. Thank you Seema, Niel, Chrissy, Cathy, Rebecka, Petra, Atakilte, Belaineh, Nonto, Johan, Emil, Malin, Cecilia, Mats and Kristina. I also greatly appreciate the hospitality shown to me by Niel and Stina and by Seema and Stefan at times when I visited Uppsala after I moved back to the UK.

To my parents-in law, Olive and George, without whose constant and generous support I probably would not have been able to complete this thesis. Their willingness to drop everything to make themselves available to look after the family on countless occasions when I needed periods of extended concentration to write, has left me feeling immensely grateful. You have been absolutely fantastic. Thank you both!

To my husband Mike, instrumental in both starting me doing a Ph.D. and in seeing me through it. He has been supportive in a host of different ways throughout the journey. From reading through endless drafts, discussing the research, enduring extended periods apart during the fieldwork phase, and not least supporting me financially during the latter (yet lengthy) stage of my Ph.D. I know that it has been a significant sacrifice and I am truly grateful to him for sticking by me and seeing it through to the end. I promise that this was the last time I took on a momentous work task like this, renovated two houses and started a family at the same time.

# TABLE OF CONTENTS

**CHAPTER 4 – URBAN AGRICULTURE AND WASTE MANAGEMENT IN THE GREATER ACCRA METROPOLITAN AREA**



**CHAPTER 5 – THE EXPERIMENTS**



**CHAPTER 6 – EXPERIMENTAL RESULTS**

## List of Tables

## List of Figures

## List of Graphs

## List of Boxes

## List of Photos

# GLOSSARY

| | |
|---|---|
| Constructionism | A philosophical position which takes an ontological position that reality is socially constructed and that as such there are multiple representations of the empirical world (multiple constructions of reality). Constructionism rejects the notion of truly independent observation and a single objective claim about reality. It takes the view that there is interaction between the researcher and what is researched and as such the research findings are a constructed reality that is as informed and sophisticated as it can be at a particular point in time. |
| Epistemology | From the Greek word for knowledge (epistêmê), it is the philosophy concerning the means by which we express knowledge (the nature of knowledge and how we come to know). |
| Feedback | Information which modifies (controls) a process or system by the results or effects of that process or system (i.e. a modification resulting from its own effects and outputs). |
| Interdisciplinarity | Approaches that involve articulated conceptual frameworks which claim to transcend the narrow scope of disciplinary world views. It is different from multidisciplinarity in that the inquirer take on board inputs provided from other perspectives. These overarching thought models are holistic in intent |
| Metabolism | The chemical process that occurs within living organisms, resulting in energy production |
| Mineralisation | The conversion of an element from an organic form to an inorganic state as a result of microbial decomposition. |
| Multidisciplinarity | Approaches that involve the simple act of juxtaposing several disciplines, but no systematic attempt at integration or combination. Incompatible research approaches are pursued in parallel with little or no communication between them The results can be confusing because each specialist is speaking her/his language, using her/his particular concepts and focusing on her/his aspect of the problem |
| Ontology | A branch of philosophy concerned with the nature of reality (what the world is or contains). |
| Paradigm | A pattern of thought which makes sense of out perception of existence. A paradigm comprised epistemology, ontology and methodology |

| | |
|---|---|
| Peri-urban | Loosely defined as areas outside formal urban boundaries and urban jurisdictions, that are in a process of urbanisation and which therefore assume a mixture of rural and urban characteristics. As peri-urban areas are in a process of transition they cannot be precisely defined spatially as they change over time. |
| Pluralistic | A system that recognises more than one ultimate principle. |
| Positivism | A philosophical position characterised by an ontological approach where it is believed that an objective reality exists, and an epistemological approach where it is believed that the research is detached from the system studied. Put simply, it is believed that a reality really exists and that this reality can be known through objective study. |
| Qualitative research | In-depth descriptive inquiry which captures people's personal perspectives and experiences. |
| Realism | The philosophical notion that universals or abstract concepts have an objective existence. The belief that matter as an object of perception has real existence independent of the mind. |
| Reductionism | The doctrine that a system can be fully understood in terms of its isolated parts, thus it can be studied by breaking it into its constituent parts and analysing each in isolation. |
| Soil Organic Matter | Material found in soil derived from living matter; it includes labile and stable forms. |
| System's Boundary | The conceptual division between a system and its environment; it may or may not correspond to recognised geographical, physical, legal or cultural division and will be drawn according to the observer's purpose. |

# ACRONYMS

| | |
|---|---|
| ADAS | Agricultural Development Advisory Service |
| AEA | Agricultural Extension Agent |
| AKCPP | Ashieedu Keteke Community Participation Project |
| AMA | Accra Metropolitan Assembly |
| ANOVA | Analysis of Variance |
| AR | Action Research |
| C&CW | City and County Waste |
| C:N ratio | Carbon:Nitrogen ratio |
| CBO | Community Based Organisation |
| CCC | Communal Container Collection |
| CEC | Cation Exchange Capacity |
| CFU | Colony Forming Units |
| CSH | Critical Systems Heuristics |
| CST | Critical Systems Thinking |
| CWIQS | The Core Welfare Indicators Questionnaire Survey |
| DFID | Department for International Development |
| DOFR | Developmental On-Farm Research |
| EOFR | Experimental On-Farm Research |
| EPA | Environmental Protection Agency |
| ERP | Economic Recovery Programme |
| ESP | Exchangeable Sodium Percentage |
| FAO | Food and Agriculture Organisation of the United Nations |
| FFS | Farmer Field School |
| FPR | Farmer Participatory Research |
| FS | Farming System |
| FSR | Farming Systems Research |
| FSR/E | Farming Systems Research and Extension |
| GAMA | Greater Accra Metropolitan Area |
| GAPFA | Greater Accra Poultry Farmers Association |
| GDP | Gross Domestic Product |
| Gopa | An independent German development consultancy |
| GROWTH | A local NGO focussing on Integrated Development programmes and overseeing the AKCPP |
| GSS | Ghana Statistical Service |
| GST | General Systems Theory |
| GTZ | Deutsche Gesellschaft für Technische Zusammenarbeit |
| HDRA | Henry Doubleday Research Association |
| IBSRAM | International Board for Soil Research and Management |
| IDRC | Canadian International Development Research Centre |
| IIED | International Institute for Environment and Development |
| JT | James Town |
| KRAV | The certifying body for organic produce in Sweden |
| MAFF | Ministry of Agriculture, Food and Fisheries |
| MCW | Municipal Composted Waste |
| MOFA | Ministry of Food and Agriculture |

| | |
|---|---|
| MSW | Municipal Solid Waste |
| MWC | Municipal Waste Compost |
| NGO | Non Governmental Organisation |
| NPK | Nitrogen, Phosphorus, Potassium |
| OM | Organic Matter |
| PAR | Participatory Action Research |
| PAYD | Pay As You Dump |
| PFA | Poultry Farmers Association |
| PLA | Participatory learning and Action |
| PRA | Participatory Rural Appraisal |
| PTD | Participatory Technology Development |
| PTE | Potentially Toxic Element |
| RAAKS | Rapid Appraisal of Agricultural Knowledge Systems |
| RAL | The German Institute for Quality Assurance and Certification / Deutsches Institut für Gütesicherung und Kennzeichnung |
| SAP | Structural Adjustment Programme |
| Sida | Styrelsen för Internationellt Utvecklingssamarbete / Swedish International Development Cooperation Agency |
| SLIM | Social learning for the Integrated Management and sustainable use of water at catchment scale |
| SMS | Subject Matter Specialist |
| SNV | Statens Naturvårdverk / Swedish Environmental Protection Agency |
| SSI | Semi Structured Interviews |
| SSM | Soft Systems Methodology |
| ToT | Transfer of Technology |
| TUAN | Urban Agricultural Network |
| UA | Urban Agriculture |
| UKROF | UK Register of Organic Food Standards |
| UNCHS | United Nations Centre for Human Settlements |
| UNDP | United Nations Development Programme |
| WB | World Bank |
| WCED | World Commission of Environment and Development |
| WDC | Waste Derived Compost |
| WM | Waste Management |
| WMD | Waste Management Department |
| WWF | World Wildlife Federation |

# CHAPTER ONE - THE PROBLEM AND RESEARCH QUESTIONS

This chapter sketches the scope of the problem addressed in this thesis. It presents and explores three key conceptual domains: urbanisation, waste (volume, composition, collection, disposal), and urban agriculture. The research agenda that emerges from this review is presented. The chapter concludes with the initial research questions that oriented the research journey reported in this thesis, and an outline of the structure of this thesis

## 1.1 Introduction to the issues defining the research problem

### *1.1.1 Population growth and urbanisation*

As the world's population continues to increase, it is becoming increasingly urban. Whilst this is a global trend, urbanisation rates are particularly high in the South. Between 1950 and 1990 the urban population doubled in developed countries. During the same period the growth was five fold in the developing countries. In many parts of the world the urban population already exceeds that of the rural (e.g. many countries in Latin America 73%, Industrialised countries 75%, (UN, 1998 in O'Meara, 2001) and it is predicted that this will be a global pattern within a few years.

Cohen (2001) talks of cities representing 'engines of growth' thereby complementing their ability to provide arenas for the economic and social exchange needed to create productivity and dynamism. The current pattern of globalisation makes this perhaps more so now than ever before. Migration to the city holds the hope of a better life and the promise of opportunities not present in the rural hinterlands. It is generally accepted that new jobs and business opportunities, better education, more entertainment and a 'modern' cosmopolitan lifestyle are all pulling factors, drawing people to the urban centres. However, the shanty towns and slums built up around many of the South's cities bare witness to the fact that for many people the dream of a better life in the city is never realised. Instead, many find themselves living under poor conditions without prospects of improving their situation.

Slums are not new, nor are they exclusive to the South. However, whilst many national histories illustrate rapid urban growth, with associated ribbon development and expansion of consolidated settlements, it is the sheer scale of it that is unprecedented. Urban expansion has outgrown the management and financial capacities of many cities in the South, threatening human health, environmental quality and urban productivity. The problem is acute in many parts of the world, but perhaps especially in African cities. Traditionally, Africa has been one of the least urbanised parts of the world, and yet it has some of the highest rates of urbanisation (4% to 7% per annum) (Fekade, 2000) and resources and capacities are lacking to deal with the housing, food supply & distribution, infrastructure provision and urban services.

Until recently, poverty has been considered a predominately rural problem in the South (Levin *et al.*, 1999). However, urban poverty is developing into a serious problem and many analysts believe that the locus of poverty and under-nutrition is gradually shifting from rural to urban areas (Haddad *et al.*, 1999, World Bank, 1991:4, Koc *et al.*, 1999). As a result, addressing urban poverty and deteriorating urban environments has risen higher on the policy agenda. (Beall, 2000:844)

Koc *et al.* (1999:3) reflect that the ranks of urban poor have swelled as a result of factors such as:

- the continuous migration of the rural poor into the cities
- the limited ability of the urban informal sector to absorb the unemployed
- the limited employment opportunities in formal labour markets
- the negative impact of the global economic crisis
- the austerity measures adopted to deal with foreign debt

Often lacking education, access to skills training and information on markets and job opportunities, the urban poor are faced with unemployment, food insecurity and malnutrition. Unable to afford legal housing, many live in informal, sometimes illegal, squatter settlements in the sprawling urban fringes. Frequently the land they live on is environmentally hazardous, including steep hill slopes, river banks, railway cuttings or industrial sites. With dubious land tenure, the threat of eviction hangs over many. Whether in squatter settlements or not, the living conditions of the most disadvantaged tend to be inadequate and crowded. Municipal services and infrastructural provision are most likely to be insufficient, or entirely lacking. These services include access to safe drinking water, electricity, sewage, refuse collection, affordable healthcare and credit. The World Bank Development Indicators (2000) estimate that in Africa, only a third of urban households have running water and just one in ten have mains sewage. Less than half have electricity. Such living conditions increase the risk of ill health, pollution and crime.

It has been documented (e.g. Koc *et al.*, 1999) that the urban poor typically spend a high proportion of their income on food and that contrary to common assumptions, urban commercial marketing systems are beyond the reach of the vast majority of the urban poor (Leybourne and Grant, 1999). The same is true for water. Families with no piped water may have no other option than to pay for safe water from vendors at a price which may be five times that of the normal price (Mattingly, 1999). Water purchases may account for as much as 20% of the household expenses. A study on environment and health in Accra carried out in 1991, revealed that 50 percent of the poorest households obtain their drinking water from vendors, and 20 percent from communal standpipes (Benneh *et al.*, 1993).

Failure to manage urban service provision poses a serious challenge to productivity and the urban quality of life. The larger the city and the more global the economy, the more complex the challenge of governance facing local governments and city managers.

### *1.1.2 Sustainability issues*

Over the past two decades the relationship between cities and their natural environment have gained increasing attention in the development debate and the seemingly paradoxical terms ‘sustainable cities’ and ‘sustainable urban development’ have become frequently used. The concept of sustainable development in general, and perhaps sustainable urban development in particular, is one which is much contested and fraught with controversy.

‘Sustainability’ is not clearly defined; it means different things to different people, depending on one’s objectives, the perspective taken and boundaries chosen, both in time and space. For example, some may define the concept in relation to carrying capacity or the ability of a system to maintain its productivity (economic perspective). Others may take a more ecological, or environmental stance and consider sustainability to be *the capacity of a system to maintain its current state*, that is, that the biophysical and ecological balances within and outside the system are not disrupted. There are also those that view sustainability from a wider perspective and define the concept as *sustaining sociocultural elements of the system as well as its ecological and economic functions*. This might be described as a socio-cultural perspective. Some may take sustainability to mean that which is to be sustained must not change, whilst others may be of the opinion that changes *per se* are not problematic as long as they do not have any detrimental consequences. One common question seems applicable to all of the above definitions and their variants: the issue of time and duration. That is, is the aim for long or short-term sustainability?

Back in 1987, the World Commission on Environment and Development defined sustainable development as “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (Bruntland, 1987:43). Since then, a whole range (80 according to Pretty, 2000) of complementary and alternative definitions have been proposed. The Bruntland definition is ambiguous because what constitutes one’s need is highly dependent on assumptions and value judgements. Pretty (2000:25) stresses that “*in any discussion on sustainability, it is important to clarify what is being sustained, for how long, for whose benefit and at whose cost, over what area and measured by what criteria. Answering these questions is difficult, as it means assessing and trading off values and beliefs*”.

One widely adopted definition of sustainability is that of a triangular (balanced) relationship between environmental, economic and social aspects. As Figure 1.1 illustrates, according to this definition, it is only in the central area, where all three intersect that the criteria for sustainability are met. The rationale central to this definition is that the environmental, ecological, economic and social are all interrelated (co-dependent). For example, in the case of agriculture, farmers are unlikely to adopt practices which are ecologically sustainable if they are economically unviable, or unacceptable from a social or cultural point of view. Conversely, practices which are economically or socially beneficial, but that are ecologically damaging, will invariably result in both economic and social costs in the long run. Unsustainable practices are not just harmful to the environment; they are harming our potential for economic and social well-being too.

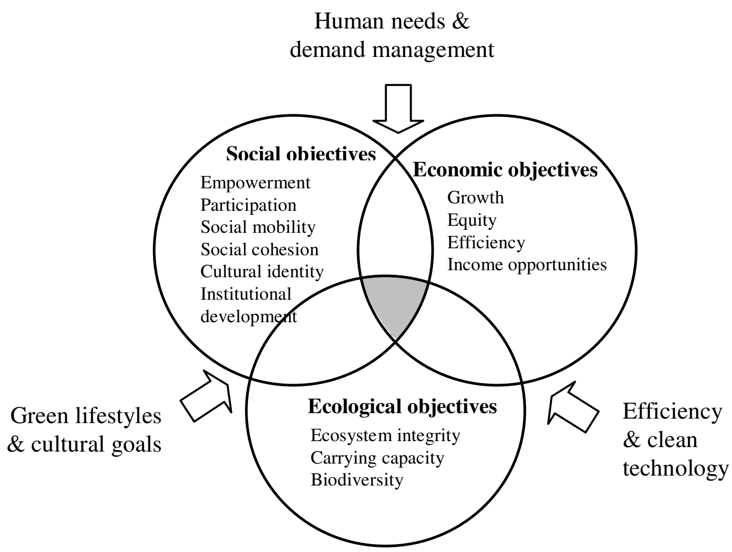



*Figure 1.1 Conceptual illustration of sustainability. Sustainable development is achieved through the integration of three sets of objectives*

*Source: Adapted from Campbell and Heck, 1997 and Ravetz, 2000*

In discussions on sustainability the notion of trade-offs, particularly between the ecological and economic, tend to take a prominent place (e.g. Conway, 1994). It would seem that the forces of economics do not accommodate ecologically sound natural resource management. Conversely, practices that are ecologically sustainable invariably carry an economic cost. Within the prevailing economic paradigm, social and environmental costs of production do not fit into the theoretical framework (Pearce *et al.*, 1989; Capra, 1996). As such, environmental costs, for example, such as pollution and resource mining, are labelled as 'externalities' and therefore not directly incorporated in the cost of production and subsequent price. One of the underlying principles of sustainability, however, is that to talk about trade-offs between measures that are environmentally and economically sustainable, can be both misleading and counterproductive, as that which is environmentally unsustainable is invariably economically unsustainable. Our dependence on the natural environment is as strong and real today as it has ever been.

With reference to the commonly perceived dichotomy between the environmental and the (socio-) economic, Holmberg *et al.* (1991:6) highlights the fallacy in assuming a dichotomy between the environmental and the (socio-) economic:

> "*This false dichotomy made logical discussion impossible, for development benefits such as irrigation, electricity and flood control always tended to be seen as more appealing than something as vague and woolly as 'environmental problems'. But these environmental problems were usually economic problems, 'development problems' in disguise. …… Even today one constantly reads statements in journals such that 'installing irrigation systems without proper drainage often leads to environmental problems'. Nonsense! Installing irrigation systems without proper drainage often turns good farmland into wet, salty, unproductive deserts, wasting the investment money, cutting yields to zero, impoverishing farmers and requiring new investments in reclamation. Installing irrigation systems without proper drainage often causes economic and social problems, but such grim economic realities hide behind reference to the environment, and the trade-offs are muddled.*"

This is not to say that devising policies that lead to sustainable development is in any way straight forward and that trade-offs never need to be made. Clear-cut win-win scenarios do exist, but these are perhaps more the exception than the rule in today's economic climate. One such example may be where local waste collection and management initiatives lead to job creation, income generation and improved health and living conditions. However, such win-win scenarios, where improvements in all three areas are achieved, are not all that common. Just as reaching consensus in conflict management is less common than having to settle on a compromise, the common and seemingly unavoidable scenario is that focus and action leading to positive outcomes in one area results in negative outcomes in another.

There are numerous examples of win-lose outcomes where environmental improvement results in economic and social negative outcomes and vice versa[1]. Such outcomes raise further questions;

- is it acceptable to undertake ecological conservation if it results in social and/or economic deterioration?
- is it justifiable to keep an economic activity going if it provides jobs and social security for a lot of people, but has negative environmental impacts?
- is certain environmental conservation justified at the expense of economic and social welfare?
- where is the cut-off point where we decide to accept economic and/or social disruption to protect our environment?

---

[1] For example the introduction of fishing quotas in the North Sea resulting in loss of livelihoods with serious implications for many rural fishing communities. See also Powell 1999 for a discussion on how WWF policies to protect elephants in Namibia has resulted in environmental degradation and loss of livelihood for indigenous bushmen.

- what is most important, how many people suffer from loss of jobs and livelihood security, or the number of people suffering economically, socially or health wise from the negative environmental impact?
- how sustainable are measures to clean up the local environment if such measures lead to increases in property prices, resulting in local people not being able to afford to live in the area?

These are but a few complex questions which do not have any clear answers, but which are typically faced in sustainable management. They highlight just how value-laden the concept of sustainable development is; when it is applied practically, the measures taken are governed by people's assumptions and objectives. Whether it is a natural resource, ecosystem, human health, quality of life or some other valued asset which is to be *sustained*, the actions taken and the indicators used for assessing sustainability (or success) are likely to differ. What is rational and reasonable from one perspective is often deeply irrational from an other. In reviewing the above list of questions, one generic question may be immediately added to each and all of them; that of *who decides*?

Clearly sustainability cannot be precisely defined. However, this does not have to be seen as a problem, or a reason for abandoning the concept of sustainability altogether. The term was born out of debates in the 1980s and early 1990s on how to tackle complex environmental problems in an increasingly globalised world. These debates were influential in contributing towards changes in policy and project approaches, particularly in the area of natural resource management. Although ambiguous and vague, the notion of sustainability holds a certain degree of commonality among many people. Certainly, whilst most may agree that in today's world nothing can be truly sustainable (in the dictionary definition of the word, which implies something static), the need to strive towards some degree of sustainability is recognised by most. Perhaps the point to stress is that the identification of goals needs to be negotiated between stakeholders on a case-to-case basis.

The term sustainability has been likened to ideals such as "freedom" and "justice"(Holmberg *et al*., 1991). "*While there is broad general agreement around the world about what such terms mean, the actual achievement of approximations of the ideals of human freedom, justice and sustainable development will be specific to local conditions and possibilities.*" (*ibid*:6). We all know that we are consuming resources faster than they are regenerated and that we are polluting at a rate faster than the earth's assimilation capacity. We know that this is detrimental to the environment, and subsequently to our economy, health and social well-being. What changes are needed and what approach to take to bring about the desired changes is not universally agreed, but there is almost universal agreement that we cannot carry on as before and that systemic thinking and transdisciplinary, flexible approaches are required if we are to tackle the challenges that lie ahead.

How can cities, with their large concentrations of people and the associated economic activities, consumption and waste generation, possibly be managed sustainably? Some may argue that that there can be no such thing as sustainable cities; that it is a contradiction in terms and indeed that the notion of sustainable urban development is not only a paradox, but outright ludicrous. In fact, cities may be seen as 'parasites' (Giradet, 1992), with an 'ecological footprint' that means that "*every city is an ecological black hole drawing on the material resources and productivity of a vast and scattered hinterland many times the size of the city itself*" (Rees, 1992 in Stren, 2001:330).

Although cities have always relied on their hinterlands, the extent of concentration and sheer magnitude of resource and waste in and out flows are unprecedented. For example, London requires in the order of 58 times its land area to supply its residents with food and timber; to meet the need of everyone in the world in the same way would require at least three more Earths (IIED, 1995 in O'Meara, 2001).

The metabolism of cities is linear whereby large amounts of natural resources from the rural hinterlands and abroad are imported and consumed. The wastes produced, unless emitted to air or water, are then disposed of within the urban or peri-urban areas. The nutrient mining, fossil fuel use and pollution that takes place to sustain city life is certainly not sustainable, and it is difficult to see a way in which it could ever be. In fact it may be argued that true (ultimate) sustainability is an impossibility, with the world's high and still rising population, with rapid change, increasing globalisation and subsequent interdependence. The larger the city and the more global the economy, the larger its 'footprint' In other words, the further afield resources are drawn from. This in turn requires ever more transportation and associated fossil fuel use.

Revisiting the Bruntland definition in the context of the sustainability of urban development, most would agree that today's cities fail to meet the needs of the present whilst the needs of future generations are severely compromised. Clearly, cities are not developing or being managed in a sustainable way. However, some take a somewhat less gloomy view. Stren (2001:330) for example, points to the fact that there are some positive benefits from urban living in comparison with other forms of living. He notes that *"dense patterns of urban living save an enormous amount of energy in the form of more efficient transport and heating; that most of the important and creative ideas about environmental improvement come from intellectuals and activists resident in urban areas, and that the social diversity that many cities sustain is often the seedbed of new approaches to political, scientific, and cultural challenges in the wider society"*.

As much as truly sustainable development may not be possible where cities are concerned, I would argue that it is not futile to have it as an aim, or as an ideal to strive towards. Much can be done to improve the urban environment and to modify the way that resource flows to and from cities are managed, so as to lessen the negative impacts of the 'ecological footprint' of cities.

Sustainable management is political and it always involves both natural and social disciplines. In fact, effort towards sustainable management is probably best served if we abandon the strict demarcation of disciplinary boundaries altogether. In the words of Bawden (1991:2371) "*As what we do in the world is function of the way we see it, there is a drastic need for us to change the way we go about our seeing as a prelude for fundamental shifts in the way we do things*."

### *1.1.3 Solid waste management challenges*

One of the most pressing concerns of cities in the South is the problem of solid, liquid and toxic waste management (Onibokun and Kumuyi, 1999; Asomani-Boateng and Haight, 1999). It is the solid fraction of the urban waste stream with is primarily considered in this study. Causal factors seem to fall into two broad areas; volume and composition:

- The amount of waste generated from Southern cities is constantly growing as a result of rapid urbanisation coupled with changes in lifestyle. The changing consumption patterns, accompanying rapid urbanisation have contributed to increases in the waste generated *per capita.*
- The changing nature of the wastes is also of concern. Whilst waste streams in the South used to be mainly organic and non hazardous this has gradually been changing over recent years, with a move towards higher concentrations of hazardous wastes. Examples include more packaging and plastic, and more car related wastes such as exhaust fumes, waste oils and rubber tyres.

Whilst the amount of waste produced is more voluminous in the countries of the North, it is more visible in the South. The sight of uncollected or indiscriminately dumped waste piling up along roadsides, on unused land and in drains and water bodies is commonplace in cities in the South. Landfill sites are often un-sanitized and unlined open dumps inappropriately sited near residential areas and/or waterways. Furthermore, toxic wastes are often disposed of in an inappropriate manner. Apart from the odours, unsightliness and risk of flooding from blocked drains, there are serious environmental degradation and health implications of such action, through contaminated waterways containing toxic substances and water-borne diseases, and disease-carrying fly and rodent infestations (Schertenleib and Meyer, 1992; Jalan *et al*., 1995; Beall, 1997). Scavenging animals and humans are at a particularly high risk of injury and of catching and spreading diseases. IDRC (1998:8) has estimated that "*each year 5.2 million people including 4 million children, mostly in cities, die from diseases caused by improper disposal of sewage and solid waste*".

Municipalities are hard pushed to manage this growing problem. Of all operational costs of municipal services, the collection and transportation of household waste is usually the highest (Deelstra, 1989; Jalan *et al*., 1995). Cities usually manage to keep the business districts and main roads clean, whilst in residential areas, particularly in slums, wastes accumulate in the streets and at transfer stations. In 1997 Eitrem & Törnqvist estimated that 20-50 percent of the solid waste generated remains uncollected in cities in the South. This is even though as much as 30-60 percent of municipal expenditure frequently goes towards waste collection. Schertenlieb and Meyer (1992/93) reflect that "*usually, not even* *the operation costs of the collection services are covered by adequate feed and the available budgets are insufficient to finance adequate levels of service to all segments of the population*." In Accra the proportion of solid waste collected is in the region of 50-60% (see Chapter 4). Clearly, an important reason for the failure to tackle the waste problem is a lack of financial resources by local governments, typically operating within Structural Adjustment Programmes and with insufficient tax bases. However, apart from financial constraints, inadequate organisational structures and policy responses, coupled with poor management and technical skills are also contributory factors to failures in meeting the increasingly complex challenge of urban waste management. Collection also proves problematic in many residential areas because of narrow and poor roads that are largely inaccessible. Moreover, land for new and expanded landfill sites is scarce and as cities grow, the distances to dump sites grow, leading to increased transportation costs.

There is considerable variation in the levels of waste generation between countries at differing levels of socio-economic development. Generally, the more developed and urbanised a country is, the more waste per capita is produced (Deelstra, 1989). Estimates from cities vary considerably, and under situations where much of the waste remains uncollected and where urbanisation is rapid estimates can not be anything but crude. However, documented information on the subject[2] suggests that in the larger cities of developing countries each inhabitant generates between a quarter and half a kilogram household waste per day (Table 1.1). This compares with an estimated 1.4 kg per person per day in western Europe (European Environment Agency, 2005) and 2 kg in USA (United States Environmental Protection Agency, 2003a).

*Table 1.1 Examples of household waste generation levels of some cities in developing countries*

| CITY | Population Million inhabitants | Daily Waste Generation | | Year referred to | Source |
|---|---|---|---|---|---|
| | | For City Tonnes | Per Person Kg | | |
| Manila | 12 | 4000 | 0.33 | | Medina, 1993 |
| Jakarta | | 5000 | | | Simpson, 1993 |
| Accra | 2 | 1100 | 0.55 | 1999 | This research |
| Abidjan | 2.4 | 509 | | 1994 | Attahi, 1999 |
| Ibadan | 3.6 | 754 | | 1994 | Onibokun & Kumuyi, 1999 |
| Dar es Salaam | 3 | 740 | 0.25 | | Lopez-Real, 1995 |
| Calcutta | 10 | 3000 | 0.30 | | Kundu, 1995 |
| Kano, Nigeria | 1.4 | 450 | 0.32 | | Lewcock, 1994 |

[2] It seems reasonable to assume that the figures provided in the literature refer to amounts collected rather than amounts generated. Consequently the amount actually generated is expected to be higher than those stated in the table.

The urban waste stream in the South is made up of a whole range of materials, originating from a variety of sources, including those listed in Box 1.1. Of these, household waste constitutes the bulk and certainly the vast majority of the waste collected by municipalities.

The types of waste from cities in developing countries also differ from that of industrialised country cities. Whilst in the West the organic fraction of the total solid urban waste tends to be between 15 and 50 percent and contains a high proportion of paper (typically around 30%), in developing countries the organic fraction of the waste stream tends to be significantly higher, comprising anything between 50 and 80 percent of urban waste with the proportion of paper typically as low as 2-3%. The high proportion of organics in the urban waste stream of developing countries is partly due to the extensive informal salvage and recycling systems which exist for materials of value such as metals, glass and cardboard, partly the lower level of industrialisation and packaging used. A relatively new feature of the waste stream in cities on the South is the rapid increase in plastics as a result of a trend towards more convenience foods and packaging in the larger cities in the South (e.g. School of Public Policy *et al.*, 1998).

*Box 1.1 Urban Waste Characteristics*

| **Sources of urban waste** | **Types of solid wastes in the urban waste stream** |
|---|---|
| • Households<br>• Markets<br>• Street refuse and sweepings<br>• Commercial and institutional (e.g. shops, offices and restaurants)<br>• Livestock producers<br>• Slaughterhouses<br>• Hospitals<br>• Human wastewater and sewage<br>• Agro-industrial (e.g. sawmills, food processing plants etc)<br>• Heavy Industrial waste (e.g. mechanical, construction) | • Organics, including fruit and vegetable wastes, garden wastes, and fish and meat wastes and various agro-industrial wastes such as hulls, husks and fruit pulp, sawdust, fish processing waste.<br>• Plastics<br>• Paper<br>• Cardboard<br>• Glass<br>• Metal<br>• Textiles<br>• Sand, stones and ash dust from road and yard sweeping<br>• Livestock manure<br>• Livestock carcasses (bones, horns, skin)<br>• Nightsoil<br>• Toxic waste such as batteries and biomedical waste<br>• Sawdust<br>• Miscellaneous combustible waste<br>• Miscellaneous inert/non-combustible waste |

The constituents of the waste stream not only vary from country to country, but also between neighbourhoods and seasons. In Accra, for example, waste from poor and medium income areas tend to contain a lower proportion of organic material than that from the more wealthy areas. A lot of the better quality organic material is often recycled as animal feed leaving the collected waste with high concentrations of carbon rich organics (such as coconut husks, leaves etc) and inert materials such as sand from street and yard sweeping.

Wastewater is also an important component of urban waste. However, the focus in this study is on the solid fraction of the urban waste stream, and, more particularly, the organic fraction of this.

*Table 1.2 Proportions of different constituents in the urban waste stream of some different cities in developed and developing countries (%)*

| | Lima[a] | Accra[b] 1995 | Abidjan[c] 1994 | Dar es Salaam[d] 1993 | N European city[e] |
|---|---|---|---|---|---|
| Organics | 34.7 | 65 | 52.8 | 59.8 | 3-16 |
| Plastic | 7.2 | 3.5 | | 1.9 | |
| Glass | 7.1 | 1.2 | 1.2 | 0.4 | 10-11 |
| Paper | 3.9 | 4.2 | 4.18 | 8.7 | 2.7-4.3 |
| Cardboard | 2.1 | | | | |
| Ferrous metal | 2.8 | 1.8 | 0.9 | 2.8 | 7-10 |
| Textiles | 1.4 | 1.7 | 1.3 | 0.9 | 3-7 |
| Refuse | 41 | | | | |
| Inerts | | 22.8 | | | |
| Wood | | | 9.5 | | |
| Sand, ash, dust etc | | | 25.7 | | |
| Rubber | | | 4.7 | | |
| Synthetics | | | | | 3 |
| Other | | 1.2 | | 25.5 | 13-16 |
| Various | | | | 1 | 1-3 |

*a Diaz, 1997*
*b Accra Waste Management Department, 1995*
*c Attahi, 1999*
*d Kironde, 1999*
*e Deelstra, 1989 and Dalzell et al., 1987*

The waste management systems developed and used in the West rely heavily on engineering solutions for waste collection, transportation, storage and treatment. These systems have been copied in the South, frequently with limited success (Byrne, 1995 (South Africa); Asomani-Boateng and Furedy, 1996 (Ghana); Deelstra, 1989; Jalan *et al.,* 1995 (India); Furedy, 1992; Lardinois and van de Klundert, 1994a & b; Ali, 1997; Schertenlieb and Meyer, 1992). This experience is similar to that of many other cases of technology transfer from the West, from agriculture (see Chapter 2) through to telecommunications (Collins, 1999), and in common with many of these, there is growing recognition that the Western waste management systems are largely inappropriate to cities in the South.

Western systems tend to be too expensive. For example, mechanised refuse trucks and lorries are imported requiring a high capital outlay of foreign exchange.

They also demand complex and costly maintenance which typically needs the importation of spare parts. Schertenleib and Meyer (1992:4) note that "*it is quite common that governments are paying back long-term loans for vehicles grounded after two to three years of operation",* and that *"typically less than 50 percent of the vehicle fleet is in operational condition*".

The same is true for large scale composting operations. Many examples exist (e.g. Deelstra, 1989; Jalan *et al*., 1995; Furedy *et al*., 1997; Onibokun, 1999) where large scale, high tech composting projects have run into difficulties because installations have been too expensive, too complicated and have not been tailor made for local conditions. Lardinois and van de Klundert (1994a) note that in cities in both Asia and Africa many such facilities have closed, others have scaled down, and many operate well below their planned capacities. In Ghana this has been the experience with regards to a large scale mechanised composting plant in Accra, where lack of equipment and technical personnel, machinery breakdowns and financial constraints have rendered the facility largely inoperable for much of the time since its commission in 1989. Furthermore, the municipality has never managed to recover anywhere near enough revenue through sale of compost to meet the operational costs. This example is discussed in more detail in Section 4.2.5 in Chapter 4.

It is not just the capital-intensive nature of Western waste management technologies that renders them inappropriate in the South. They are designed for different situations and are often not suited to the conditions of cities in the South. For example, in areas of seasonally high rainfall, large, heavy waste collection vehicles are often rendered inoperable, and they cannot be used in urban and peri-urban slum, or low-income areas, with narrow unpaved, pot-holed lanes. This is a frequently cited reason why municipalities fail to provide waste management services in slum areas (Deelstra, 1989; Schertenleib and Meyer, 1992; Baker, 1997; Perla, 1997).

Furthermore, sophisticated compactor trucks, bought by, or given to many municipalities, were developed to save transportation costs and are suitable to conditions where waste has a low bulk density as is the case in the West where much of the domestic refuse is made up of packaging. In cities in the South, where due to the high proportion of organic waste and inert materials such as sand and dust, the bulk density is typically 2.5 times higher, the whole purpose of using compactor trucks to save costs is lost (Schertenleib and Meyer, 1992).

Since the 1980s there has been a trend towards decentralisation and privatisation of the waste management operations in many cities in the South. This trend is in line with the resurgence of market-oriented prescriptions globally (Beall, 1997), and has been implemented to fit with Structural Adjustment Programmes and the often associated Economic Recovery Programmes adopted by many governments. More recently (during the 1990s and presently) civic/community engagement and stakeholder participation have been added as themes to the debate on waste management. Evidence is mounting that a decentralised integrated approach, integrating the efforts of the private sector, scavengers and local communities, holds promise of making a considerable contribution towards urban solid waste management. Box 1.2 lists the key principles increasingly seen as important by many within the waste management domain.

*Box 1.2 Current thinking in waste management incorporates the following principles*

- Privatisation
- Decentralisation
- Community involvement
- Participation of different stakeholders
- Appropriate cost-effective technology options, (many of which invariably are small-scale)
- Involvement of people already familiar with waste handling, i.e. build on existing systems
- Plurality of approaches

Lately many experiences of alternative waste management systems of public-private-community partnerships have been gained. Most of them have focussed on the collection and/or recycling aspects of solid waste management. Examples include:

- Cairo, Egypt, where the Zabbalean people collect and recycle a significant proportion of the municipal solid waste in the city (Schertenleib and Meyer, 1992; Lardinois and van de Klundert, 1994a).
- Jakarta, Indonesia, where several waste recycling and composting enterprises relying on small-scale private, community run operations have been put in place, with the dual objective of cleaning up the local environment and creating jobs within local communities (Perla, 1997; Simpson, 1993).
- Bamako, Mali, where a trial project using a local women's group for the collection of refuse with donkeys and carts proved so successful that local legislation was passed encouraging decentralisation and persuading local cooperatives to collect the refuse in their quarter, with residents paying for the service. Some of these cooperatives are engaged in composting to reduce their waste and provide extra income (Baker, 1997; Lardinois and van de Klundert, 1994a).
- Bangalore, India, where several NGOs have been involved in solid waste recovery as a means of poverty reduction, social justice and environmental advocacy, particularly, but not exclusively with focus on street children (Beall, 1997).
- Lima, Peru, where the Alternative project has helped create micro-enterprises collect refuse for recycling through a special agreement with municipal authorities (Böhrt, 1994)

Many other examples of alternative waste collection and/or recycling have been documented, including:

- Porto Novo, Benin (Massey, 1991).
- Accra, Ghana (Schweitzer, 1989; Asomani-Boateng and Furedy, 1996)
- Cameroon (Ngnikam *et al*., 1993)
- Equador (Landin, 1994)
- Argentina (Seifert, 1992)
- Guadeloupe (Clairon, 1979)
- India (Rosario, 1994)
- Manila, Philippines (Lardinois and van de Klundert, 1994b)
- Colombia (Medina, 1997)
- Guatemala (Barrientos, 1989)
- The Stswtla township in Johannesburg (Byrne, 1995)

All the examples above share certain common aspects and illustrate alternatives to the conventional approach to municipal waste management. Common to most of these and other similar schemes and initiatives is that they have tended to have assistance or backing in the form of logistics and management support from NGOs and development organisations and financial support for equipment and operational costs. For example, UNDP and GTZ have given financial support to many such initiatives during the 1990s (e.g. Accra, Jakarta, Benin).

Although these isolated, and small-scale examples do not manage to make a significant dent in the overall waste mountain, they are important because they provide examples of alternative approaches that have contributed to a shift in thinking among many professionals in the domain of waste management and urban development. Their level of success has varied. Many have experienced financial difficulties with subsequent falling motivation once external support is withdrawn, yet whilst both the mode of execution and the motivating forces behind the initiatives may vary, all the above cases include some components which are increasingly recognised to be important for successful waste management in cities of developing countries as outlined in Box 1.2 above and elaborated further below.

Many professionals within the waste management and urban planning sectors suggest that:

- There is a need for decentralised systems and ways to integrate public and private initiatives. In this respect, the importance of the informal sector is slowly recognised and valued (Lardinois and van de Klundert, 1994b). Waste pickers and itinerant waste buyers play a crucial role in waste management in many urban areas of the South. Waste picking fulfils a service gap in the solid waste management and is a survival strategy for a large number of the poor. It is also a significant employment sector in the urban economy (Ali, 1997).
- Local communities need to be involved and assume some responsibility. They can play a role in separation and primary collection and such efforts can be combined with both the regular waste system and private-sector recycling (Furedy, 1992).

- Alternative waste management strategies involving some or all of the above components could be particularly important for women. Because of their responsibilities within the household, they are most likely to participate in community waste recovery activities (Lardinois and van de Klundert, 1994b). Experts suggest that waste management improvement projects have a greater chance of success if they are attuned to women (Deelstra, 1989).

Jalan *et al.* (1995:17) argue that "*the development of waste management systems and processes should take cognisance of the prevailing situation in terms of its techno-socio-economic factors, the roles and capabilities of various 'actors' involved in the management of solid waste, and their dynamic interplay. This will generate flexibility in the management process to cope with the dynamically changing socio-economic scenario, to create a more adaptive and responsive waste management system. Such a flexible waste management system will keep a dynamic balance among the various alternative approaches of disposal recycling and utilisation of solid waste and will be more integrative and innovative in character*". Similarly, Karki *et al.* (1997:4) in their paper on municipal solid waste in Kathmandu argue that although "*managing solid waste is the primary function of every municipality and should be their main concern, the involvement of the community is a pre-requisite for sustainability for such efforts. Different actors such as local bodies and community-based organisations and NGOs have to play a collaborative role with municipalities and government*". This sentiment is echoed in reports on experiences throughout the developing world. Deelstra (1989:21) suggests that "*public authorities could support self-planned activities and the initiatives and suggestions of district and neighbourhood organisations and environment groups. They may consider themselves as sponsors and partners of the people who are building up, improving and maintaining their own surrounding*".

This is not to say that municipalities do not need to play an active role. Schertenleib and Meyer (1993) reflect that secondary collection, transport of primary collected waste to the dumpsites and operation of the landfill is usually beyond the scope of communities and small-scale operators. The same is true for hazardous waste. The waste management system of a city should be geared to the needs and possibilities of the various districts and situations. The need for a pluralistic approach to waste management is emerging. Deelstra (1989:25) reports that "*in Rio de Janeiro, for example, there are more than ten different collection systems in operation, varying from crack-and-press trucks in business centres to chutes and donkey carts in slums*". With increased privatisation, there is a risk of 'cherry picking' at the exclusion of the non-lucrative and difficult to reach areas, and of illegal dumping of collected waste by contractors to avoid transport costs to designated dump sites. Pluralistic approaches to waste management may well involve privatisation and decentralisation and different technologies for different districts. If this is so it is important that all aspects of the waste management procedure, through collection, transportation, recycling and disposal, are appropriately coordinated and regulated.

It is important that robust governance capacities are in place. In relation to the waste management issue in Africa, Onibukun *et al.* (1999:5) stress the need for appropriate governance along with techno-financial solutions. They point out that "*an increasing interest in public-private-communitive partnerships is evident in the sector, but this is often related to a concern with technical and financial issues, rather than with the political, sociological and environmental relationships involved*". The authors go on to argue that "*efficient and effective service delivery depends on several key elements, the most important of which are managerial and organisational efficiency, accountability, legitimacy*[3]*, and responsiveness to the public, transparency in decision-making, and pluralism or policy options and choices*" (*ibid.*:6).

Batley (2001) uses the examples of waste collection and waste disposal to point out that the difference in the functions of supply of these services. There are differences which have implications for the case for public responsibility for service provision. He argues that waste disposal has attributes which approximate a public good, whereas solid waste collection does not. It is in principle possible to charge people for waste collection and exclude non-payers. However, the high negative impact of uncollected waste indicates a need for some degree, or form of, public sector involvement. It may be argued that there us a need for public sector intervention to ensure that collection takes place, but the operation of service can be contracted out to firms or communities. Waste disposal on the other hand, is different. According to Batley, it has public good characteristics in that it is difficult to exclude non-payers and one customer's disposal space hardly restricts that of others. Furthermore, the service has some features of a monopoly in that once established, the cost of extending it to additional users is low. Waste disposal is best provided through the public sector as (1) land acquisition for disposal sites is difficult other than through compulsory purchase, and (2) there are negative impacts on those living near disposal sites which can only be compensated by some government intervention in charges and re-allocation of benefits. The differences in the functions of supply of these services illustrates the need for (the appropriateness of) combining the private and public sectors in various organisational arrangements.

The issues discussed in this section will be revisited in other parts of the thesis, particularly in Chapter 4 which discusses the experience of waste management in Accra, and in Chapter 7 where governance and institutional structures are explored.

### *1.1.4 Urban Agriculture*

Sawio (1994) claims that perhaps the largest emerging challenge in relation to the rapidly growing cities in the South is how to feed the urban populations. Hubbard and Onumah (2001) go further, stating "with their expanding population and sprawl, developing cities are increasingly dependent on distant food supply sources, including imported food. As a result transport and handling costs make up

---

[3] Onibukun uses this term because they note that in some cases waste recycling and management systems are informal and, in this context therefore, 'illegitimate'.

an increasing part of food costs to the urban consumer (usually more than half the retail price)". By 1980, nearly 50 percent of all food consumed by people in the cities of the developing world was imported from other countries (Austin, 1980 in Mougeot, 1994).

The urban poor spend a high proportion of their income on food. According to FAO estimates, urban households spend 30% more on food than rural households and the urban poor spend 60-80% of their income on food (FAO, 1998 in Hubbard & Onumah, 2001). In a UNDP report it is noted that for the world's poorest urban households it can be as much as 90 percent of their income (Smit *et al*., 1996). In Sao Paulo, Brazil urban households (including all income classes) devote about 50 percent of their income on food. In Istanbul the figure is 60%, in Lima, Peru 70%, and in Ho Chi Minh City, Vietnam the figure is as high as 80 %. In the peri-urban areas of KwaZulu Natal, close to Durban, up to 52% of total household expenditure is spent on food (May *et al.* in May and Rogerson, 1995). In Accra, the estimated expenditure on food is lower at 47% (Ghana Living Standards Survey, 2000).

Drakakis-Smith et al. (1995) argue that although food is the most important of the basic needs, there is little information available on urban food systems and their links to the poor. In the cash economy of cities most households purchase most of the food they consume and their ability to do so depends in their income. Drakakis-Smith et al. (1995) point out that changes in the nature of the food retailing system have increased the difficulties which face the poor in this respect, and note that the expansion of urban agriculture over the last decade is as much the result of inadequacies in the retail supply system as it is of structural adjustment. They argue that "any attempt to evolve policy responses to the 'problems' posed by urban agriculture must take this complex context into account" (ibid:184).

Such trends call into question the long-term urban food security and consequently urban agriculture (UA) has received a lot of attention recently, being frequently mentioned in the development literature. Urban agriculture is nothing new, in fact, history points to the fact that it has always been a feature of urban centres; the hanging gardens of Babylon being a case in point. In cities of the ancient Greek, Roman, Arab and Aztec civilisations urban food and fuel production and animal husbandry played important roles (Mougeot, 1994). In northern Europe too, food cultivation was often carried out within the walls of medieval cities. Today even, in more modern times, urban agriculture remains common. The extent, sophistication and importance of it in Asia is well documented (Yeung ,1988; Honghai, 1992; Jansen et al., 1995). In Europe allotment gardens are a common feature of cities and towns. Smit and Nasr (1992) report that in Chile, Japan and the Netherlands urban farmers outnumber rural farmers.

What is new is that urban agriculture has increased in many parts of the developing world (e.g. Mosha, 1991; Mougeot, 1994; Drakakis-Smith et al., 1995; May and Rogerson, 1995). Mougeot (1994) ascribes this development to a whole range of factors: rapid urbanisation, ineffective agricultural policies, crippled domestic food-distribution systems, constrained public spending and subsidies, wage cuts, soaring inflation and unemployment, plummeting purchasing power and lax urban land use regulations or enforcement. Mougeot also stresses that civil strife, war and natural disasters disrupt rural food production and supply lines to cities and in some places have contributed to the increase in UA.

Mbiba (1995) reports that in Harare, the area farmed doubled between 1990 and 1994, whilst the proportion of families in Dar es Salaam engaged in farming rose from 18% in 1967 to 67% in 1991 (Jacobi, 1997). Mosha (1991) report that in Tanzania literally every open space in the cities and towns has been taken up for planting seasonal and permanent crops ranging from vegetables, maize, bananas to fruit trees etc., and that the increase in the numbers of livestock of different kinds in Dar es Salaam has been startling. Similar urban land use changes has been observed and documented in many places, particularly in Africa, by, for example: Freeman (1991) in Kenya, Maxwell and Zziwa (1992) in Uganda, Rakodi (1988) in Zambia, Streiffler (1987) in Zaire, Tabatabai (1988) in Ghana and Drakakis-Smith (1995) in Zimbabwe. In 1993 UNDP estimated that 200 million urban dwellers in developing countries are urban farmers and that they are providing food for about 700 million people (DGIP/UNDP, 1993 in Mougeot, 1994). In a later UNDP report it was estimated that there are 800 million urban farmers worldwide (Smit *et al*., 1996).

The World Commission on Environment and Development noted that UA, "*having been ignored by academics, planners, government officials and policy makers, … is increasingly acknowledged as having an important role to play in improving the nutritional quality of the diet of the urban poor and providing valuable income and employment*" (Bruntland, 1987:254). Also, on a more macro scale, one of the possibilities of tackling the challenge of ensuring sufficient food supplies to rapidly growing cities, is to improve food production in and around urban agglomerations (Basler, 1995).

Since the 1980s (the subject of) urban and peri-urban agriculture, as a means of addressing food security, has become included on the research agenda of several international organisations (e.g. IDRC, FAO, UNDP), and it is an area of research that is currently expanding. In addition to a limited body of research focused on the Francophone parts of Africa (Vennettier, 1961; Jeannin, 1972; Morriniere, 1972), the Canadian International Development Research Centre (IDRC), and UNDP with assistance from the Urban Agriculture Network (TUAN), have been behind the most extensive research on urban agriculture to date. The first IDRC funded study was of six urban centres in Kenya (Lee-Smith and Memon, 1994). This has been followed by a number of additional studies, mainly in Africa. UNDP supported research has been more global. TUAN has documented urban agriculture practices in more that 20 countries in Asia, Africa and Latin America (Smit *et al*., 1996). Other development organisations and donors are addressing this area including WB, FAO, DFID, GTZ and Sida.

As with so much in development, UA has a range of definitions. Mougeot (1994:1) defines it as encompassing the "production of food and non-food plants and tree crops and animal husbandry, both within (intra-) and fringing (peri-) built-up urban areas". Gebre-Egziabher (1996:21) defines it as "the practice of food production within a city boundary or on the immediate periphery of a city", while Sawio (1994:25) refer to it as "crop growing and livestock keeping in both intra-urban open spaces and peri-urban areas".

It commonly involves the cultivation of crops and animal keeping, but included in the term urban agriculture is also fruit production, fuelwood plantations, aquaculture and others (e.g. snail-rearing, silkworms, medicinal and culinary herbs). Smit and Nasr (1992) in their influential paper included the following in urban agriculture:

- Aquaculture in tanks, ponds, rivers and coastal bays;
- Livestock (particularly micro-livestock) raised in backyards, along roadsides, within utility rights-of-way, in poultry sheds and piggeries;
- Orchards, including vineyards, street trees and backyard trees; and
- Vegetables and other crops grown on roof tops, in backyards, in vacant lots of industrial estates, along canals, on the grounds of institutions, on roadsides and in many suburban small farms.

As the definitions above suggest, urban agricultural activities can be very diverse. In a survey by UNDP, over 40 different farming systems were identified, and in one city no less than 17 different systems were in operation (Smit and Ratta, 1992 in Mougeot, 1994).

The terms 'urban agriculture', 'urban farming' and 'urban food production' are used interchangeably in the literature, and both urban and peri-urban are included in the term. Consequently, urban farming systems can vary immensely in size, intensity and production mixes. It can be anything from rooftop container gardening in areas of extreme housing density, to arable production on peri-urban farms not dissimilar to rural locations. In this study, urban agriculture will be used to include all the food and non-food producing systems found worldwide.

It is not possible to make a general statement about who cultivates in urban areas. However it is a useful exercise to 'define the limits of the main group', defined perhaps for funding, research and extension purposes. Indeed, although UA is practised in diverse economies, cultures and by people in all social classes, some trends emerge from this literature review. Based on this, it is possible to conclude that the majority of urban farmers tend to be:

**Women, producing food for their families**. Studies consistently show that the majority of poor urban farmers are women, particularly in Africa and Latin America ( Sanyal, 1987; Rakodi, 1988; Maxwell and Zziwa, 1993; Freeman 1993; Bohrt, 1993; Egziabher, 1994; Böhrt 1994; Lee-Smith and Memon, 1994; Mbiba, 1995). For this group, farming is an important survival strategy.

**People in the low-income class.** Although studies have shown that urban farmers span a wide spectrum of socio-economic groups, they also reveal that cultivation is primarily conducted by low-income families who grow food crops for consumption and income supplementation (Sanyal, 1986; Freeman, 1993; Drakakis-Smith, 1992; Gebre-Egziabher, 1996; Maxwell and Zziwa, 1993).

**Established urban dwellers,** rather than recent rural migrants: A rather common notion is that people, from lack of choice, carry on farming during a temporary adjustment period when they first migrate to cities from rural areas (Sanyal, 1986; Freeman, 1993). Contrary to this assumption, many studies have shown that it is long established urban dwellers who make up the majority of urban farmers (Drakakis-Smith, 1992; Sanyal, 1986; Lado, 1990; Sawio, 1993; Vennetier, 1961 in Mougeot, 1994). As Maxwell and Zziwa (1993:97) report from Kampala: "gaining access to farming in the city, especially for lower-income persons and households, is a slow process that depends on a network of connections and obligations". Bohrt (1993:3) in a report on urban agriculture in Latin America says that recent migrants from rural areas feel that farming is "a typical agrarian activity and that they wish to adopt city ways and activities which supposedly improve their cultural status".

Studies systematically show that urban agriculture contributes considerably to food supplies, both on a city and household level. Table 1.3 and 1.4 illustrate examples of contribution of food produced in urban and peri-urban areas on a city and household level.

*Table 1.3 Examples of urban agriculture's contribution to city food requirements and consumption (%)*

| COUNTRY OR CITY | | SOURCE |
|---|---|---|
| Singapore | 25 % of vegetables consumed | Yeung, 1985 |
| Hong Kong | 40% of fish requirements | Smit & Nasr, 1992 |
| China | 85 % of vegetables consumed (6 large cities) | Skinner, 1981 |
| Calcutta | 10 % of fish consumed | Panjwani 1985 |
| Latin America | 30 % of vegetables consumed (some cities) | Heimlich, 1989 |
| Addis Ababa | 6 % of cabbage, 14 % of beetroot, 63 % of swiss chard consumed | Egziabher, 1994 |
| Kampala | 70 % of poultry consumed | Maxwell, 1994 |
| Buenos Aires | 20% of city's nutritional needs | Helmore & Ratta, 1995 |
| Java | 18% of calories consumed in the cities | Helmore & Ratta, 1995 |
| Dar es Salaam | 90% of spinach consumed<br>25% of city's food requirement | Mosha, 1991<br>Sawio,1993 |
| Russia | 30% of food produced in Russia | Helmore & Ratta, 1995 |
| Cuba | 30% of local food needs | Windisch, 1994 in Wright, 2005 |

*Table 1.4 Urban agriculture's contribution to food consumption of urban farm households*

| COUNTRY OR CITY | | SOURCE |
|---|---|---|
| Jakarta | 18 % of food for 100 % of urban farmers | Yeung, 1985 |
| Kenya | 77 % of food for 100 % of urban farmers | Lee-Smith & Memon, 1994 |
| Pointe-Noire | 100 % of cassava for 33 % of population | Vennetier, 1961 |
| Dar es Salaam | 20-30 % of food for 50% of urban farmers | Sawio, 1993 |
| Kampala | 40–60 % of food for 100 % of urban farmers | Maxwell & Zziwa, 1992 |

## 1.2 Synthesis of the issues of urban agriculture

The overarching potential of urban agriculture lies in its contribution to sustainable development of cities. Although urban agriculture only contributes a small proportion of national food supplies (Ellis and Sumberg, 1998) and cities rely on rural areas to provide the majority of foods, urban agriculture has an important complementary function (Maxwell *et al.*,1999). It can meet the basic needs and improve the socio-economic position of the urban poor (May and Rogerson, 1995). Another important potential benefit of urban agriculture lies in the broader environmental and ecological effects it can have (Rogerson, 1993). The benefits discussed in the literature are summarised below. Urban agriculture can:

- Improve food security in both quantitative and qualitative terms. Even if the complete food requirement may not be met through urban production, urban agriculture has the potential to improve diet and nutrition as it contributes to a more diversified food basket and provide access to fresh, perishable foods (see Tables 1.3 and 1.4). This is particularly important for the urban poor and vulnerable who may not have access to enough food.
- Generate income and employment, not only for farmers and farm labourers, but through multiplier effects (Helmore and Ratta, 1995) on other industries such as farm inputs, transportation, marketing, food handling and processing activities.
- Recycle organic wastes generated in urban areas, which can contribute to a healthier urban environment. In other words, urban agriculture can act as a tool for transferring urban wastes into food, jobs and improved environment and health.
- Increase agricultural production by using otherwise unutilised land, water and waste resources.
- Save economic and environmental costs of transportation and cooling facilities for perishable food commodities. (See for example a study on food miles by Pretty *et al.*, 2005). For consumers this may make a big difference. According to Tinker, food typically costs at least 60 percent more to city-dwellers than to people in rural areas, due to food handling and transportation costs (pers comm. in Helmore and Ratta 1995). She argues that "*when you add up all the costs and the pollution involved in bringing food into cities and getting rid of all the trash, you have a system that half the people in the cities cannot afford*" (*ibid.:23)*

## 1.3 Problem Statement – Linking Urban Waste to Agriculture

It is against the background of the issues outlined so far that the research reported in this thesis is set. The unsustainability of cities can, in part, be ascribed to the way the environmental metabolism, or input-outflows, are managed. Natural resources are imported into the urban areas and waste and pollution is pushed out into the bioregion and biosphere. According to the World Resources Institute the overall metabolic efficiency (of Western cities) for primary to final material and energy usage is less than 5 percent (Adriaanse *et al.*, 1997). Concentrated human activity tends to disrupt eco-cycles (e.g. carbon cycles, nutrient cycles, water cycles) by introducing a linear metabolism, depleting resources and exceeding assimilative capacity (*ibid*.).

Viewed from this perspective the wider environmental implications of urban food provision and organic waste become clear. Systems designed to remove and dispose of waste in a speedy and efficient manner into sewers and landfills interrupt the nutrient cycle. Food and other natural resources such as timber and fibre are trucked, shipped and flown into cities from great distances. The nutrients 'mined' from the land are generally not returned, resulting in an increased need for manufactured fertilizer and a gradual decline in soil fertility. The same is true for non-organic materials. The less we repair, reuse and recycle, the greater the demand for landfill space and new goods, and consequently the need for new resources with associated mining, logging and transportation.

For cities to be sustainable there is a need to move towards a situation where the through-put of resources is reduced, or in the words of Ravetz (2000), where it contains its own eco-cycle. An example of this would be where food is grown and digested locally and the nutrients returned to the land. Clearly, this is not achievable on a scale whereby the nutrient cycle of an entire city would be closed. In view of the sheer size of many cities and the rapid rate at which urbanisation is taking place, the notion of an utopian situation of sustainable cities and of closed nutrient loops may seem somewhat naïve. However, it is certainly possible to do more than what is done in today's cities, and building mechanisms that allow for management systems that go some way towards this ideal is widely recognised as not only feasible, but also increasingly urgent. Returning organic materials from cities back to agricultural land is one part of this process. It can help reduce reliance on artificial fertilisers, whilst at the same time (substantially) reduce the amount of waste which needs landfilling (Sanio *et al*. 1998), providing compost can be made of a sufficiently good quality.

This then, is the point of departure of this research. It is concerned with looking at the potential for linking waste to agriculture as a means of contributing towards more sustainable urban management. The focus of the research is on the potential for agricultural use of composted urban waste. The main focus is not on how best to handle and treat urban waste, but rather on what to do with the end product once organic waste is composted. There is a common assumption that compost is good for soil fertility and that there is demand or a market for it. Similarly, it is widely assumed that the real problem lies with waste management, i.e. in separating out the organic fraction and composting it. Once those constraints have been overcome, the end product, compost, it is assumed provides a valuable resource to farmers and horticulturists.

This study is located historically in a time when research and development interventions in the fields of urban agriculture and appropriate waste management strategies 'mushroomed'. In 1998, when the research topic was conceived, only limited research had been done on linking composting as an urban waste management strategy to compost use as an agricultural input, i.e. examining how useful the end product really is. Constraints and opportunities for linking waste to agriculture are likely to differ widely throughout the world. A system that is workable in one contextual setting may not be so in another. As such the research was undertaken with the full expectation that most of the insights gained were likely to be site specific. However, it was anticipated that some of the research findings and, certainly, the research approach used could be adaptable to other contexts and serve as a useful tool in other, related interventions. The fieldwork was carried out in the city of Accra in Ghana.

## 1.4 Initial Research Questions

The underlying assumption behind the research was that there is a synergy between organic waste and agriculture and that by addressing the relationship between urban waste management and urban agriculture, and investigating the links of waste to agriculture, environmental, economic and social benefits could be identified. The approach taken to problem analysis, generalisation of the research, and analysis of research outputs, was interdisciplinary. The potential was explored from a combined technical and socio-economic perspective.

Central to the exploration of the potential of linking waste to agriculture are three research questions:

1. Does the use of composted urban waste in agriculture have any benefits for farmers, consumers and waste sector professionals?
2. Does it have a positive contribution towards sustainable management of the urban environment?
3. If so, how can changes be implemented that lead to a shift towards more efficient increased composting and agricultural utilisation of urban waste?

These questions were explored through a set of subsidiary questions including:

- What are the short and long-term effects of using urban waste derived compost as a soil amendment?
- How willing are farmers to use it?
- How appropriate is it to farmers, in relation to other options for soil improvement?
- Are farmers interested in using the material as an integral input in their production system?

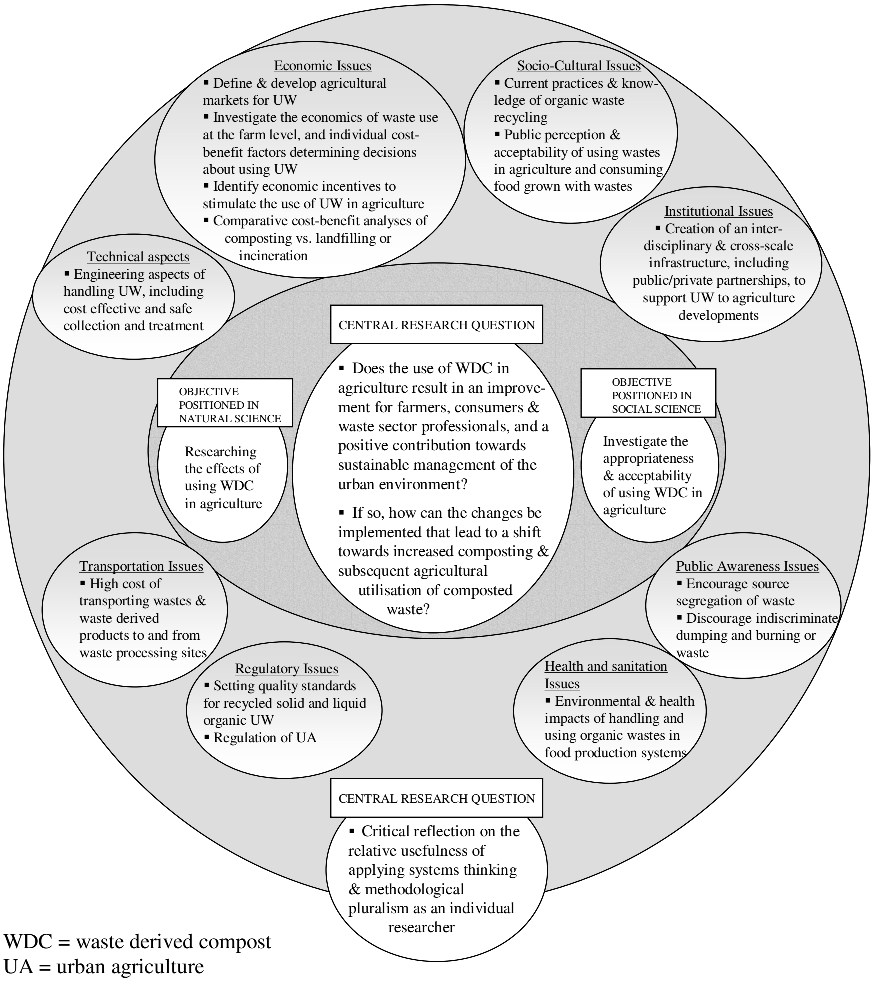
One question that had to be tackled early on was whether or not it would be possible to answer these questions using a conventional scientific research approach. In this chapter it was suggested that the disciplinary divide between not only the waste management and agricultural sectors, but also between other sectors, notably health, affects the links that are perceived and created between waste and agriculture. This divide poses an important constraint to linking waste to agriculture. In view of this and of the preceding discussion about sustainability, it would seem that any research or intervention approach aimed at understanding or changing the situation, needs to take a broad, interdisciplinary stance, both in terms of theory and methodology. It will be argued in this thesis that exploring the potential for using composted urban waste in agriculture using conventional reductionist scientific methods of enquiry alone, does not give a full understanding of the complex interrelated issues at play.

If reductionist science alone would not be sufficient, the question arises how to approach such a complex issue, which involves multiple, heterogeneous stakeholders? What combination of complementary methods would be required to answer the research questions outlined above? It was decided to use a systemic approach using a plurality of methods, blending reductionist scientific methods with the softer methods of enquiry used in constructionist social research. Choosing to take such an approach as a sole researcher clearly meant that boundary choices had to be made and that trade-offs were inevitable. Rather than exploring one aspect in great depth, the choice was made to take a broad-brush approach and to look at the issue from a variety of perspectives. The choice was guided by the reality of the constraints and opportunities of the situation studied. It was the belief of the researcher that by taking such an approach, a fuller and more appropriate understanding of the issues would be gained. How well this thesis has achieved this purpose will be re-considered in the final chapter. The chosen approach is not proposed as the only way in which to research this topic, nor is it argued that it will provide a complete picture. Rather it is suggested that it is the most appropriate way to go about tackling the kind of issue addressed. The case for this choice will be argued further in the next chapter.

In view of the above, a further research agenda emerged. Carrying out research in a theoretical and methodological pluralistic way, as an individual, without a large research team of professionals from different disciplines to work with, is likely to have both merits and drawbacks. At the initiation of and throughout the research, the pre-analytic choices made regarding methodology were critically reflected on. The research process, then, became a research objective in its own right. Through critical reflection on the research as it progressed, the research set out to explore:

1. The relative usefulness of carrying out the research in this way, using a combination of more or less complementary methods.
2. What were the learning experiences gained through the research process and how useful were they in terms of bringing about improvements (be it for the farmers, waste managers or myself in my future professional life)?

There is much, albeit cautious, optimism in the literature (e.g. Furedy *et al.* 1997; Sanio *et al*., 1998) with regards to the potential of urban and peri-urban agriculture as one of the means available for dealing with urban wastes. However, there are many challenges that need to be overcome. Issues that need to be addressed, identified in the literature (e.g. Furedy *et al*., 1997; Allison *et al.,* 1998), are outlined in the grey ovals in the diagram below (Figure 1.2). The research purposes, given in the white ovals, touched upon and/or contributed towards many of the researchable needs. Whilst the research focused on one element, or sub-system, within this area, it contributed to the 'larger picture'




WDC = waste derived compost
UA = urban agriculture

*Figure 1.2 Conceptual framework: the central research questions and research objectives are surrounded by issues that need to be addressed*

*Source: This thesis*

## 1.5 Structure of this thesis

**Chapter 1** has set out the research agenda. It has introduced the context to the problem area in this research is set and presented the research question.

**Chapter 2** presents the main theories and research traditions that I have drawn upon in this research. They are mainly in the interrelated areas of systems thinking, participatory agricultural development, action research and adaptive management. Key concepts such as positivist realism and constructivism, participation, power, social learning and theoretical and methodological pluralism are introduced and the way these were important in guiding the research examined.

**Chapter 3** outlines the organisation of the research and how a range of different research activities fitted together to inform the study. The rationale for the use of methodological pluralism as essential for this study is justified.

**Chapter 4** provides a detailed description of the study setting, Accra in Ghana. It presents (and analyses) the context in relation to urban and peri-urban agriculture and solid waste management. The chapter concludes with a presentation and discussion of the results of a baseline survey into agricultural activities and soil fertility management practices in and around Accra. In terms of agriculture, particular focus in given to urban vegetable production systems whilst in terms of waste management particular focus is on composting.

**Chapter 5** presents and discusses the choices made in the design and implementation of the experimental work conducted with vegetable growers and an on-farm trial farmer, and the analysis of composts and manures. The research process followed during the collaborative experiments is introduced and discussed. The chapter concludes with a reflection on the researcher's role in process management.

**Chapter 6.** This chapter presents the results from the experimental work with vegetable growers and the on-farm trial. This includes soil analysis and crop experimental results, but also farmers' assessments and their general perception of the performance of WDC and their experience of carrying out the experiments. The chapter concludes with a reflection of the researcher's role in the process and the relative merits of collaborative experimentation of this nature.

**Chapter 7**. In this chapter the findings from the various research activities are drawn together and synthesised to explore the potential for using waste derived compost (WDC) in agricultural systems within the Greater Accra Metropolitan Area (GAMA). The findings are presented from the perspectives of multiple key stakeholders with varying objectives and capacities. It examines the existing institutional structures and discusses how the largely lacking interaction among them represents a serious constraint to effective governance of the waste management problem. It is concluded that the situation lacks a process and procedure, for bringing stakeholders together in order to initiate a social learning process.

**Chapter 8**. This chapter provides a critical reflection on the research experience. More personal than the previous chapters, this Chapter discusses my experiences of carrying out interdisciplinary research the way this was done as an individual researcher. It discusses the benefits and drawbacks of the approach and seeks to distil the learning experiences that took place.

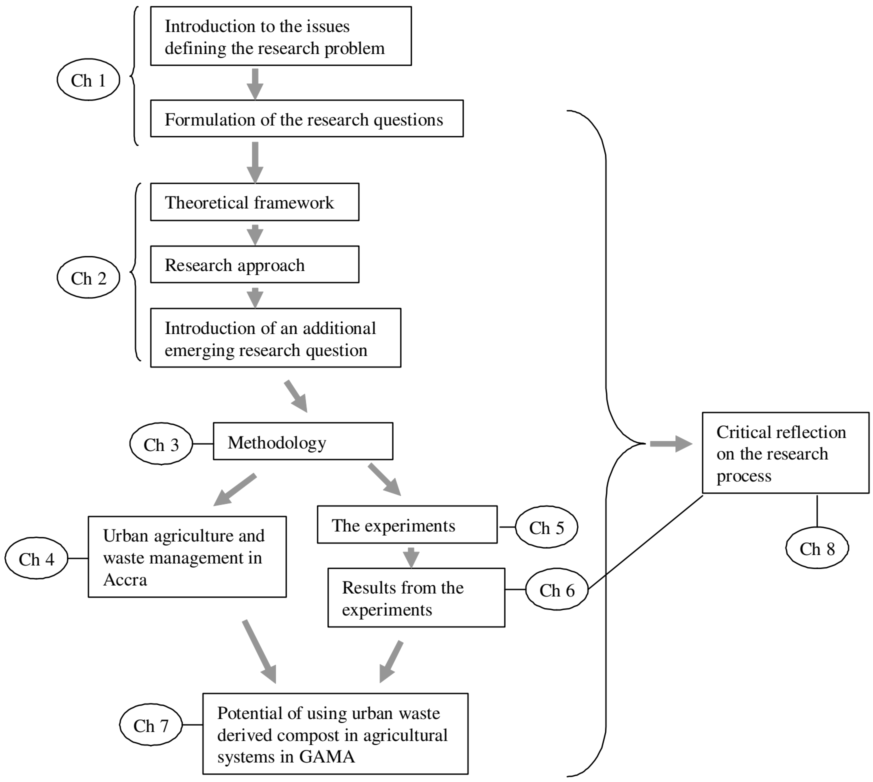



*Figure 1.3 Diagrammatic representation of the structure of the thesis*

*Source: This thesis*

# CHAPTER TWO – CHALLENGES FROM THEORY

By their very nature, urban dilemmas are almost always multisectorial and city management has to be studied from a variety of angles and disciplines (Freire, 2001). The issues linked to this problem area are no exception. From the discussion so far, it is clear that it is a systemic problem, with a series of interconnected and interdependent issues. Efforts to link waste to agriculture need to address constraints and potentials in relation to issues such as environmental effects, health and safety, institutional, administrative and managerial structures, economics of organic waste recycling for a range of stakeholders, and social and cultural factors. It is an endeavour which requires an integrated and adaptive approach linking actors from a broad arena across temporal and spatial scales, organisational hierarchies and disciplines, including urban planners, waste engineers, agricultural development organisations, policy makers, farmers, semi-formal and informal waste traders, consumers and donors. The previous chapter laid out the general case for taking a systems perspective and choosing for methodological pluralism. This chapter explores in greater depth the theoretical framework shaping these choices. Key concepts are introduced: systems thinking, positivist realism and constructivism, participation and power. The implications for research are discussed in terms of farming systems research, PRA, and action researching. The notion of managing adaptively - based on social learning - is introduced as a way forward for resolving particular kinds of social dilemma.

The chapter is divided into two major sections:

1. The first section reviews the theoretical background to systems thinking and other related research traditions, and explores the epistemological and ontological concepts that underpin this thinking. It traces the history of systems thinking and the emergence of soft systems thinking and participatory approaches to research and development intervention. Particular attention is given to the shift in thinking that has taken place within agricultural/rural development and extension theory, but also in the areas of environmental management and ecology. The review lays the ground for the design of my research on the three substantive questions formulated in Chapter 1, as well as for the two questions on research methodology and process with which the chapter concluded.
2. Following the general overview of the relevant theoretical approaches and perspectives, the second part of this chapter outlines the research approach adopted. It provides a rationale for the choice of research approach and explains how the research was entered into from a constructionist position (ontology) and how systems concepts were used to underpin the research.

## 2.1 Key Concepts

The 20$^{th}$ century saw a gradual undermining of the mechanistic worldview as a dominant paradigm from medieval times onwards, helping to shape Western society and subsequently influencing much of the world. The mechanistic view is a metaphor for a claim about 'how the world works', i.e. that everything is made up of parts that together work as a machine. It is associated with a positivist-realist ontology that assumes that (through science) we can gain knowledge of the world and that this knowledge accurately reflects reality (Pepper, 1986). If the world is made up of a collection of parts, it follows that it can be fully understood by breaking it into its constituent parts and analysing the parts in isolation (reductionism). It assumes that a given system is no more and no less that the sum of its parts; thus we can understand the general through the study of the specific. The reductionist scientific approach has, and continues to serve us well in terms of technology development and in advancing knowledge in many branches of science. However, during the 20th Century there has been growing recognition that this is not enough and that reductionist science and positivist realist perspectives cannot be applied usefully, or even meaningfully, to every enquiry and problem[4]. In fact, we have seen time and time again, in the management of both natural and social systems, that solving one problem often leads to the creation of another.

The world is becoming more and more inter-linked and with it comes a realisation that it is more complex and less certain than ever the Enlightenment theorists assumed. We need to, as Checkland (1994:75) puts it "*enlarge and enrich our thinking*". Many of the problems we are faced with are interconnected and cannot be understood in isolation. The claim of systems thinkers is that a more holistic approach to understanding would allow us to manage problems in a systemic way and thus avoid the unwanted effects of managing single target variables. Systems thinking emerged as a way of understanding and dealing with complexity. "*Systems theory attempts to provide a conceptual framework across very wide fields of intellectual endeavour for dealing with problems which are seen as being incapable of being solved by traditional, 'reductionist' methods*" (Mettrick, 1993:47).

There are fundamental ontological and epistemological differences between the mechanistic and the systemic worldviews. In addition to the obvious tension between a focus on the parts and on the whole (Capra 1996), are important epistemological differences in the notion of reality and our perception (or construct) of a reality, and between the subject and object, bringing into question the idea of objectivity (Maturana and Varela, 1980, 1987, 1992; Ulrich,1987; Midley, 2000). The next section looks at some of the key concepts of systems thinking and the epistemological and ontological perspectives that underpin them.

[4] There are a number of root causes for the shift in thinking. Developments in quantum physics and the understanding of the biology of organisms during the first half of the last Century have led to fundamental changes in our understanding of how the world works. Also, the use of mathematical modelling to develop chaos and complexity theory has undermined the mechanistic view of predictability and of what can be known. Added to the changes in concepts that have occurred in science, are ever-growing environmental problems (e.g. WCED, 1987; Pepper, 1986; Meadows et al., 1992; Capra, 1996), which have made clear that the use of reductionist science and a positivist realist approach to enquiry and management is not enough to safeguard the conditions that sustain human life.

In Box 2.1 some of the characteristics of complex systems are given. Many of these will be discussed further within the sub-headings of this section. This is followed by an outline of changes in systems thinking that have emerged over time, particularly in relation to agricultural/rural development (2.2).

**The Whole and the Parts**

The holistic worldview assumes the world to be an integrated whole rather than a dis-associated collection of parts. "*It recognises the fundamental interdependence of all phenomena and the fact that, as individuals and societies, we are all embedded in (and ultimately dependent on) the cyclical processes of nature*" (Capra, 1996:6). Intimately linked to the notion of holism is systems thinking, which is a way to understand the complexity and interconnectedness and interactions between parts of a whole. The key concept in systems thinking is that the world is made up of interconnecting elements that affect, and are affected by, each other. Consequently, a situation or problem cannot be understood by examining the parts of a system in isolation. Following Checkland (1981:3):

> "*The central concept 'system' embodies the idea of a set of elements connected together which form a whole, this showing properties which are properties of the whole, rather than properties of its component parts*".

A system therefore, is more than just the sum of parts

A similar definition is offered by Ackoff (1981:64-65)

> *"A system is a set of two or more elements that satisfies the following three conditions:*
> - *The behaviour of each element has an effect on the behaviour of the whole*
> - *The behaviour of the elements and their effects on the whole are interdependent*
> - *However subgroups of the elements are formed, each has an effect on the behaviour of the whole and none has an independent effect on it*
>
> *A system, therefore, is a whole that cannot be divided into independent parts. The essential properties of a system taken as a whole derive from the interaction of its parts, not their actions taken separately."*

**Hierarchies, Nested Systems and Emergent Properties**

The notion of hierarchies, or levels[5], nested systems and emergent properties are fundamental to systems thinking and linked to the concept of boundaries. Any system is made up of parts, or sub-systems (who in turn are made up of sub-sub-systems and so on), that interact. Similarly the system is nested within other, wider systems with which it interacts. In other words, the world is made up of a hierarchy of nested systems from the simplest cell structure, through to organisms, groups, organisations, ecosystems, planet, galaxy into the infinite. What we call the system, the environment and the sub-systems, is simply a reflection of the level at which we chose to operate (our boundary judgement).

[5] Many systems thinkers prefer to use the word level instead of hierarchy to avoid connotations of power often associated with the word hierarchy (e.g. Checkland, 2000; Midgley, 2000).

As we move up the hierarchy complexity is increased and predicting outcomes to changes become more difficult. Properties which do not exist at the lower levels emerge at each higher level as a result of the interactions between the component parts of the system. This is referred to as ‘emergent properties’, a term coined by the philosopher CD Broad in the early 1920s (Capra, 1996). An emergent property results from the interaction of a system as a whole rather than from one or two of its parts in isolation. For example, Röling argues (2000) that sustainability is an emergent property of a ‘soft’ system, as it is the possible outcome of the collective decision-making that arises from interactions among stakeholders. Capra (1996) uses a perhaps more concrete example of the taste of sugar not being present in the carbon, hydrogen and oxygen atoms that constitute its components.

Regardless of the level (hierarchy) we chose to look at, the idea of a nested set of systems with new properties emerging at ‘higher’ or ‘wider’ levels is critical to understanding many phenomena. This is fundamentally different from reductionist analysis where the concept of emerging property does not feature. In the research reported in this thesis, the notion of exploring the problem at different levels within an overall framework of a complex system appeared relevant to the contextual issues highlighted in the literature (see Chapter 1).

**Communication, Feedback and Control**

One of the characteristics of systems is that they are controlled and regulated through mechanisms of communication and feedback. With everything linked to everything else in hierarchical, coupled systemic structures, it follows that communication flows occur within a system, as well as between sub-systems and its environment (suprasystem). The behaviour of complex systems can be very difficult to predict, because the links are not merely complicated but often irreducibly unknowable and surprise is normal. As often experienced in ecosystem management (e.g. Holling, 1995) and as demonstrated through Chaos theory (e.g. Gleick, 1987), a very minor change can have massive, unforeseen consequences in ways that are seemingly unrelated and far removed (in both space and time). In relation to decision making, Senge and Sterman (1992:142) note: “*dynamic decision making is particularly difficult, especially when decisions have indirect, delayed, non-linear and multiple feedback effects*”.

*Box 2.1 Characteristics of complex systems*

Drawing on work by Checkland, 1988; Flood and Jackson, 1993; Chilliers, 1995 and Bronte-Stewart, 1997, a notional complex system can be said to include the following characterising phenomena:

- The existence of a large number of elements which influence, and are influenced by, each other
- Inclusion of both things and people
- An environment that it is open to and that it affects and is affected by
- A namer- someone who is interested in it
- A (nominal) boundary identified by the system namer, which separates it from the environment
- Inputs and outputs
- Transformational processes that convert inputs to outputs
- Communication and feedback loops in the interactions, whereby the effects of any action taken by a certain element can feed back into itself
- Dynamism - it is not static, but rather subject to change over time including adaptation, growth and decay.
- Non-linearity – the interactions operate in a non-linear manner.
- Non-equilibrium conditions under which it operates
- Self-organisation leading to emergence and new order
- The existence of parts, or subsystems, that interact (in a pattern of relationships) in a purposeful manner generating their own goals
- A purpose – it does, or can be perceived to , do something
- Layered, or hierarchical structure - each part (subsystem) is a system itself and can be treated as such
- Interdependence – alteration, addition or removal of a part changes both the part and the system as a whole
- An adaptive whole showing emergent properties - the whole system exhibits properties and outcomes, sometimes unpredictable, which derive from its parts and structure but cannot be specifically attributed to them
- Control within subsystems and through the hierarchy
- A history which has influenced its current properties and is relevant to future developments

**Systems in Relation to Environment and Boundary**

A system can only be identified by separating it out from a yet larger whole, which in turn necessitates the drawing of a boundary around the system of interest and the surrounding environment. The concept of boundary judgements is a critically important aspect of systems thinking, and particular attention is paid to it within soft systems thinking (e.g. Ulrich, 1983; Flood, 1999; Midgley, 2000). Where the boundaries are constructed and what the values are that guide the construction, will determine how issues are seen and what actions will be taken. The values (worldview) that we have will affect how we choose to draw a boundary around a perceived system. As such boundary judgements and value judgements are intimately linked.

When setting a boundary, critical reflection on who is included and who is not needs to be made as "*a boundary does not only mark what is included within the system; it also marks what is excluded*" (Midgley, 2000:36). Who may benefit from any intervention within the boundary set and who may be worse off as a result of being excluded? What may be the possible (social and environmental) consequences of setting the boundary in a certain way as opposed to another? Since boundary judgements introduce subjectivity it is important to be explicit about this and break through the illusion of objectivity that frequently surrounds boundary setting. As Ulrich (2001:12) reflects "*not so much what our boundary judgements are but how we treat them will determine the quality of our systems thinking in the first place*".

In the design and execution of this research, boundary judgements were made all the time; critical reflection on the process of reaching such decisions formed part of the research. For example, the boundary was widened or narrowed depending on the (sub-)issue being explored and a particular stakeholder's role within the system. Emerging issues (e.g. the importance of the vegetable marketing system to farmers' decisions) led to the initial boundary frame being altered to incorporate sub-systems that emerged as relevant to the overall research.

**What is Real? – Positivism and Constructionism**

As we come to realise that our understanding of the world is imperfect the concept of a true reality is called into question. How we perceive reality depends on our previous experiences and the environment we are in (Guba & Lincoln, 1994; Pearson and Ison, 1997). What seems obvious and common sense to some may not be at all obvious to others. For example, someone regarded as a terrorist by one group of people, may be revered as a freedom fighter by others. What is someone's waste may be someone else's resource. There are multiple perceptions of reality (Guba & Lincoln, 1994) and there is a multitude of ways to deal with issues and solve problems. It is all about our perspectives. There is a realisation that we can never be sure about what the 'true' reality is, all we can hope to do is have an understanding of reality (Checkland, 1994). A perception of reality is thus a construct (e.g. Berger and Luckman, 1967). Midgley (2000:2) points out that "*just about every philosopher of science who has been taken seriously in the latter half of the 20th Century has argued that we cannot know the exact relationship between human knowledge, the language we use to frame this knowledge, and reality. This* *is because whatever we know about reality is just that – knowledge, not reality itself.*"

Constructionism is the term for a strand of epistemology within philosophy which admits multiple representations of the empirical world (Jiggins, pers. comm.). Thus it is fundamentally different to the positivistic paradigm in that it rejects the notion of a single objective claim about reality (Röling, 1997). Rather it assumes a relativist ontology where multiple perspectives of reality are admissible as the products of human intellects (Berger and Luckman, 1967; Guba and Lincoln, 1994). Under most circumstances different people will view an issue ('reality') differently and have different opinions on how to best handle it. Constructionism underpins the thinking about soft systems and is, according to Röling, (1997) increasingly accepted as a description of the way we acquire knowledge, including the way natural scientists develop facts through a highly specialised set of procedures. In Röling's view "*a constructionist perspective is essential because people's activities can only be understood on the basis of how they construct reality, and not by some casual factors that a scientist 'reveals'* " (*ibid*.:250). Bell (1998:181) reflects that "*reality is complex and no single view will be adequate to explain the nature of the complexity within and around us. …. The potential world is not the potential world of the single discipline*."

What is at issue here is understanding how people generate knowledge that is effective for action and fit for purpose. Positivism and constructionism in this sense are not so much competitive epistemological claims but complementary. This thesis presents research that opts for a constructionist entry point as fit for the purpose of understanding people's actions (and potential for new action), within a system perceived as complex. As the presentation proceeds, it is shown how normal science can complement and deepen participatory knowledge development to produce knowledge that is effective for managing a complex system.

**Subject/Object Dualism**

Subject/object dualism refers to the claim that the separation of the observer (the subject) and the observed (the object) is possible (Midgley, 2000). In this perspective the observer is independent of the observed. Providing that proper measures (controls) are taken to ensure that the observer does not in any way affect that which is being observed, objectivity can be assumed (and objective results can be ensured). Dualism underpins reductionist science and methodology and the mechanistic worldview.

Soft systems thinking is fundamentally different in that it does not assume subject/object dualism. However, some (e.g. Midgley, 2000) argue that most systems thinkers have not abandoned the deeply embedded notion of subject/object dualism. Certainly, this was the case in the early stages of (hard) systems thinking during the 1950s and 1960s. Those working more closely with biological and social entities came to argue, however, that there is no such thing as true independent observation and that the notion of objectivity is an illusion (Maturana and Varela, 1980, 1987, 1992; Ulrich, 2001). Moreover, once we accept that everything is linked to everything and that there are different viewpoints and ways of handling things, the notion of subject/object dualism becomes problematic. As an observer we have to make a decision which part of the whole system to separate out for study (thus call an object). By so doing we affect objectivity in three ways. Firstly, if everything is seen as connected in some way to its surrounding environment, then it follows that the notion of truly independent observation is flawed. If reality is seen as a web of systemic relationships, it is no longer possible to separate out any one part without acknowledging that it is affecting the whole or the part in some way. To isolate an object for study is to ignore the interactions.

Secondly, as observers we position ourselves as part of the system; it is literally impossible to be independent, or external to what is observed (Pearson and Ison, 1997). Influenced in part by the work of biologists/neuroscientists Maturana and Varela (1980, 1987, 1992) on how organisms observe, some researchers (e.g. Luhmann, 1989, 1990; Röling and Wagemakers, 1998; Ison and Russel, 2000; Midgley, 2000) have stressed that humans are incapable of perceiving and communicating information objectively, because our brains are structurally coupled to the environment and to the language we use to frame our knowledge[6]. Röling (1997:254) explains the coupled relationship between organisms and environment by using the metaphorical example of a plane flying through dense fog using its instruments. Although the instruments are 'informationally closed', the environment can trigger changes in the instruments which adjust the navigation, thus enabling the plane to fly safely through the fog. Thus reality (i.e. anything external to the observer) is not imprinted objectively on the mind, but is constructed in inter-subjective sense making (*ibid*:252) (i.e. perception is accomplished by the brain). Under this model, the observer cannot be kept outside the analysis and the concepts that are applied in the process of intervening in the world (Jiggins, pers comm.).

Thirdly, since we as observers make decisions about what is admissible as, and what constitutes an object we invariably introduce subjectivity into the act of researching (Ulrich, 2001). By deciding to isolate out objects, through drawing a boundary around them in a specific way, the objects of study are different from what they would be had we drawn the boundary in a different way. Which parts of a system a researcher decides to isolate as the object affects the outcome of the research. For example, a study on nitrogen materialisation dynamics from organic material in a soil can be done in many different ways and include a range of different variables. Different scientists legitimately may choose different boundary frames for what to include in such a study, resulting in the production of different results, without one piece of research being more 'right' than another. Even in

[6] Through their theory of autopoiesis (=self-producing) and empirical investigation, Maturana and Varela (1980, 1987, 1992) have shown that the brain (nervous system) is informationally closed, conditioned to react to sensory information about outside factors on the basis of its structure. The brain reconstructs the external environment from environmental triggers, but it does not directly experience it. Maturana and Varela suggest that the exact relationship between knowledge, language and reality is inherently unquantifiable and, furthermore, implies the possibility of a non positivist-realist biological theory.

natural science, the pre-analytical choices made by the observer (scientist) thereby introduce subjectivity into the research.

In the section on action research below, the concept of subjectivity in systems studies is discussed further in terms of how it and can be incorporated into methodology and how in this research subjectivity was assumed and made explicit.

## 2.2 A Brief Overview of Relevant Developments in Systems Thinking

**First Generation Systems Thinking – Hard Systems Thinking**
Modern systems thinking originates in the late 1940s and is primarily associated with the work in the biology of organisms by the German biologist Ludwig von Bertalanffy[7] who developed open systems theory and later laid the foundations for general systems theory (GST) (Checkland, 1988). During the 1950s and 1960s (general) systems thinking came to profoundly influence science and engineering[8] as well as organisational theory and management[9]. With an emphasis on quantitative applied science, it influenced scientific language and led to numerous new disciplines and methodologies including systems engineering, systems analysis, ecosystem biology (ecology) and systemic management (Capra, 1996).

Many aspects of systems thinking, especially as developed within the disciplinary traditions of ecology and organisational management, have greatly influenced agricultural research and development. In the 1960s the success of agricultural modernisation through reductionist scientific research and transfer of technology (ToT) began to be called into question. There was a growing realisation that the trade-offs for the achievements experienced in agricultural development included long-term degradation of biophysical and socio-cultural environments (e.g. Bawden, 1991a, Reijntjes *et al.*, 1992; Steffen *et al.*, 2004; Millennium Ecosystem Assessment, 2005) There were clear signs that many farmers in the South had failed to adopt the new technologies on offer, yet there was still a need to further increase food production to support growing populations (e.g. Farrington and Martin, 1988; Pretty and Shah, 1999). By the 1970s, there were clear signs in the South that the ToT model of agricultural development had resulted in considerable inequality. These outcomes were linked to the way that formal agricultural knowledge had been conceptualised and generated (Drinkwater, 1994),

---

[7] Although there have been many people through history whose work can be regarded as systems thinking (e.g. Aristotle, Marx, Boganov), it was not until Bertalanffy's (1950) development of open systems theory in the 1940s, and later his contribution to general systems theory (GST) (1956, 1968) that the notion of holistic and systems thinking became institutionalized (Capra, 1996).
[8] Notably the cybernetics movement (e.g. Wiener, 1948; Bateson, 1972, 1979; Ashby, 1956; Maruyama, 1963; Neumann, 1966 and Beer, 1959).
[9] Notably within the human relations movement, family therapy and operational research (e.g. Churchman, 1956; Ackoff, 1957; Boulding, 1956; Vickers, 1965; Trist (e.g. Trist *et al.,* 1963) and Forrester, 1961).

signalling a wider interest in a systems approach to agricultural research and development. Early examples were Farming Systems Research (e.g. Spedding, 1979; Byrelee and Collinson., 1980; Byrelee *et al*., 1982; Shaner *et al*., 1982) and agro-ecosystem analysis (e.g. Conway 1985, 1990; Altieri, 1987).

The purpose of early FSR was to improve the efficiency of agricultural knowledge and technology development by making research and the implementation of research findings more relevant to resource poor farmers (Collinson and Lightfoot, 2000). It was envisaged that a systems approach, in which the farm was seen as a complex system of interacting components, would help identify technologies that would increase whole farm system productivity under the challenging and diverse farming conditions experienced by resource poor farmers (Dixon *et al*., 2001). Multidisciplinary teams typically consisting of farm advisors, agro-economists and natural scientist such as agronomists, animal scientists, soil scientists, pathologists and hydrologists worked with farmers to design, test and evaluate new or improved technologies that would be suitable in local conditions.

**Second Generation Systems Thinking – Soft Systems Thinking**

Over time, different strands of systems thinking have emerged and evolved within different disciplines and research traditions. General Systems Theory has not influenced systems thinking elsewhere to the extent that it has in USA (e.g. Miller, 1978; Bailey, 2000). A different interpretation of the notion of 'system' gained ground, which was largely rooted in key work by Churchman (1968, 1971, 1979). He came to develop his ideas about systems thinking in terms of what he called the Critical Systemic Approach. It was fundamentally different from GST in that it took subjectivity seriously. Churchman's work gave birth to a new way of thinking about systems, which became widely known as soft systems thinking[10].

On a practical level there is a commonly used distinction between hard and soft systems thinking which concerns the type of problems that are to be tackled and the presence or absence of humans in the system of interest. Originally designed to deal with engineering type problems, hard systems approaches have proven to be powerful in terms of gaining comprehensive knowledge about a tightly bounded system and for using that knowledge to predict (model) outcomes in order to design and improve the system of interest (Checkland, 1994). Hard systems thinking is used to tackle well-defined, technical problems; soft systems thinking is more suitable for tackling fuzzy, ill-defined, complex problems involving human beings and socio-cultural issues. Situations suitable for a soft systems approach are those whose purpose is not defined, boundaries are not given, and which are subject to change. They typically involve many stakeholders with different, often conflicting, objectives and perspectives on the nature of the problem to be addressed (Checkland, 2000). Thus, an investigation of the systems for composting

[10] Midgley (2000) avoids using the term soft system thinking and refers to this paradigmetic shift in systems theory as 'second wave' systems thinking. Similarly, he sees the subsequent evolution of critical systems thinking as a third wave in the development of the systems thinking tradition.

technology could be an example of hard systems thinking, whilst an exploration into workable waste collection and management strategies would fall into the area of soft systems thinking.

However, the critical distinction between hard and soft systems thinking, and this is where the subjectivity comes in, is rooted in underlying philosophical difference between the two perspectives. In hard systems thinking, 'systems' are seen as real world entities and the boundaries of a system are given by the structure of reality (Checkland, 1994). Churchman and other systems thinkers came to challenge this notion, arguing that systems are constructs to aid understanding and that boundaries are merely social or personal constructs (Ulrich, 2001). The difference lies in the theory of reality which underpins the two approaches. In the hard perspective the word 'system' is used to describe ontological realities, whilst in the soft perspective the word 'system' is seen as an epistemological device for knowing about the world. Checkland (1988) stresses that a system is an abstract concept, a perceived reality, which we use consciously in an effort to make sense of the world. One could say that hard systems thinking is positivistic whilst soft systems thinking is constructionist. "*With its foundation in cognitive science, the systemicity [in soft systems thinking] is transferred from the world to the world of investigating the world*" (Bawden, 1991a:2362).

In addition to Churchman, the work of two other people has become widely known for generating the soft systems approach, Ackoff (1981) for the development of Interactive Planning in the 1980s and Checkland (1981, 1990), who is widely regarded as the 'father' of soft systems methodology (SSM). Hard systems approaches, focussing on quantitative applied science, were criticised for failing to see the value of bringing the subjective insights of stakeholders into the activities of planning and decision making (Midgley, 2000). In soft systems thinking attention was given to complex interactions in which people play an important role. Focus was placed on problem solving and decision making, with emphasis on dialogue and stakeholder participation. Both Interactive Planning and SSM are participatory, iterative methods for bringing out the knowledge and creative abilities of all stakeholders within the system of interest. Other theoretical and applied work that influenced the formation of soft system thinking include: Vicker's (1970) theory of appreciative systems, Silverman's (1970) theory of organisations, developed in the 1970s, Berger and Luckman's (1967) influential book 'The social construction of reality' and Maturana and Varela's (1980, 1987, 1992) concept of autopoiesis, or self-producing systems[11].

Many of these concepts and applications were introduced into agricultural development practice. Many FSR practitioners and theorists came to see that their work remained rooted in a form of modelling and technology development informed by hard systems thinking. They came to accept that what was needed was a more complete reformulation, in order to incorporate soft system theorising and a

[11] Lovelock's Gaia theory (1979,1980), of Earth as a living, self-regulating system is premised on this concept.

methodology appropriate to constructionist research (e.g. Chambers and Jiggins, 1986; Chambers *et al*., 1989; Scoones and Thompson, 1994).

The new, more participatory approach sought to strengthen the role of farmers in the research and development process, arguing that many of the answers and solutions to problems lie in interaction with farmers and other actors (Chambers and Jiggins, 1986; Chambers *et al*., 1989). The approach was further expanded and strengthened by taking into account questions of social justice, equity, ethics and empowerment (e.g. King, 2000; Long and Long, 1996; Guijt, 1996; Mosse, 1993). Emphasis was placed on bridging the gap between professionals (scientists, researchers, extensionists, planners) and farmers and creating environments in which local people were involved as active and equal partners in all aspects of the research and development process, from priority setting through to planning, implementation and evaluation.

Another new dimension was the more important role given to the social sciences. Whilst in earlier FSR practice agro-economists had played an important role (Bawden, 1991a), the requirement of multidisciplinarity was now widened to include a much wider range of social scientists. One consequence was that gender issues were placed high on the agenda, in recognition of the key role that women play in farming and rural communities.

The increased interest in farmer participation stimulated also the proliferation of new applications in the field. Examples include Farmer Participatory Research (FPR) (Farrington and Martin, 1988), Participatory Technology Development (PTD) (van Veldhuizen *et al*., 1997), and Farming Systems Research and Extension (FSR-E) (Coutts, 1994 in King, 2000). One consequence was that research designs that lent themselves to sophisticated analysis of results were down-played in favour of research designs that fit more readily into normal farm practices and produce results which are interpretable by and make sense to farmers. The 'farmer first' rhetoric become familiar in institutions ranging from the smallest NGO to the World Bank (Cornwall *et al*., 1994). It spread outside the original rural and agricultural sphere to be applied in many other contexts and frequently also in urban areas (Chambers in Holland and Blackburn, 1998). Stakeholder participation increasingly became a prerequisite for research and extension project funding.

**Third Generation Systems Thinking - Critical Systems Thinking**

Soft systems thinking continued to evolve and, by the end of 1980s, a third generation of systems thinking began to take form. This branch within the systems tradition has been called critical systems thinking (CST). There were essentially two sets of criticisms of early soft systems methodologies that led to the emergence of CST.

Firstly, many systems thinkers, notably Mingers (1980, 1984), Jackson (1982, 1985, 1987), Ulrich (1983) and Flood (1990a), argued that existing soft systems approaches did not adequately recognise and deal with the issues of power and conflict which are inherently embedded in social systems. There was a feeling that the soft systems approach of Churchman, Ackoff and Checkland was not 'radical' enough (Jackson, 1985), especially when dealing with social systems characterised by large inequalities of power and resources and by conflict and contradiction. Under such conditions, it would be unrealistic to assume unconstrained debate and full participation by all stakeholders. The importance of critical reflection on the role and effect of systemic intervention became an important part in the framework of thinking[12]. This notion is central to Ulrich's (1983, 1988, 1994) theory of Critical Systems Heuristics (CSH) (which, Midgley notes, constitutes one of two foundation stones of CST). Building on the work of Churchman and influenced by the work of Habermas, Ulrich stresses the need for critical reflection on the boundary and value judgements made by researchers and planners: the values we have affect the way we draw boundaries. He argues for stakeholder involvement in the process of making boundary judgements and is of the view that boundaries should be derived from dialogue. Boundary critique also features strongly in the thinking of Midgley (e.g. 1992, 2000). See Section 2.3.5 for more on boundary judgements.

Within participatory agricultural research, development, and extension the thinking evolved along parallel lines amongst development professionals and scholars. Systems practice became both deeper and more comprehensive, to incorporate a greater diversity of views of a given problem or situation (King, 2000), and a broader understanding of farm systems to livelihood systems.

The thinking about the concept of participation also evolved as field experiences of participatory research and extension in the South was amassed and digested. Expectation that participation in research and development projects lead to improvements for local people, came to be seen by many as unrealistic and naïve (Guijt, 1996). Furthermore, emerging questions like 'whose knowledge counts?', 'is some knowledge more valid than others?', 'how is knowledge generated?' and 'who benefits?', led many scholars and practitioners to reflect on the underlying philosophy behind the populist notion of a participatory approach (e.g. Russel and Ison, 1991; Bawden, 1991a; Scoones and Thompson, 1994; Röling, 1997; King, 2000). Several areas of challenge emerged including questions surrounding the nature of knowledge, participation in relation to power relations and the issue of conflict.

As a result of considerations of this nature, agricultural development theory and practice began to focus more on the social construction of knowledge systems, power relationships and conflict issues (Scoones and Thompson, 1994). This shift occurred from the grassroots level of rural development in the South to the macro level of issues of sustainable agriculture in the broader, increasingly urban and globalised society.

The second critique emerged from a frustration with the ongoing paradigmatic conflict between first (hard) and second (soft) generation systems thinkers

[12] In 1991, Checkland, together with Scholes, published a revised version of Soft Systems Methodology designed to deal with issues of power and internal politics within organizations.

(Midgley, 2000). The third wave thinkers advocated methodological pluralism (sometimes called complementarism). They argued that hard and soft approaches are complementary (not in competition), and suited to deal with different kinds of problems (see Box 2.2).

*Box 2.2 Three different types of systems thinking are useful for dealing with three different types of problems, as proposed by Jackson (1987)*

1. First wave systems thinking for dealing with situations where there is agreement on the nature of the problem
2. Second wave systems thinking when there is non-coercive disagreement between the stakeholders
3. Critical Systems Heuristics in situations characterised by coercion

*Source: Jackson, 1987*

Initiated in a 1984 publication by Jackson and Keys, the argument for pluralism in epistemological as well as methodological issues has been expanded and become an important aspect of current systems thinking (see for example Midgley, 2000; Flood, 1990; Ulrich, 2001 and Röling, 1997). Rather than being an argument for using different systems methodologies for different kinds of systemic intervention (as proposed by Jackson and Keys in 1984 and later by Jackson in 1987), the notion of pluralism has lately been expanded to incorporate the complementary and concurrent use of multiple theories, methodologies and methods in complex systemic intervention. Ulrich (2001:19) *reflects that "the unavailability if a satisfactory answer is probably responsible for the current rise of pluralism in epistemological and methodological issues*." Midgley (2000:215) argues for pluralism at the methodological level " *in the sense of respecting the fact that others may have useful insights that we may learn from in constructing our own methodological ideas*". He also argues for pluralism at the level of methods "*meaning that we can draw upon methods originally produced within other methodologies and reinterpret them though our own methodology. This means that, if we are using systems methodology, even methods developed outside systems paradigms can be used as part of systemic intervention*". Systems thinkers who subscribe to the notion of pluralism, tend to see hard systems as being embedded in larger, soft systems. Whilst it is seen that change towards more sustainable systems rely on shared learning through interventions in the form of, for example, creation of safe platforms for dialogue, mediation to resolve conflict, facilitation of learning, and participatory approaches that involve people in negotiating collective action (Röling, 1997), some of the knowledge that goes into that shared process is gained through reductionist methods. Critical systems thinkers have raised concern about the futility of arguing about the relative merits of one or the other approach and argue for methodological pluralism. My research fits in this tradition of methodological pluralism.

**Concluding Remarks**

The changes in thinking within agricultural development since the 1960s have tracked developments within systems thinking; from hard systems thinking (e.g. agroecology and early FSR) in the 1970s and early 1980s, to soft systems thinking of the model proposed by Churchman, Ackoff and Checkland, during the 1980s and early 1990s (e.g. PRA, PTD), through to critical systems thinking and critical heuristics as proposed by thinkers such as Habermas (1984), Ulrich (1983, 1988, 1994), Jackson (1982, 1985, 1087) and Midgeley (1992, 2000), (e.g. Action Research and Learning, Facilitation of social learning).

The new approaches that have emerged have not replaced the old ones but rather added to the repertoire of perspectives and methodologies used in different aspects of agricultural development. The rapid rise of participatory methodological approaches created a perceived and experienced tension with the then conventional ToT approach, as well as between hard and soft systems thinking. Professionals in the soft systems participatory camp were critical of the positivistic approaches of formal science and hard systems methodologies, whilst professionals in the conventional camp were critical of the participatory approach to research and knowledge generation. Participatory approaches were criticised for being too subjective, site specific and non-replicable, and of having little value beyond problem identification and needs assessment. Furthermore, participatory approaches have also been criticized, from both within and outside the circle of practitioners, for paying lipservice to participation, whereby participation amounts to little else than the application of participatory tools to extract information or to satisfy the demand from donors.

Lately, many theorists and practitioners within the ‘participatory’ tradition have raised concern about the futility of arguing about the relative merits of one or the other approach and argue for methodological pluralism. The approaches do not have to be mutually exclusive, but can be complementary. Certain knowledge is best advanced in the science lab, other is not. Certain changes are best brought about through empowering people to take responsibility and action to bring about change from within through participation and facilitation of learning, whilst other changes require initiatives and active intervention from outside.

## 2.3 Implications for this research

This section provides the rationale for the research approach adopted. Drawing on key concepts in systems thinking and located within the tradition of participatory agricultural research and development, it outlines how a systemic approach embedded in constructionism provided an appropriate perspective from which to frame the enquiry.

The research focus was on the actual use of composted waste, rather than on waste management technologies *per se*. An important component of the research involved on-farm experimentation. However, the systemic linkages are critical and it was not possible to simply choose to ignore waste handling and management.

The interdisciplinarity of the subject necessitated that the issue be approached from a variety of angles combining a range of methods, as illustrated in Figure 2.1. Many of the methods and tools used fit within the participatory and action research approaches. Others are typical of the scientific method of enquiry. Together these form a systemic enquiry, which relies on pluralism of theory, methodology and methods alike. Figure 2.2 provides a diagrammatic representation of the organisation of the research.

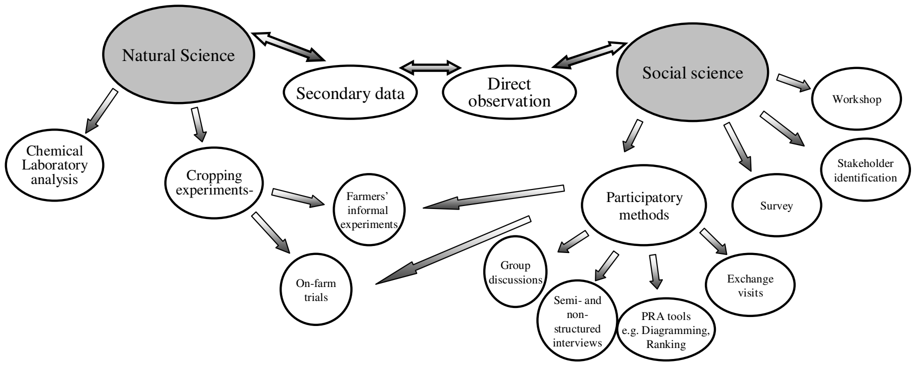



*Figure 2.1 Conceptualisation of the methodological pluralism used*

*Source: This thesis*

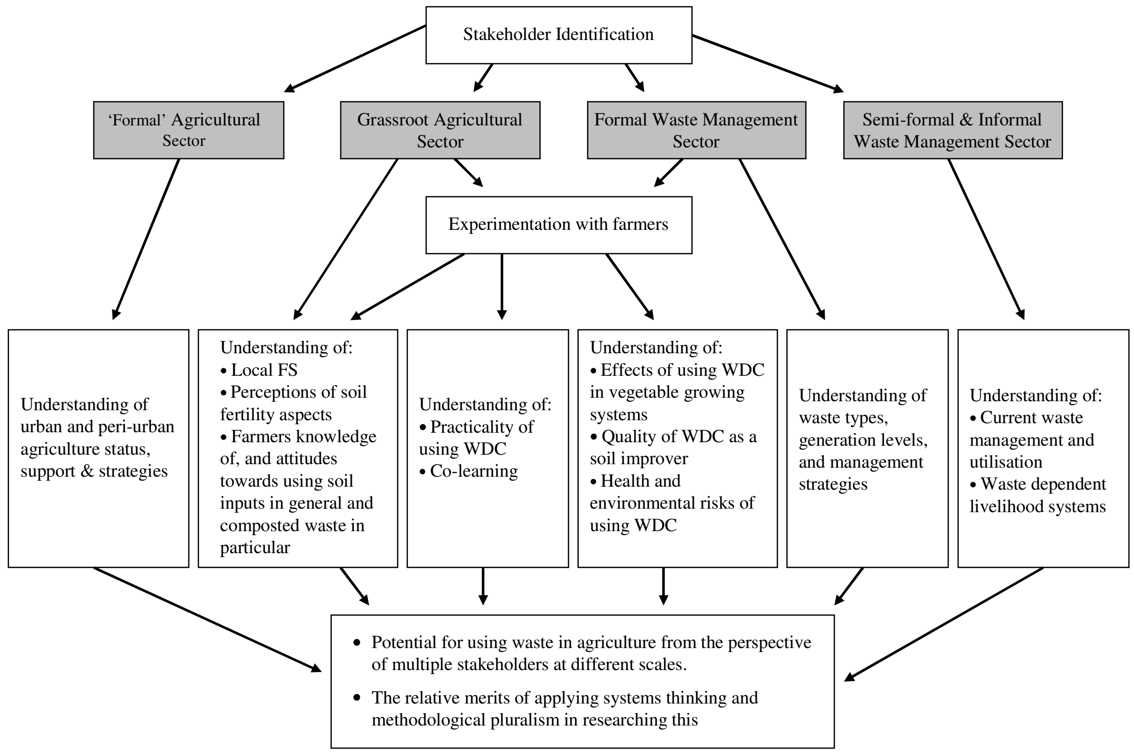



*Figure 2.2 A conceptual sequence of the path-dependent steps in the research*

*Source: This thesis*

### *2.3.1 A Constructionist Perspective*

The nature of the research was such that it involved different stakeholders who (1) perceived the problem differently and thus had different opinions on how to best handle a situation, (2) had different knowledge bases and, (3) had varying purposes and motivations. The research was entered into with awareness that multiple realities and perspectives were likely to be evident and that the research questions would not have single answers. Therefore, scientific objectivity of the sort assumed in the positivist-realist paradigm would not be possible to obtain, nor would it be appropriate to attempt to view this research from that perspective.

For certain research problems a constructionist framework is appropriate whilst for others, a positivist-realist paradigm, in which orthodox reductionist science is embedded, is most useful (Jiggins, pers comm.). Since most hard systems can be seen as sub-sets of larger, soft systems (Bawden, 1995; Röling, 1997; Midgley, 2000), a constructionist perspective does not preclude the use of positivist-realist methods for some of the research questions within the overall research problem (Röling and Wagemakers, 1998). In this research such a combined methodological approach was used, relying on both reductionist and constructionist approaches. Since it explored both the technical and the socio-economic potential for using composted waste, both natural and social science approaches, and a combination of qualitative and quantitative methods of enquiry were used, for different aspects of the research.

Figure 2.3 illustrates the methodological organisation of the research whereby the methods used were split between natural and social science. The natural science methods of enquiry were quantitative and of a positive-realist nature (reductionist). These methods were used for testing the effects of compost amendments on crop productivity and soil fertility and for testing the quality of composts through chemical analysis. The social science methods were used for all the other parts of the research, i.e. for looking at the potential for using compost in agriculture in terms of logistics of compost production, and farmers' ability and willingness to use the material. This component of the research was essentially constructionist in nature and relied to a large extent on qualitative PRA methods of enquiry. However, in part, social science methods seated in a positivist-realist frame, such as formal surveys, were also used. Combined together the elements of the research were nested in a constructionist framework.

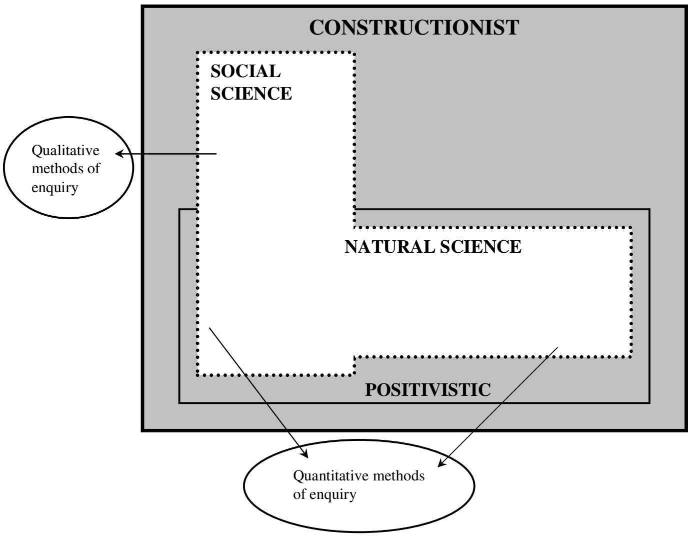



*Figure 2.3 The overall constructionist perspective of the research encompassing sub-elements*

*Source: This thesis*

## *2.3.2 The Action Research Cycle*

Action research (AR) is an interventionist research tradition that has developed in parallel with systems thinking. Originating from the work of Lewin (1947, 1948) in the 1940s, and that of Revens' Action Learning (1982, 1983) in the 1940s and 1950s, AR places humans squarely at the centre of the research process. Characterised by intervention rather than observation, AR is an interactive process whereby problem solving or research, (and ultimately learning) is carried out in repeated cycles involving steps of planning, action, observation and reflection (Figure 2.4). Critical reflection on the outcome of the first action cycle may lead to a redefinition of the problem, initiating modification of the action plan (subsequent action cycle) (Udas, 1998). The aim is for individuals to learn by doing, and through experience gain insight and understanding (Webber, 2000), which, in turn, may lead to improvements in a problem situation. Central to action research is the emphasis on experiential learning, developed within educational theory. Kolb's (1984) 'learning cycle' model is perhaps the best known. According to this model there are four different ways of learning; abstract, concrete, reflective and active. Learning is a process which, to be effective, involves all four ways of knowing. Kolb's learning cycle involves abstract conceptualisation, active experimentation, concrete experience and reflective observation. Different people learn in different ways such that learning may occur as a result of either or all of these processes in different patterns of interaction.

Since the early work of Lewin and Revens, different strands of AR and action learning have developed and it has been used widely in various disciplines, including agricultural development, where it has come to be used as an important methodological approach in much participatory and systemic research and intervention (e.g. Ison and Russel, 2000; King, 2000; Bawden, 1991b).

AR experienced something of a revival in the 1970s and 1980s, at the time when soft systems thinking and participatory approaches to intervention were being developed. Action science (Argyris and Schön, 1974; Schön, 1983), Participatory Action Research (PAR) (Whyte, 1991; Udas, 1998), Co-operative enquiry (Reason, 1988, 1994; Reason and Heron, 1995; Heron, 1996), Critical Action Research (Carr and Kemmis, 1986; Kemmis and Taggart, 1988), action learning, Participatory Learning and Action (PLA), RAAKS (Rapid Appraisal of Agricultural Knowledge Systems, Engel *et al*., 1994; Engel, 1995), Systemic Action Research (e.g. Ison and Russel, 2000) and Checkland's Soft Systems methodology (SSM) (Checkland 1981; Checkland and Scholes, 1990) are all examples of AR approaches which have developed since the 1970s. Although their specific methods may vary slightly, they all have in common a focus on working with others for better management, where research and praxis are intertwined and where the underlying principles are participation and critically reflective inquiry.

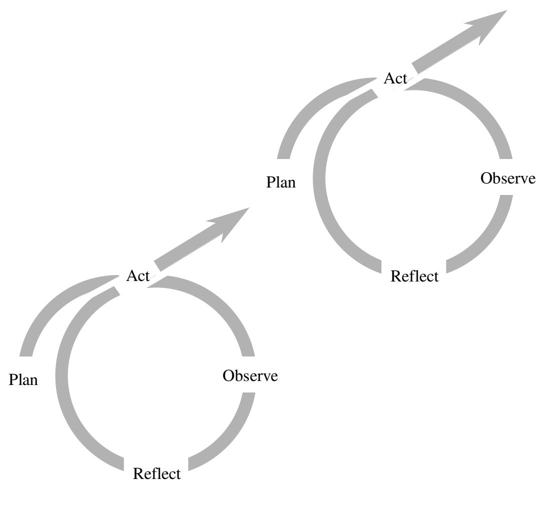



*Figure 2.4 Illustration of the cyclical process in action research of steps of planning, action, observation and reflection*

*Source: Adapted from King, 2000*

In AR the researcher or practitioner is actively and explicitly involved in the research process, thus become both subject and co-researcher (Argyris and Schön, 1991 in Udas, 1998). The inquirer is cast in the role of participant and facilitator in a process of change (Guba and Lincoln, 1994), thus research and praxis are intrinsically intertwined and with that the approach is purposefully and explicitly subjective, (i.e. rejecting the notion of independent observation). The practitioner is no longer an observer, but rather a change agent. Engel (1997:13) notes that "*innovation in agriculture is socially constructed among a variety of actors who are, one way or another, stakeholders in the process*". In action research it is recognised that the researcher is also a stakeholder.

Checkland and Holwell (1998) puts it clearly when they say that a researcher using AR immerses him or herself in a human situation and follows it along whatever path it takes as it unfolds through time. They stress the importance of recognising that the researcher will deal not in hypothesis, but in research themes within which lessons can be sought. It is the change process and co-learning that becomes the focus of the research, rather than hypothesis testing with scientific objectivity. Udas (1998) points out that (participatory) action research is not concerned with problem solving *per se*; rather it is a process through which problems may be solved, but where the process itself has value.

Having used a problematic question as the starting point of this research and having accepted that multiple perceptions of reality would need to be explored, it followed that the nature of the research could not be fully known from the outset. As such, the methodology needed to be flexible, responsive and adaptive. It had to be capable of allowing for new questions to emerge and new, initially unanticipated, lines of enquiry to be pursued.

Action research methodology makes explicit an ongoing process of planning, action, observation and critical reflection (e.g. Dick, 1993; Reason, 1994). Although my research did not fully fit into the moulds of the action research methodologies, it was an appropriate approach for particular steps in the research process. Specifically, the justifications for using Action Research are:

1. The research was positioned in the domain of action research in terms of the role the researcher played. She had a pro-active role acting more as a change agent than a passive observer, actively involved with stakeholders in developing ways of utilising composted waste. It is made explicit that in being part of the research process, her intervention is likely to have affected the outcome of the research. As with much systemic and participatory research, research, development and intervention merge.
2. The open-ended nature of the initial research question needed an approach which could allow for issues to be explored as they unfolded through time. Action research provided a suitable methodology since it places great value on responsiveness and flexibility. Whilst some research questions guided the lines of inquiry initially, new lines of inquiry emerged through cycles of planning, action and reflection.
3. Important aspects associated with action research are the reflective and iterative nature of the learning process (Udas, 1998). In this research it was anticipated that through working with farmers and composting agents to explore the potential of utilising compost, mutual learning would take place

as a result of discoveries made in the attempt to bring about change. The change process and experiential learning were important aspects of the research. Recording technology changes taking place, the events that lead to those changes and how people (including the researcher) within the research-experience are changed as the research progressed, provided a methodological framework.

One of the criticisms of action research is its lack of replicability and standardization; important hallmarks of conventional research. In action research replicability is scarified in favour of responsiveness. Dick (1993:36) argues that this is a necessary trade-off and the choice for responsiveness is a conscious one: "*Conventional research sacrifices responsiveness in the interests of achieving replicability. That is what often makes it unsuitable as a change technique. Action research values responsiveness over replicability*". He goes on to say; "*…responsiveness and rigour are both virtues. In a change program you need responsiveness. If you can achieve it in ways which allow some replicability, so much the better*" (*ibid.*).

The lack of 'generalisability', or external validity, is another commonly criticised feature of action research discussed by Dick (1993). He notes that there is a trade-off between local and global relevance. When designing a research intervention, choices have to be made. By making the research responsive to the local situation the global validity is somewhat compromised. However, drawing on the work by Kirk and Miller (1986), Dick argues that the criticism can be reversed in that research which pursue global relevance can often be rendered irrelevant and inappropriate in local contexts. The nature of the research in terms of its topic, aim and objectives, ought to determine the extent to which local relevance versus global validity is pursued.

### *2.3.3 On-Farm Research and Farmers Experimentation – pragmatic research within a real life situation*

As mentioned earlier, an important component of the research involved on-farm experimentation. The rationale for the choice of experimental approach is explained in this section.

**Pre-analytical phase**

In order to explore the potential for using composted municipal waste in agriculture, a number of methodological choices had to be made. The following pre-analytical questions arose:

1. Should the research question be tackled through surveys and interviews, or through testing the effects of using compost, or a combination of both?
2. If research into the effects of using composted municipal waste should be tested, what form should such experimentation take? For example, should it explore detailed nutrient release and uptake dynamics and/or mechanisms, or

should a more crude, pragmatic approach be used in which crop yield following compost application was examined.

3. Should the research take place on-station, on-farm or both?
4. If exclusively or partially on-farm, what level of scientific control in relation to farmer participation should be aimed at?
5. Should compost be produced for the purpose of the research, or should existing material be used?
6. Should a whole range of compost application methods and regimes be explored, or should the focus be on one or two?
7. What kinds of farming systems should the research concentrate on?

The decision taken in relation to the first question above has already been discussed in the previous sections. There were several reasons for deciding to carry out experiments with compost. Firstly, it was assumed that in order to gain a comprehensive understanding of the potential for using composted municipal waste in agriculture, the issue needed to be explored from several angles and viewpoints. This is why a systemic framework lent itself well to this type of enquiry.

**Diagnostic phase**

During an initial reconnaissance survey (August-September 1999) carried out in a number of different farming systems in the area, it became clear that farmers had limited knowledge about the use of compost in general, and of waste derived municipal compost in particular. Consequently, they felt unable to discuss questions regarding constraints to, and opportunities for use of WDC. Common comments were: 'I don't know anything about it.', 'I don't know what it looks like and how it works.', 'Give me some to try and I will let you know what I think of it.' In view of this, it seemed appropriate to incorporate testing of compost use into the overall research. These findings served to validate earlier assumptions made in the pre-analytic phase and strengthen my conviction that it would be appropriate to incorporate experimentation into the research.

Having decided to undertake compost use experiments, a decision had to be made whether to carry out research under controlled conditions on a research station or opt for on-farm testing. The latter would invariably mean less control, but with the added advantage of real life conditions and farmer participation, which are important principles within the systemic approach chosen for the research. Mettrick (1993) notes that the primary rationale for on-farm experimentation is the testing of new technologies under farmers' conditions, in the real environments. He provides a number of reasons for carrying out experiments on-farm rather than on-station (see Box 1), many of which were important considerations in this research. In addition to the reasons provided by Mettrick, one commonly claimed benefit (e.g. Hildebrand and Poey, 1985; Martin and Sherington, 1997) of on-farm research and farmer experimentation is that it can aid adoption. If farmers can see for themselves how a technology is performing, and how it is to work with within their farming system, they are more likely to try out the technology than if they are told about it from an extension worker or scientist.

*Box 2.3 Reasons for carrying out an experiment on-farm rather than on-station*

- Although once typical of the region in which it is placed, soil fertility and weed incidence on the station may have diverged from surrounding farms due to its management history, or in the case of livestock research, the composition of the vegetation may have changed.
- Soils or other physical conditions on-station do not represent the broad range of circumstances on farms in the region.
- To test technologies under the resource constraints experienced by farmers
- To test technologies under the management levels of farmers
- To evaluate technologies at the scale on which they would actually be implemented by farmers, i.e. to estimate parameters such as family labour input.
- To identify management problems that do not show up on small experimental plots
- To see how technologies fit into the overall farming system
- To provide a framework for dialogue with farmers about their farming practices, constraints, opportunities and attitudes to new technologies
- To learn from the ways in which farmers modify technologies to suit their circumstances.
- To give farmers themselves an opportunity to test selected technologies.

*Source: Mettrick, 1993*

In view of the above, it was considered appropriate to be pragmatic and to test the use of compost with farmers, on their farms, under real conditions, using existing municipal compost. The rationale for this decision is explained below:

Firstly, the decision to use existing municipal compost was guided by the principle of striving towards real life conditions. In fact, the existence of municipal composting activities in Accra was one important reason why that location was chosen for the fieldwork. To have produced compost specifically for the research would to some extent have defeated the objective of the research. Although it is possible that the quality of the compost would have been better if it had been produced as part of the research[13], it would not have represented a real life situation, thus the exploration into constraints and opportunities to use would only be partial and somewhat artificial. Furthermore, due to the limited time period available, to have gotten involved in composting would have limited the time available for testing the effects of compost applications over time. This was an

[13] It would have enabled the use of uncontaminated high quality waste and the control of the composting process to ensure optimum conditions.

important consideration in view of the fact that many of the perceived benefits of compost amendment to soil are long term (HDRA, 1998).

The decision to carry out the experimental work with farmers within their existing farming systems was taken for a number of largely interrelated reasons:

- Because of the systemic perspective and the overall interdisciplinary approach taken, scientific research such as looking at detailed mechanisms of nutrient movement in compost following application was never intended. Furthermore, research of that nature requires controlled conditions, where variables can be isolated and there is access to reliable and sensitive measurement and analysis equipment. Such conditions were not available to the researcher in Accra, thus it was considered that anything other than an applied pragmatic approach would be inappropriate. Consequently the research was designed to look at physically observable crop responses to compost amendment.

- That plants respond to compost amendments is a well-known and long established fact. There seemed very little point in carrying out the kind of straightforward research proposed (whereby crop response and yield was measured) on a research station, since it was unlikely to provide new or relevant insights. It was anticipated that more insights, and hopefully benefits, would be gained by experimenting with farmers on their own farms, in a way that made sense to them. Only then would it be possible to gain knowledge about the practical potential for this material.

- Even if the conditions for carrying out controlled trials had been available, it is questionable whether research into the effects of using MCW in agriculture can be anything but crude, or specific to the event studied, since there are so many variable factors that can affect the results. The quality of the compost is likely to be variable depending on: (1) the type of material that went into make the compost, which is likely to vary from place to place and between seasons, (2) the environmental conditions during the composting process, (3) the method of composting used and (4) the age of the compost. Notwithstanding the variability of MCW, its performance as a soil improver is also likely to differ depending on the soil type and weather conditions following application. Results from controlled experiments carried out on a scientific research station would not necessarily be reproducible, nor would they be universally applicable.

- The municipality in Accra has composted waste from the city since 1980, and apart from the periods when the composting plant has been out of operation, compost has been available for over 20 years. Yet few farmers have tried it or even know about it. The possible reasons for this will be discussed later, but suffice to say, over the years trials with the compost have been undertaken in several different set-ups with varying degree of scientific control, without leading to dissemination of the results, and uptake by, farmers. In view of this, it seemed reasonable to let farmers try it and explore their perceptions of the material.

- Another reason why on-farm testing was considered appropriate within the framework of this research relates to issues of farmers' rationale for choosing particular technologies. The literature is full of examples where a technology tested on-station and assessed scientifically has shown great promise in terms of increased production yet has failed to be adopted by farmers. The reasons for this could be many, such as, for example, the fact that it is too labour demanding. Research and technology development which fails to take a systemic approach (Mettrick, 1993) and/or enable farmers to adopt and adapt technology to suit their particular conditions and needs (Hinchcliffe *et al*., 1999), is likely to fail to identify key constraints to the technology proposed. Similarly there may be opportunities which will only emerge as farmers explore and possibly adapt, the technology within their current practices. To ask farmers about the suitability of a proposed technology is not particularly useful if their prior knowledge of it is limited. In the case of municipal compost use in Accra, the farmers needed to test it in order to voice an opinion about it.

- Finally, notwithstanding all the rational reasons for why on-farm research would be most appropriate given the existing circumstances, the research approach aspired to (1) a certain degree of farmer participation, (2) to explore the issue from the perspective of a range of stakeholders, and (3) to gain understanding through action and collaborative learning. On-station research would not have fitted into the systemic approach and methodological framework of the research.

The next question which had to be addressed was what form the on-farm research should take. What degree of researcher control in relation to farmer management should be aimed at? Should the research seek to get farmers to carry out pre-designed experiments or should it encourage farmers to experiment in a more 'loose' way?

Atta-Krah (1994:235) points to the fact that there are two distinct types of on-farm research: experimental on-farm research (EOFR) and developmental on-farm research (DOFR), and explains the difference between these:

> *"EOFR is that form of on-farm experimentation which involves validation or comparison of different technologies or component of technologies, on the basis of standard experimental designs, research controls and statistical analysis. Such trials are expected to provide quantitative data on the technological, biological and, to a lesser extent, economic parameters of the system under study, and require a high level of researcher control. The farmers' input in such trials is often highly structured in order to obtain comparable (and analysable) data. DORF on the other hand, is often much less tightly controlled and structured. It is concerned with the introduction of new technologies or systems to the farmer community, and involves the assessment of their relevance, workability and acceptability by farmers, within a framework for research-development interaction. DORF enables researchers to study how farmers react to an introduced technology, and how they might adapt and adopt the system to meet their local needs and resource patterns".*

In this research both types of on-farm research were undertaken. The experimental on-farm research hereafter will be referred to as the **on-farm trial** whilst the developmental on-farm research hereafter is referred to as the **vegetable growers' experimentation.** By carrying out both types in conjunction, a more comprehensive understanding was gained than had only one or the other been undertaken. The on-farm trial provided a means of obtaining data of a scientifically analysable nature and of validating the information gained from the informal experimentation. The vegetable growers' experiments provided insight into farmers' perceptions of the potential for using MCW in local farming systems. Both types of on-farm research provided the opportunity for co-learning, but the informal experiments with vegetable growers allowed for a more flexible, responsive dialogue in which there was more room for changes and adaptation as new insights and learning was gained.

### *2.3.4 Degree of Participation*

The degree pf participation aimed at, and achieved, varied for different aspects of the research. The nature of the research, in terms of topic, time available and remit in relation to funding, were such that a stakeholder driven research process with full participation as the foremost objective was not attempted. The research was technology driven and focussed on the potential for using composted waste in agriculture. The researcher none the less had to ensure that the research process was sufficiently participatory to be of value to the stakeholders, (particularly the farmers). This topic will be revisited throughout this thesis, both in relation to specific activities, and in relation to research on the research process.

### *2.3.5 Research on the research process - Boundary Judgements*

From the discussion so far, it is clear that this study is trans-disciplinary, multi-scale and cross-hierarchical, involving actors with multiple perspectives, goals and purposes. As such a number of boundary judgments had to be made throughout the research process. As discussed in earlier in this chapter, critical reflection on and being explicit about the boundary judgement made was taken to be an important aspect of the research.

There may be a multitude of implicit and explicit criteria for drawing a systems boundary including issues ranging from the fact that:

- people have varying perspectives and thus perceive a system and its boundaries differently; or
- funds and time available for research or development intervention may determine scope of system considered; through to more open bias such as the fact that
- objectives and motivations may differ, or even
- the drive for increased power and control may drive the decision of boundary choice.

Choosing scales and setting boundaries in situations characterized by multiple interactions between phenomena and problems is difficult and contentious

(Midgley, 2000). As a single researcher operating within boundaries in terms of time, resources, the knowledge and capacity of the researcher, and, to a certain extent, within the framework of a pre-determined research topic, it was necessary to narrow the focus to concentrate on certain aspects of the overall problematic situation.

Some of the considerations and decisions taken in relation to choosing the experimental approach and design and degree of participation, discussed in sections 2.3.3 and 2.3.4, relate to boundary judgments. For example, by choosing to carry out crop experiments with farmers, a choice was made in terms of how to allocate the time and resources available. Had the research issue been tackled from a different perspective, and efforts concentrated in another area, it is most likely that the research findings and insights gained would have been different. Thus the boundary judgments made affects the outcome of the research and its impact. The process followed in making the boundary choices of this research are discussed further below.

The boundary judgements made affect the outcome of the study. By looking at the same problem using different boundary frames, (i.e. changing levels) the problem is redefined and seen in a different light (Figure 2.5). Flood (1999:7) argues that "*boundaries are always subject to further debate and are thus temporary*". Boundaries are not static or absolute, they can (and should) be changed according to the particular aspect of a situation being considered. For certain aspects of a problem or issue under study, a narrow, detailed or short-term view may be considered appropriate (e.g. boundary 1 in the figure below), whilst other aspects of the problem or issue under consideration may be better understood and dealt with by expanding the boundary, in space and/or time (e.g. boundary 2 or even 3). Everything that falls outside the chosen boundary is referred to as the environment and the interactions between elements within and outside the system boundary are considered to be of secondary importance.

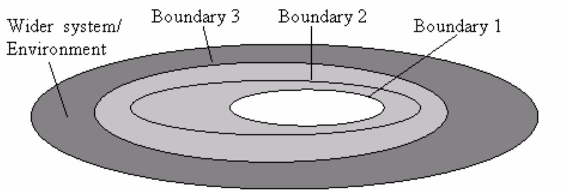



*Figure 2.5 Different systems boundaries may be chosen by different systems observers, or by the same observer for different aspects of the same problem or issue under consideration*

*Source: Adapted from Midgley, 2000*

Engel (1995 in King, 2000) discusses the importance of approaching a problem or issue at a level which is appropriate in order to maximise the benefits of any intervention. Drawing on the work of Kramer and De Smit (1987), he proposes four questions as guidelines for identifying boundaries:

1. Which entities are perceived as part of the system?
2. Which entities do not form part of it, but influence it?
3. How do the entities within the constructed system relate to each other?
4. How do the entities within the constructed system relate to the outside?

King (2000) adds a fifth question in her work on human activity systems:

5. What are the emergent properties of the constructed system?

Reflection on these questions assisted me to identify appropriate levels at which to address each particular question or issue. Boundary choices were also influenced by practical considerations of resource availability (time, skills, funding, technical assistance and equipment available etc.). The level (hierarchy) at which boundaries were drawn differed between the research components, in terms both of the spatial (geographical) and organisational level. Throughout the research process emerging findings caused new lines of enquiry to be incorporated whilst other aspects of the research were abandoned or excluded. Some of the specific boundary choices made are outlined below.

**Site Selection Criteria**

The decision to locate the research in Accra was made for several reasons:

- The existence of municipal composting operations enabled access to material and the possibility of testing under a real-life situation.
- The existence of both a large-scale municipality operated composting plant and a small-scale CBO operated enterprise provided the opportunity to compare the benefits and problems with such different approaches to organic waste recycling.
- Urban farming systems of different kinds existed in Accra.

**Hierarchical Level for the Different Components of the Study**

*Spatial boundary choices* - For issues regarding waste generation and management, the chosen level for study was the Accra Metropolitan Area. This is a political boundary, tracing the area covered by the Waste Management Department of the Accra Metropolitan Assembly. Although much of the wastes in Accra have originated from the rural hinterland and beyond, setting the boundary at the level of the municipality was considered appropriate since the waste is managed and disposed of within this area. For exploration of the urban and peri-urban farming systems, a slightly wider focus was used to include the peri-urban periphery, For specific questions, such as food marketing and labour dynamics, a wider perspective was used. For the part of the research which involved working closely with farmers and experimenting with compost use, the scale was reduced, to zoom in on the farm, or farming area level.

*Stakeholder and institutional boundaries* - Similarly, the stakeholders, issues and institutions included within the boundary of the system of interest varied depending on the questions explored. For example, in exploring the performance of compost on crop growth, the stakeholders involved were farmers, composting plants, and extension services. When exploring farmers' perception of the potential for using compost, a wider boundary was drawn to also include stakeholders such as poultry farmers, market women, transporters and irrigators. However, when addressing the potential beyond farmers' perceptions, the boundary was widened considerably to include a wider range of stakeholders, institutions and issues. Box 2.4 lists stakeholders and issues included within the framework of the research. See also Figure 1.2 for issues considered.

*Box 2.4 Key stakeholders, institutions and issues considered in the research*

**Stakeholders / Institutions**

- Farmers
- Agricultural extension service
- Waste management professionals (public and private)
- National and local government officials within: Min of Food and Agr, Min of Health, Accra Metropolitan Assembly and the Environmental Protection Agency
- Development organisations (governmental and non-governmental, international and Ghanaian. E.g. DAO, DFID, IBSRAM, Growth, Universities, CSIR)
- Community based organisations (CBOs)
- Market trader's associations and individual vegetable marketers
- Poultry farmers' associations and individual poultry farmers,
- Consumers

**Issues**

- Transport
- Irrigation
- Labour
- Health
- land security
- Cost of compost production
- Cost of landfilling

**Type of Waste examined**
There are many types and sources of urban waste (see Figure 2.6). It may be in solid, liquid or gaseous form, it may be organic or non-organic, it may range from completely clean to extremely hazardous. It may originate from a wide variety of sources including: households, manufacturing, commercial and retail establishments, institutions, street sweepings, construction industry, livestock enterprises and human vital functions (sewage or night soil).

Some of the waste generated is recycled and never ends up in the waste stream as such. Much of that which does has the potential for being recycled. It is waste of that nature which is the main focus in this research, and, more specifically, that which can be recycled into agriculture, i.e. the organic fraction of the waste stream. Organic waste can be in both liquid and solid form and both can be used within agriculture (Figure 2.7). Liquid organic waste has potential for use in agriculture, particularly for irrigation but also in aquaculture systems. However, many forms of organic waste did not fall within the research boundary, only composted municipal waste used as a soil improver was included. Figure 2.6 illustrates different waste types and the system of interest for this research.

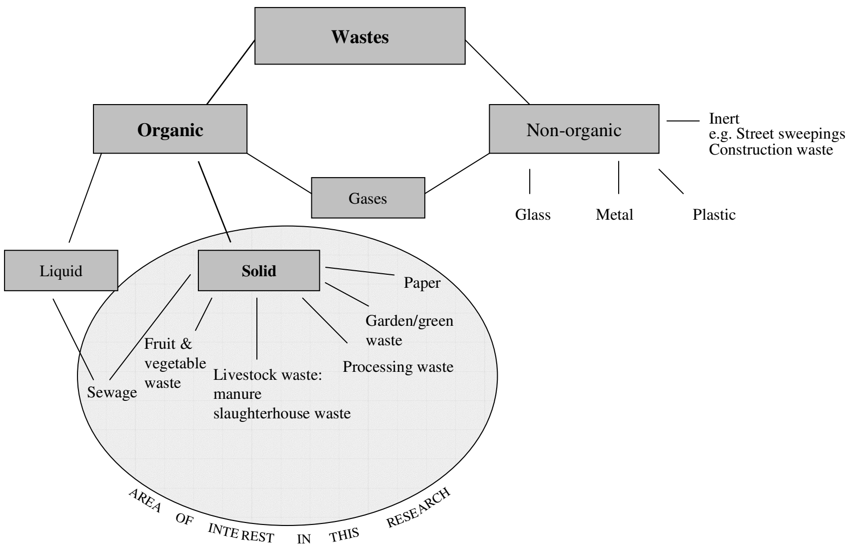



*Figure 2.6 Illustration of different types of urban waste and the area of focus in this research*

*Source: This thesis*

The flow diagram in Figure 2.7 illustrates different agricultural uses of organic wastes. Of these, it was primarily composted waste for use as a soil improver that was explored. However, animal manure was also explored to some extent, since those farmers who use some form of organic inputs in their cropping system, tended to mainly use animal manure, particularly chicken manure. The manure used originated from animals that were kept within the municipality of Accra, thus constituted an urban waste.

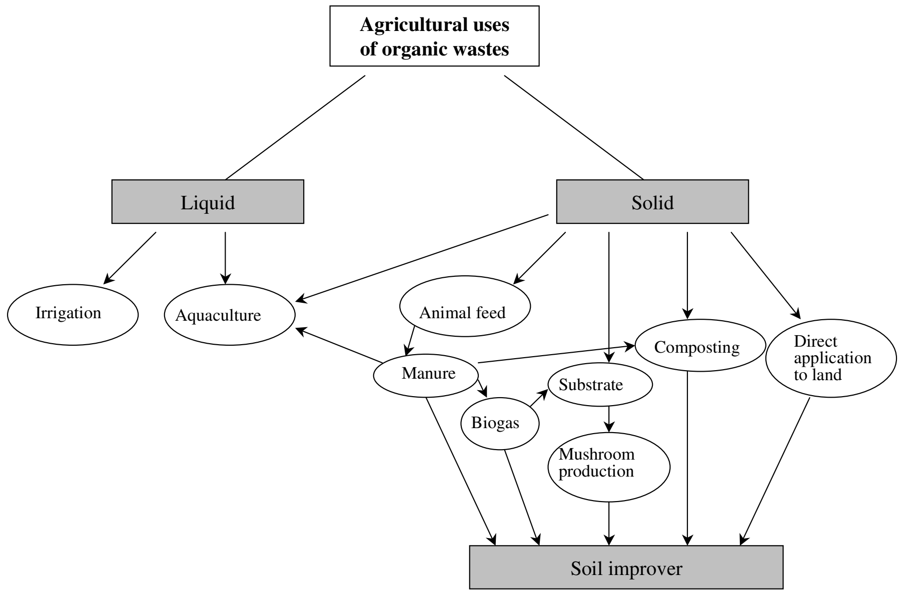



*Figure 2.7 Different agricultural uses of organic wastes*

*Source: This thesis*

**Type of Farmers who were engaged in the research**

A choice to focus on urban and peri-urban farming systems was made from the onset, since it was assumed that those would be the farmers most likely to be able to utilise urban waste derived compost. Since compost is a dense and heavy material with relatively low nutrient content, transportation over long distances tends not to be feasible.

In the experimental research with farmers the boundary was narrowed to work with urban vegetable growers. There were several reasons for this:

1. The initial baseline survey indicated that these farmers were amongst the ones who would be most likely to be able to use municipal compost in the future. This was partly because they are close to the composting plants, partly because they crop commercially and already invest in external soil fertility

inputs. These farmers were judged to be most likely to be able and willing to spend money on compost.

2. With the limited time of 1.5 years available for the experimental work, it was considered important to work with farmers who had access to irrigation and were able to crop continuously. Most of the effects of compost amendments are not immediate and the main recognised benefits of compost are typically long term (HDRA, 1998). 1.5 years is not really enough time to gauge some of the more long term, soil improving effects that compost may have (a minimum of 3 years have been estimated for UK growing conditions, (*ibid.*). However, with continuous cropping in a tropical climate, where mineralisation rate and microbial activity is faster than in the temperate regions, it was hoped that the available time period would be sufficient to allow for the monitoring of some, if not all, longer term effects. It was therefore desirable to maximise the number of compost applications and crops grown in the time available for the research. Seasonal rainfed farming systems would only have given two to three crops whilst irrigated vegetable production could give between four and seven, depending on the crop grown.

## 2.4 Social Learning and Adaptive Management

Having outlined how different aspects of systems thinking were used to frame the research and justified the rationale for the research design, this section looks at the relevance of social learning and adaptive management to the management of urban waste. As mentioned in section 2.2, this study was primarily agricultural in that it explored the potential for using composted urban waste as a soil improver. However, it was also noted that the systemic linkages are critical and that it is not meaningful to ignore other issues of waste management. This section thus looks at the broader issue of sustainable waste management. Drawing on research traditions within natural resource management and adaptive management I explore the notion of social learning and how the thinking within this field has influenced my thinking.

By now it is clear that WM is not purely a technical business or a matter simply of waste collection and treatment. It involves waste producers and waste users in complex systems which are driven by human action as much as by the technical nuts and bolts of waste handling. In fact, sustainable WM is more constrained by social and political factors than by a lack of technical knowledge and/or capacity (Onibokun, 1999). The notion of social learning has attracted interest as an essential aspect of sustainable management of complex systems. (e.g. SLIM Framework Paper, 2004; King, 2000; Maarleveld and Dangbégnon1999; Röling & Jiggins, 1998). Social, or interactive learning refers to the emergence of new ways of thinking about a problem through a dynamic process of facilitated interaction and shared experiences by a range of stakeholders (SLIM Policy Briefing No.6, 2004). In contrast to the linear model of transfer of knowledge through teaching, knowledge generation according to the SL premise, is constituted in interaction. The Kolb learning cycle (1984) as described in Section 2.3.2 has been influential in social learning theory.

"*The need for social learning springs from the nature of many, if not most, natural resource management problems today*" (SLIM Policy Briefing No.7, 2004). Human interaction with natural resources, be it in the form of harvesting resources, deposition of waste materials or recreational activities, tends to lead to disruption and loss of ecosystem resilience (Holling, 1986). Adaptive management is a branch within ecology which takes a soft systems approach to understanding ecosystem complexity and recognises the central role that humans play in the management of ecosystems. It is premised on the notion that ecosystem management needs to be flexible and adaptive, to cope with the unpredictable and changing nature of ecosystems. As Gunderson (1999:1) puts it: "*it is adaptive because it acknowledges that managed resources will always change as a result of human intervention, that surprises are inevitable, and that new uncertainties will emerge*". Consequently, humans must respond by adjusting and conforming as situations change. A logical extension to this notion of management as adaptive, is that management needs to be experimental. In view of changing (often rapid) circumstances, and the fact that we only have partial understanding of the system perceived, resource and environmental policies are effectively hypotheses and management is an act of experimentation (Holling, 1995; Walters, 1997; Gunderson, 1999).

Experimentation within adaptive management takes the form of structured learning-by-doing; interventions at multiple scales are made to achieve understanding and to identify and test policy options (Holling, 1978; Walters, 1986; Lee, 1993). The challenge is to develop a capacity for learning, and to match learning across disciplines (Baskerville, 1995). Gunderson (1999) argues that this is likely to require flexible linkages among a broad set of actors or networks. It is a process that requires close coupling between natural and social science, between scientists and policy makers and between all stakeholders in both formal and informal institutions. Folke *et al.* (1998) reflect that, just like biological diversity seems to play an important role in ecosystem function and resilience, so to does the institutional diversity of management systems. Bringing about capacity for flexible, adaptive management at multiple scales of intervention requires collaborative learning.

This can be achieved through facilitation of "*debate, negotiation, dialogue, joint research and the development of a 'platform' or social spaces to enable interaction*" (SLIM Framework Paper, 2004:21). "*Disputes will always arise about, for example, the stakes, objectives and allocation of costs and benefits. Through interaction, individual stakeholders can begin to construct and grasp their interdependencies and gain insight into ways of working in concert with each other*" (*ibid.:*22). Through the process of social learning there may be a transformation in behaviour and relationships over time, which enables stakeholders to engage in concerted action and move towards more integrated and adaptive management (SLIM Framework Paper, 2004; SLIM Policy Briefing No.6, 2004; SLIM Policy Briefing No.7, 2004).

The learning process can be further analysed in terms of 'first and second order learning', or 'first and second loop learning' processes (Argyris and Schön 1996; King, 2000). First order learning occurs when someone understands what he or she is doing and how that affects the system (i.e. their role in the system). Second order learning develops an understanding of the rationale underlying their actions, in other words, why they are doing what they do. In relation to sustainable WM, for example, first order learning can develop capacity for joint action in managing the resource in a more integrated fashion. It may lead an actor in the resource management system to pose questions such as: 'what am I doing?' and 'how can I do it in a different way?' Second order learning would provide the person with the knowledge or capacity to meet this end, by questioning 'why am I doing what I do?' and why might it be done in a different way?' Second order learning causes people to rethink the epistemology of their action. Teaching usually seeks to stimulate learning of the first order kind. Experiential learning, on the other hand, often leads to second order learning. It typically provides the individual with the insights needed to transform his or her behaviour and belief system.

It is proposed that social learning and adaptive management are relevant to the exploration of the potential for recycling organic urban waste to agriculture from the perspective of a range of stakeholders with differing objectives, knowledge bases, and organisational hierarchies. Although some social and experiential learning on the part of the growers and the researcher occurred, through the growers' experimentation to test the use of MCW, and this learning process was monitored, it was not the main research objective to study learning directly.

None the less, I argue that systemic, adaptive management is necessary for moving towards more sustainable WM and that, in order to enable this, SL needs to occur.

## 2.5 Implications for this Researcher

I established from the start that this research work was going to be interdisciplinary with a systems perspective. My academic training and much of my professional background within the field of sustainable agriculture were grounded in inter- and trans-disciplinary approaches to natural and social science analysis of farming and natural resource management systems. It was therefore natural for me to choose a complex problem issue as the focus of the study and to approach it from a variety of angles. When I embarked on this PhD I became introduced to the concepts of constructionism, critical systems thinking and social learning, through the work of, for example, Jiggins, Roling, Kolb and Checkland. This influenced the way I began to think about systemic and participatory intervention and made me realise how important is critical reflection on the role I play in research and development intervention. So, it was my belief from the onset that reductionist science alone would not be sufficient for studying a complex issue that links urban waste to agriculture, and the case for this has been made (earlier in this chapter). However, carrying out research in a theoretically and methodologically pluralistic way is likely to have both merits and drawbacks, and to have implications for me as a researcher.

Although I had been engaged in both natural and social science activities as a member of a team within a multidisciplinary project, I had not undertaken an interdisciplinary project in its entirety. I saw this PhD as an opportunity to embrace such a challenge. I came to realise that carrying out research in this way, is a rather unusual practice. By acting as an individual researcher, without recourse to a large research team of professionals from different disciplines, I was likely to face both strengths and weaknesses. The end of Chapter 6 and Chapter 8 provide a critical reflection on the experience.

## 2.6 Concluding Remarks

Systems thinking, and the associated principles of multidisciplinarity, have changed the way we view the world and think about problems. It has developed within a wide variety of disciplines and taken many forms, as is the tendency with developments that grow 'organically' when times are right, and the environment is conducive.

Some of the important concepts and developments that form the core of systems thinking have been reviewed, along with those within the wider paradigm of holistic thinking. Particular focus has been given to agricultural development since the 1960s and the way the developments in this domain have paralleled those that have taken place within systems thinking. I have also reviewed adaptive management and stressed the fact that it is closely related to developments within systems theory, agricultural/rural development, and action research.

The theories and approaches reviewed have been important in informing my thinking and I have drawn upon different aspects of them for different parts of my research. My review has caused me to arrive at a general position that I wish to highlight and carry forward in my argument. It is my belief that representation of reality are a construct and that, as such, systemic approaches to development and change need to be placed within a constructionist frame. However, nested within this, there is room for reductionist scientific explorations as a subset of a wider enquiry. Also, central to my thinking is that pluralism, at all levels from theory through to methodology and methods (tools), is characteristic of systemic research and intervention.

# CHAPTER THREE - METHODOLOGY

Having outlined the research approach adopted for this study and justified the rationale for pluralism, this chapter outlines the methodological framework. It describes in more detail the organisation of the research and the methods of data collection, information gathering, analysis and interpretation. Both natural and social science was used, combining qualitative and quantitative methods of enquiry. Many of the methods and tools used fit within the participatory and action research approaches. Others are typical of the scientific method of enquiry. These are combined to a systemic enquiry.

The main part of the chapter describes the fieldwork process and the specific methods employed in the research. The quantitative data in large part are drawn from crop trials that were conducted between 1999 and 2001, and from a farmers' survey (also referred to as **baseline survey**) carried out in the initial diagnostic phase of the fieldwork in 1999. The structure of the overall methodology and the general methods used are outlined. However, detailed description of materials and methods for each individual research activity is provided in the relevant chapters (Chapter 4 for the baseline survey and Chapter 5 for the experimental work).

The blending of methods had important implications for the analysis and interpretation. Data and information from different non-commensurate sources and disciplines, and across spatial and hierarchical levels, had to be synthesised. The challenging task of synthesis formed an important part of analysis and interpretation (as discussed at the end of this chapter).

## 3.1 Organisation of the research

Structurally the study was organised as a series of path-dependent steps that allowed a progressive immersion in the physical and social contexts of the study area (Fig 3.1). These steps were:

1. A pre-fieldwork, pre-analytic period of familiarisation with the problem issues, formulation of explicit assumptions underpinning the theoretical perspective, and identification of key research issues.
2. An explorative, diagnostic phase to gain knowledge of the study area and the problem issues related to the topic and key stakeholders. This involved a baseline survey of farming systems in and around Accra, direct observation, and interviews with key informants involved in waste management and agriculture in both the private and public sectors.
3. A main research phase which was broadly split into two parts:

a) One part, where the focus was somewhat narrowed to explore the effects of and potential for using municipal compost in vegetable growing systems. This involved close work with selected farmers and testing of compost quality. It relied on both natural and social methods of scientific enquiry and was guided by the principle of action research.

b) A complementary part that explored the potential of using WDC in agriculture from a systems perspective. It involved interviews with multiple stakeholders.

4. Successive rounds of data analysis and integration with secondary data.
5. Data and information synthesis and interpretation

Figure 3.2 provides a calendar of research activities.

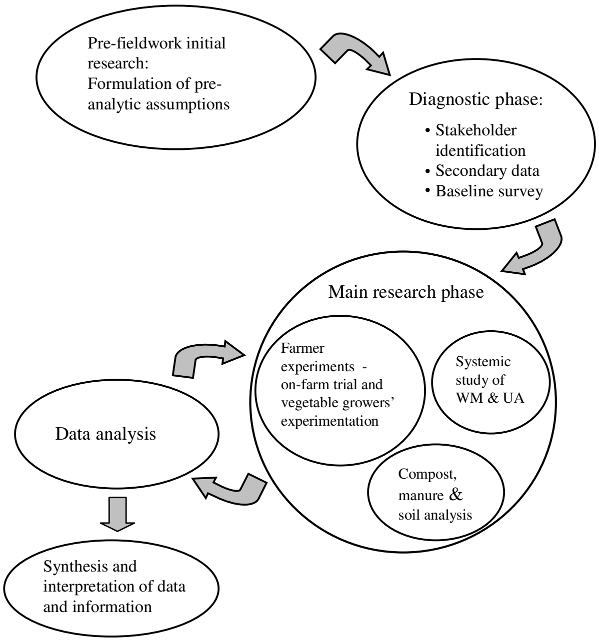



*Figure 3.1 Diagrammatic illustration of the organisation of the research stages*

*Source: This thesis*

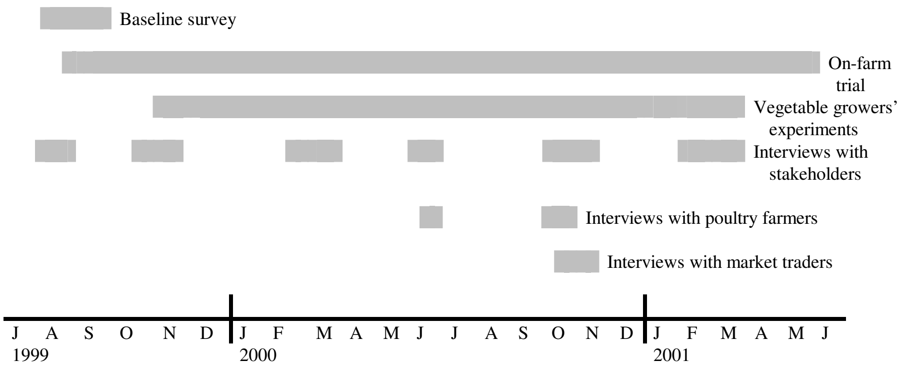



*Figure 3.2 Calendar of the research activities*

*Source: This thesis*

## 3.2 Fieldwork activities

The organisation of the fieldwork, the activities undertaken and the methods employed are represented diagrammatically in Figure 3.3.

*1. Pre-analytic phase*
This was essentially a pre-fieldwork phase to become familiar with the subject area and formulating the theoretical perspective and research approach.

*2. Diagnostic research phase*
The first objective in the diagnostic phase was to develop an overview of the waste management issues and an understanding of the existing farming systems in and around Accra. This involved stakeholder identification, direct observations and secondary data reviewing. The fieldwork was initiated by attending a 5-day international workshop on urban and peri-urban agriculture in Accra, during which important information regarding the subject area was gained and many valuable contacts were made. Following the workshop, contact was made with a number of stakeholders in the waste management and agricultural sectors and a series of semi-structured interviews were held.

As a first step in ascertaining the potential for farmers to use MCW as a soil improver, an understanding of the existing farming systems in the area had to be gained. Therefore, in August/September 1999 a baseline survey of farming systems in and around Accra was carried out. In this survey focus was placed on assessing:

- Farming activities with particular focus on cropping
- Soil fertility management strategies employed by farmers

Information gained from the survey enabled the researcher to make an informed decision about which farmers seemed most likely to be able to and benefit from using MCW and consequently which ones to work more closely with. A total of

120 farmers were interviewed from a representative selection of areas and farm type categories. Sampling was done purposefully to ensure geographical spread and engagement in cropping activities. The sampling frame was informed by a previous study carried out in 1997, that examined how urban agriculture relates to urban food nutrition in Accra. It was carried out by the Noguchi Memorial Institute for Medical Research in collaboration with the International Food Policy Research Institute (IFPRI) (Armar-Klemesu & Maxwell, 1998). More detailed information regarding the baseline survey and the methods employed is provided in Chapter 4.

*3. Empirical research with farmers*

In this part of the research the focus was placed on close work with a selection of farmers in which they tested the use of municipal compost alongside their normal practices.

Based on the criteria outlined in Section 2.3.3 in Chapter 2 and the findings from the baseline survey, the decision was made to focus on small-scale commercial urban vegetable growers as they were judged to be the ones who would benefit most and have the greatest potential for using municipal compost in the future. Two complementary on-farm research approaches were used in conjunction:

1. An on-farm trial with a scientific experimental design, conducted on a farmer's field and managed jointly between the farmer and the researcher. Two on farm trials were initially set up, with two farmers in different locations. Because of a whole series of unfortunate circumstances, one of the trials failed and had to be excluded from the research. This resulted in some comparative data being lost and the validation of the findings from the vegetable growers' experiments were weakened. However, the primary aim of looking at the potential of using such material from a systemic perspective was not compromised.

   The on-farm trial had an experimental design which made it possible to collect data that could be analysed statistically. It ran for a period of 21 months during which time five crops were grown and compost and manure was applied 4 times at approximately 6 monthly intervals.

2. Informal experimentation by small-scale urban vegetable growers, where groups of farmers in three different locations in Accra compared compost with chicken manure during a period of a little more than one year. In these experiments there were no replications within the growers' enterprises and there was less structure and control by the researcher. The objective was to let farmers gain access to municipal compost and to try it out in a way that made sense to them within their current cropping system. It was therefore desirable to allow the farmers an input into and a stake in the experimental design. The main role of the researcher was to facilitate the farmers in their experimentation and to monitor what farmers chose to do and record their conclusions about the performance of the compost. Emphasis was placed on co-learning, using an action research approach.

Compost was delivered to the farm areas and provided to the experimenting growers free of charge. Apart from getting the compost free, not payments or compensations were given to the growers for participating in the experimentation.

*4. Systemic study of the potential for using municipal composted waste in agriculture*

Building on the insights gained in the diagnostic phase, this part of the research involved collecting comprehensive, in-depth qualitative data and information regarding various (relevant) issues surrounding waste management and the potential for recycling waste to agriculture. A wide range of actors (key informants) with an interest in, or impact on, the research issue were consulted (see Box 2.4 in Chapter 2). These included waste engineers and managers, local political leaders, waste recycling entrepreneurs, researchers and academics, agricultural extension agents, key informants in the sectors of agriculture, health and environmental protection, and relevant people working within development organisations, both at the grassroots and at a more strategic level.

Various qualitative methods of data collection were used, such as unstructured and semi-structured interviews, group discussions, free chatting and dialogue. In addition, observation (of farming systems and waste management) and secondary data review were used. Over a period of 1.5 years a rapport was gained with many of the key stakeholders. This in addition to the use of triangulation, repeat visits and the mix of data collection methods ensured that a comprehensive picture of the situation emerged and helped reveal differences between theoretical and actual practices, as well as the different, sometimes conflicting, views held by different stakeholders.

An interesting point for the *research on the research process* is that the systemic study and the work with farmers gave rise to additional research components.

i. It became apparent that **poultry manure** is of critical importance in urban vegetable production systems in and around Accra. This realisation led to the decision to include a study of poultry farming and related manure handling in relation to urban waste generation and vegetable production. Poultry represents an urban waste in its own right. It is also represents the most important and favoured soil fertility input into the various vegetable production systems in and around Accra.
ii. The **vegetable marketing** system. Marketing is a critically important factor in the vegetable production system. There are concerns amongst consumers, and subsequently marketing women, about the quality of vegetable produce from within Accra, mainly due to the use of wastewater for irrigation. Such concerns are legitimate and may have important implications on the viability of using MCW as a soil improver. It was therefore considered relevant to gain information about issues such as willingness to sell food from within the city, seasonality in relation to food availability and pricing structures, perceptions of quality of vegetable produce and opinions held about different soil fertility inputs amongst the market women.

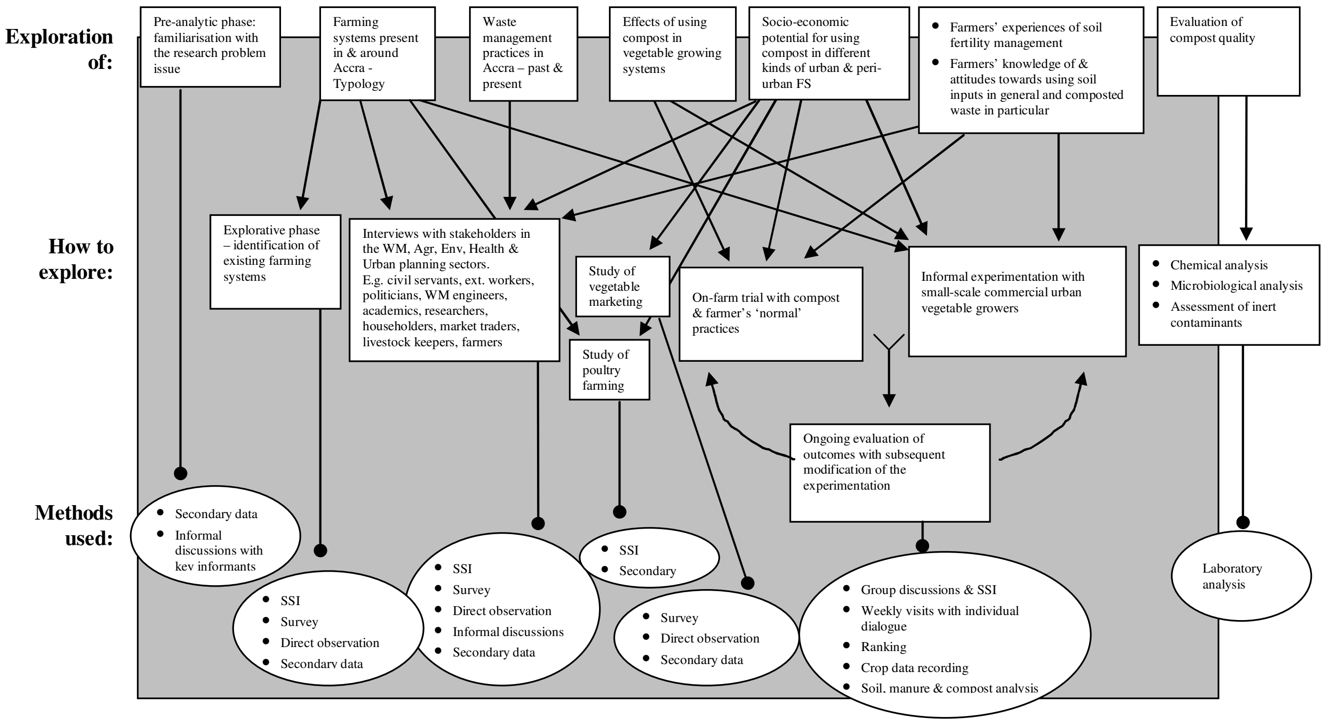



*Figure 3.3 Methodological organisation of the research*

*Source: This thesis*

## 3.3 Methods used

The selection of different sources of information and data collection methods were guided by the principle of 'triangulation'. This enabled cross-checking to ensure that a dependency on one type of person, or one source of information, or one set of tools, did not occur. The use of multiple methods, strengthens the validity of the findings from the qualitative research methods (Denzin & Lincoln, 2000).

Table 3.1 summarises the main methods used for the different components of the research.

*Table 3.1 Research methods employed for the different research activities*

| | Initial exploration of farming systems | On-farm trial | Vegetable growers experiments | Waste management | Poultry farming | Marketing of vegetable produce | Agricultural development and extension |
|---|---|---|---|---|---|---|---|
| Direct observation | ■ | | ■ | ■ | | ■ | ■ |
| Structured, semi-structured and non-structured interviews | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Questionnaire Survey | ■ | | | | | | |
| Group discussions | | | | | | | ■ |
| Seasonal calendars | | ■ | ■ | | | | |
| Matrix scoring / preference ranking | | | ■ | | | | |
| Venn and pie diagrams | | | ■ | | | | |
| Workshop | | ■ | ■ | ■ | | | ■ |
| Exchange visits | | ■ | ■ | ■ | | | ■ |
| Chemical & microbial analysis of compost, manure and soil | | ■ | ■ | ■ | | | |
| Crop assessment | | ■ | ■ | | | | |
| Secondary data | ■ | | | ■ | ■ | ■ | ■ |

*Source: This thesis*

### *3.3.1 Secondary data*

Secondary data sources were used extensively in order to enrich the primary field data. These included both published and unpublished material and documents from a variety of sources including (1) development and research organisations (e.g. FAO, DFID, IBSRAM), (2) national and local government departments such as the Ministry of Agriculture and Ghana Statistical Services, Accra Metropolitan

Assembly, the waste management department and the agricultural extension services, and (3) the University of Ghana, Legon and the University of Science and Technology in Kumasi. Information was drawn from material such as project and workshop reports, strategy documents, national and municipal statistics, articles and books.

### 3.3.2 *Structured, semi-structured and non structured interviews*

To gain information on the various issues regarding urban agriculture, waste management and the potential for utilising organic urban waste in agriculture, interviews were carried out with a wide variety of actors including national and local government officials, waste management professionals, farmers, agricultural extension staff, development workers, and vegetable produce traders. In Box 2.4 in Chapter 2 a list of actors interviewed and issues explored is provided.

The degree of formality of the interviews varied from structured (as used to interview 30 market traders across different food markets in Accra), to the non-structured format whereby informal conversations (or sometimes just chats) were held with key informants to explore the issue in a flexible, iterative manner. Overall, semi-structured interviews (SSIs) was the most commonly used format, and represented one of the most important methods used throughout the field research.

### 3.3.3 *Group discussions with PRA exercises*

Group discussions and Participatory Rural Appraisal (PRA) exercises carried out during group meetings were important in enriching the experimental work with the vegetable growers. Group discussions were held with farmers who were participating in the research to explore key points emerging in the course of the research (photo 3.1). These meetings provided an opportunity for farmers to share experiences and for emerging issues to be voiced. The discussions led to decisions about any appropriate modifications to the experimental work.

In addition to discussing the outcomes of the experiments and ways to carry the research forwards, general information about the vegetable growers' farming and livelihood systems were explored with the aid of a series of PRA tools. For example:

- Diagramming tools such as Venn diagramming and pie charts were used to gain information on labour input, and the importance of and linkages among different institutions.
- Ranking and scoring exercises were employed to gain information on preferences for different soil inputs, and willingness and ability to use WDC in the future.
- Seasonal calendars were used to gain an understanding on cropping activities and price fluctuations throughout the year

Information of this nature combined with the on-going chatting with the participating farmers over time, served to provide a fuller understanding of the livelihood system of the commercial urban vegetable growers and complemented and expanded the information gained from the baseline survey.

### *3.3.4 Direct observation*

Direct observation was a useful and important method applied throughout the field research. The types of direct observation utilised to inform the research was twofold: observations of practical activities; the interaction dynamics between different actors. During farmer group meetings and, perhaps more importantly during the workshop, observation of interactions and flow of discussion provided information about power relationships and alliances among the different actors. This kind of information is valuable, partly to understand the constraints to developments, partly to help the researcher approach the work in an appropriate manner so as to minimise biases, blockages in information flow and negative experiences on the part of various actors in the joint work.

### *3.3.5 Exchange visits*

During the course of the research, managers from the composting plants visited the on-farm trial and the vegetable growing areas where the experimentation took place. This enabled the composing professionals to observe how crops performed when grown with the material and to meet with the experimenting farmers to discuss opportunities and constraints. The composting managers had never met urban vegetable growers before and found the experience useful. Exchange visits between farmers were also organised. Such interactions enabled farmers to share ideas and experiences. Throughout the research agricultural extension workers were kept informed about the work and were encouraged to visit the experiments. The on-farm trial was visited regularly by the extension officer for that area, but there was only limited success in the efforts to involve the extension staff in the vegetable growers' experiments.

### *3.3.6 Workshop*

Towards the end of the experimental period a multi-stakeholder workshop was held with the aim to share experiences, learn from the farmers about the outcomes of the research, and to explore the potential for using WDC in the future. The workshop was held adjacent to the location of the on-farm trial which enabled the participants to observe the trial and the farmer to present his findings and experiences. A mixture of farmers, agricultural extension staff, waste management professionals and researchers participated in the workshop.

### *3.3.7 Questionnaire survey*

This method was used in the baseline survey into farming systems in and around Accra, and to gain information on the vegetable marketing system. Use of a questionnaire with a series of predetermined/set questions enabled the collection of standardised data which complemented the more qualitative data and the information gained later through less formal research methods.

### 3.3.8 Soil, compost and manure analysis

The quality of the compost was evaluated in terms of nutrient status and potentially toxic elements. Chemical analysis was done on several batches of compost as well as on animal manures and sewage sludges used in the research. Microbiological analysis was carried out on a selection of samples to ascertain any presence of harmful organisms. The compost samples were also assessed physically for inert contaminants such as glass, plastic and metal fragments.

Soil samples were taken periodically from the on-farm trial site to monitor any changes in the soil nutrient status following applications with compost and manure. In addition samples of soil were taken for chemical analysis from selected soils in the urban vegetable growing areas where the informal experimentation took place. Field assessment of the physical characteristics of the soils in all experimental beds were also carried out to determine soil type (according to the FAO system). A fuller description of the soil, compost and manure sampling and analysis procedure is provided in Sections 5.3.1 and 5.3.2 in Chapter 5 and in Appendix A.

In addition to the quantitative soil assessment the farmers' perceptions of the characteristics and fertility of their soils was explored. Several criteria for assessing soil fertility were mentioned including soil colour (the darker the soil the more fertile it is perceived to be), soil insect and worm life, weed growth, leaf colour and size, root development and physical characteristics of the soil.

### 3.3.9 Crop assessments

In both the on-farm trial and the vegetable growers' experimentation crop performance was monitored throughout the growing period, as was any differences in weed occurrence, pest and disease infestation and water requirement, both by the farmers and the researcher. The researcher was present at harvests of crops grown in the on farm trial and a range of quantitative assessments were made. In the vegetable growers' experiments quantitative assessments were carried out in the majority of harvests, either by the researcher or her assistant. However, occasionally the growers, or the market women, would harvest the crop before assessments could be made. More detailed information on the type of assessments done and the extent of crops grown by the vegetable growers that were assessed is provided in Chapters 5 and 6.

### 3.3.10 Critical reflection on the research process

Throughout the research process the relative usefulness of carrying out the research in a pluralistic way was examined. A conscious effort was made to critically reflect on the learning experiences that took place and how they contributed to guiding the research process. A diary was kept during the whole research period to record reflections on both practical and personal issues and the considerations that arose. The diary reflected the worries I had, the learning cycles I went through, events that took place and findings that emerged which affected the research in various ways. The diary was used as a valuable tool to aid the appraisal of the research process and the monitoring of the learning processes that took place.

## 3.4 Data and information analysis

Synthesising the data and information gathered from the various activities presented a challenging task. The challenges included:

- synthesising non-commensurate data and information, from within a single discipline *(e.g. soil sample analysis, and vegetable growers' views of soil quality)*
- synthesising data and information from different disciplines *(e.g. agronomy of vegetable growing, and institutional issues of governance)*
- synthesising understanding that crosses several levels of analysis, and of practice *(e.g. vegetable plots on waste land, farm enterprises, waste collection, municipal governance)*

<u>Qualitative data analysis</u>
The qualitative data generated from the various research activities was analysed using a thematic categorisation. Data from the SSIs, group discussions and informal interviews and chatting were grouped and coded according to pre-identified and emerging themes.

<u>Quantitative data analysis</u>
Data gathered from the survey, structured interviews and some of the PRA exercises were processed and analysed in Microsoft Excel. The analysis carried out was descriptive, using frequencies, means and percentages of relevant variables to identify and illustrate general patterns in the data. Where appropriate Chi Square analysis was used.

Quantitative crop performance data were entered into a coded spreadsheet and analysed using both Excel and Genstat. Data generated from the on-farm trial were analysed using analysis of variance (ANOVA). In order to ascertain the overall differences between treatments and any cumulative benefits in crop growth resulting from repeated compost applications over time, the harvest data were normalised, to allow them to add them/be added together, i.e. to look at the overall treatment differences. One possible approach to combining all crops together is analysis of normalised values which allows for the analysis of the underlying plot/plot variability (Mead, pers. comm. 2002). By normalising the values, all crops can be combined together, taking into account the differences between the crops (i.e. the fact that a cabbage head weighs much more than a tomato and that there are more tomatoes harvested from a plot than there are cabbage heads).

The analysis of the quantitative data generated from the vegetable growers' experiments was less straightforward because of the looser experimental design and the multiple sources of variation between data sets. These data were grouped according to the various sources of variation and hierarchical analysis of variance was carried out for each variable. In order to enable all crops to be analysed together, the standardised difference between treatment means was calculated, which allowed for looking at the size of the difference between the treatments regardless of crop.

As explained earlier, the choice of method was aimed at understanding the problem situation in terms of a set of interrelated questions, which needed to be addressed using different methods. In terms of analysis, data and information resulting form the various methods were used in various combinations, depending on the (sub) question explored and the level of analysis (system boundary). In the final chapter of this thesis (Chapter 8) an assessment is made of how well this study has met the challenge of methodological pluralism.

## Summary

This chapter has discussed the methodological approach adopted for the research, and the various methods used for data collection. The approach chosen for the study builds of the conceptual issues discussed in Chapter one and the theories and research traditional outlined in Chapter two. The following chapter presents a background and context to the study site.

*Photo 3.1 PRA exercises with vegetable growers in Dzorwulu*

# CHAPTER FOUR – URBAN AGRICULTURE AND WASTE MANAGEMENT IN THE GREATER ACCRA METROPOLITAN AREA

This chapter presents the location of the fieldwork, and its context in relation to waste management and urban agriculture. It is in three parts. The first part presents a general background to The Greater Accra Metropolitan Area (GAMA) in terms of location, geographical and climate characteristics, population, urban growth dynamics, as well as its history in terms of governance. The second part reviews past and present waste management in Accra (AMA) including composting experiences. The third and final part describes the nature of urban and peri-urban agriculture in and around Accra. It concludes with a presentation of selected results of the baseline survey and related studies of urban vegetable growing and marketing.

## 4.1 Introduction to Accra

### *4.1.1 Location and Administrative Boundaries*

The West African Republic of Ghana is located on the Gulf of Guinea and bordered by Burkina Faso to the north, Togo to the east and Côte d'Ivoire to the west. Ghana covers an area of 238533 km$^2$ and is divided into 10 administrative regions, that vary substantially in size, population, resources and levels of change and development (Appiahene-Gyamfi, 2002).

Accra is the national capital of Ghana. It is also the major industrial, financial, transportation and administrative centre of the country. It is situated on the south coast on the Bay of Guinea within the smallest region in the country; the Greater Accra Region. The region is divided into five administrative districts; Accra, Ga, Tema, Dangbe West and Dangbe East. The administrative boundary of Accra is referred to as Greater Accra Metropolitan Area (GAMA). GAMA is made up of three of the five district assemblies within the Greater Accra Region, namely Accra Metropolitan Assembly, Ga District Assembly and Tema Municipal Assembly. GAMA covers an area of 1286 km$^2$ (or 2% of the national land area) as shown in Figure 4.1.

Accra is an important commercial, manufacturing and communication centre. The city is linked through a road network to the North, East and West, and the international airport is located here. GAMA has easily the most diversified economy of all the regions. Its economic base is mainly in wholesale and retail trade; administration; service and repair industries; manufacturing; construction; transportation, storage and communication; and finance, insurance and real estate. Accra's economy as a whole contributes between 15 and 20% of the country's GDP and accounts for 10% of the employment in Ghana.

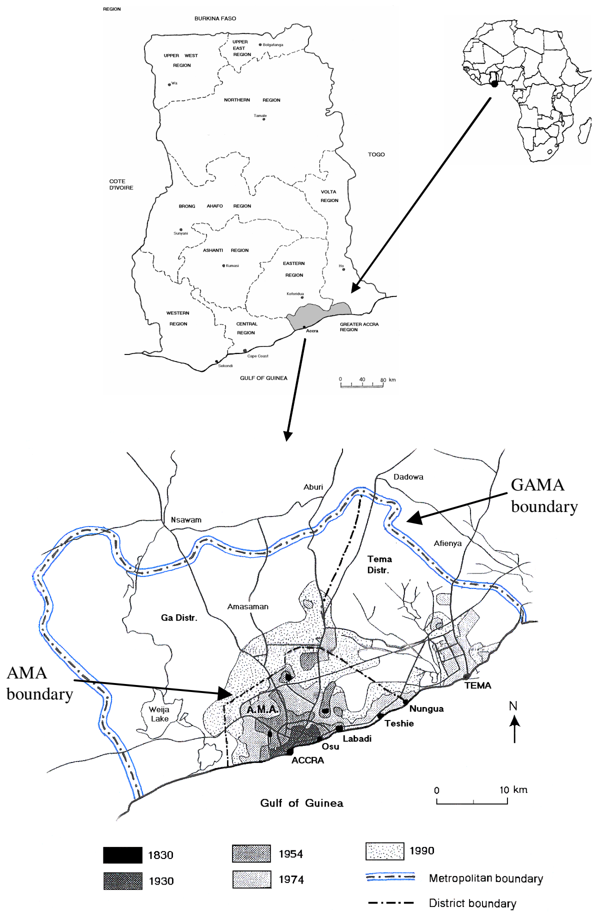



*Figure 4.1 Map of Ghana, Greater Accra Region and The Greater Accra Metropolitan Area*

*Source: Adapted from Larbi, 1996*

## *4.1.2 Geographical setting and climate*

Accra lies within the coastal savannah plain of Ghana. Most of Accra is flat or slightly undulating with the exception of the Shai Hills to the north-east. The vegetation is characterised by coastal savannah grasslands with small thickets along streams, and mangroves and swampy vegetation along the coastal lagoons. A number of introduced trees and shrubs, such as neem, mangoes, cassias, bougainvillea and palms are also common in the metropolitan area.

The soils on the Accra plain are variable. In many areas they are shallow and have a clay pan rendering them prone to waterlogging and flooding in the wet season, and cracking during the dry season (Dzomeku and Enu-Kwesi, 1997). This also applies to many areas that are farmed within Accra itself, whilst in other parts the soil is sandy and suffers from poor water holding capacity.

The coastline of Accra comprises a combination of rock outcrops and sandy beaches around the mouth of lagoons. The three largest lagoons in the area are Sakumo (Densu Delta) to the west of Accra, Korle in central Accra and Sakumo II, west of Tema. The Accra area is drained by several rivers and streams. The largest is the Densu River which has been dammed at Weija, 10 km west of central Accra. There are 7 drainage basins in the Metropolitan area, many of which are flood prone estuaries. Localised flooding is not uncommon during the rainy season.

The climate is hot and humid, yet quite dry with a mean annual rainfall of 730 mm. It is characterised by bimodal rainfall, with the main rainy season between April and June and the minor one around October. The rainfall is intense, unreliable, and generally of short duration, which has implications for farming and livestock keeping. The entire annual rainfall tends to occur in less than 80 days (Greater Accra Regional Admin, 1988 in Kreibich and Tamakloe, 1996). There is relatively little variation in temperature, ranging between 23 and 32°C, with the lowest temperatures in August and the highest in March before the onset of the rains. The dry season does not appear dry since the air humidity remains high at around 80% throughout the year.

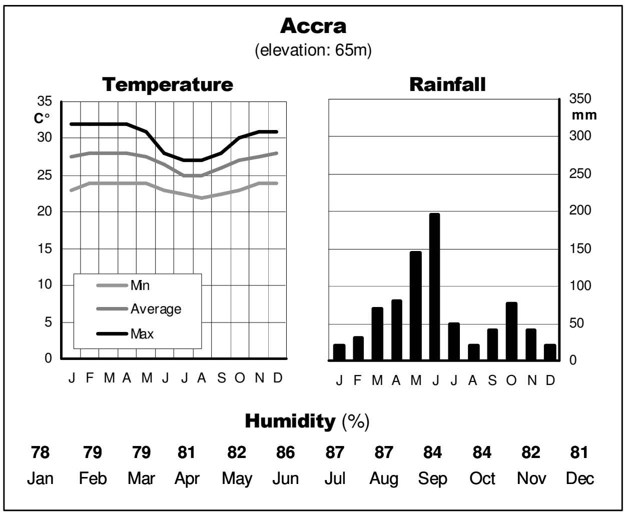



*Figure 4.2 Climate data for Accra*

*Source: Derived from Müller, 1983*

### 4.1.3 *Overview of the urban growth dynamics of GAMA*

With both Accra and Tema located within it, the Greater Accra Region is the most urbanised region in Ghana. According to the 1984 census 83 % of the population of Greater Accra live in urban settlements, compared with 32% for the country as a whole (GSS, 1995). Around 16 percent of the overall population of Ghana, and over 30% of the country's urban population[14] live in the Greater Accra Region. Migration from the north to the more developed and urbanised south is pronounced. In-migration to the Ashanti and Greater Accra regions is particularly high. The proportion of the population in urban areas has increased significantly over the past 20 years. This is a trend that is expected to continue, placing great demands on urban governance and infrastructure. The rapid increase has been the result of various urban-biased development strategies ever since Accra was selected to become the headquarters of the British colonial administration in 1877 (Konadu-Agyemang, 2001; Kreibich and Tamakloe, 1996). Rural-urban migration was particularly pronounced during the period after independence in 1957 when, under President Nkrumah's centralised, socialist-style growth and modernisation policies, the major share of public investment was directed towards large cities and towns (Konady-Agyemang, 2001). During this time Tema was developed as an industrial satellite of Accra. It is the site of Ghana's deep-sea harbour and many of the country's industries are located here. Between 1960 and 1984 Tema grew by over 600% from a population of 27 000 to 191 000 thousand people. Kreibich and Tamakloe (1996) reflect how the concentration of industry, manufacturing, commerce, business, culture, as well as educational, political and administrative functions, in the Accra/Tema conurbation has attracted migrants from all over the country and abroad, and contributed greatly to the urbanisation of the region.

The rapid growth rate (6% annually) carried on until the late 1970s when a series of economic disasters and the subsequent introduction of Economic Recovery Programmes (ERPs) in 1983, slowed the growth rate somewhat to 3.5% as in-migration reduced. Similar trends have been observed in other major cities of West African countries where economic crisis and the hardship following the implementation of Structural Adjustment Programmes have been experienced (Giraut, 1997; Briggs and Yeboah, 2001). During the 1990s the growth escalated again and is currently believed to be around 4.3% (Konadu-Agyemang, 2001). In the period between the 1984 Census and the last Census in 1997, the population of GAMA more than doubled from 1.3 million to 2.73 million (GSS, 2000a). According to the 2000 population Census[15] the overall population growth rate for Ghana between 1984 and 1997 was 50%, whilst for the Greater Accra Metropolitan Area it was 110%, far exceeding the national average. Although the majority of the population of GAMA is in the Accra District, the Tema and Ga Districts are growing more rapidly, as they are experiencing a spill-over effect from Accra District. Using 1992 data from the Ministry of Local Government, Maxwell *et al.* (1998) report that in the peri-urban Ga district, annual growth rates are about 6% and in the southern part of the district, i.e. the northern and western

---

[14] Urban population is defined as settlements exceeding 5000.

[15] This Census was carried out in 1997 and it was published in 2000.

fringes of Accra city, the growth rates are in the order of 10%[16]. Here new settlements are expanding rapidly and agricultural land is being lost, partly to housing developments, partly to sand and gravel mining for building materials.

*Table 4.1 Population changes in The Greater Accra Metropolitan Area*

| | | Accra | Tema | Ga | Total (GAMA) |
|---|---|---|---|---|---|
| **Area ($km^2$)** | | 241 | 163 | 857 | 1261 |
| **Population** | 1960 | 388,390(6) | 27,127 | 33,907 | 449,430 |
| | 1970 | 636,660(7) | 102,430(1) | 66,336 | 804,834 |
| | 1984 | 969,195 | 190,917 | 136,358 | 1,296,470 |
| | 1997 | 1,657,856 | 511,459 | 556,581 | 2,725,896 |
| **Change (%)** | 1960-70 | 63.9 | 277.6 | 95.6 | 79.1 |
| | 1970-84 | 52.24 | 86.4 | 105.6 | 61.1 |
| | 1984-1997 | 71.1 | 167.9 | 308.2 | 110.3 |
| **Growth rate** | 1960-70 | 5.1 | 14.2 | 6.9 | 6.0 |
| | 1970-84 | 3.1 | 4.5 | 5.3 | 3.5 |
| | 1984-1997 | | | | |
| **Density (pers/$km^2$)** | 1960 | 1612 | 166 | 40 | 356 |
| | 1970 | 2642 | 628 | 77 | 638 |
| | 1984 | 4022 | 1171 | 159 | 1028 |
| | 1997 | 6879 | 3138 | 649 | 2162 |

*Source: Ghana Population Census 1984 and 199 7(GSS, 1987; GSS, 2000a)*

### *4.1.4 Socio- Economic History*

Ghana was the first African colony to gain independence, when Kwame Nkrumah led the independence movement to victory in 1957 (Horton, 2001). He embarked upon a development strategy of industrialisation and the centralisation of planning and administration in line with a socialist ideology (Larbi, 1996), and Ghana became a one-party state. The country's economy, which was one of the most promising in Africa in the 1950s, steadily deteriorated after Nkrumah came to power. Horton (2001) notes how '*departments grew, Soviet-style purges were common, detention without trial was introduced, and corruption was endemic*'. Kondy-Ayemang (2001:26) report that by the mid 1960s GDP growth rate had decreased from about 5 to 0.4% and the foreign reserves that amounted to £200 million (equivalent to 3 years' imports) in 1957 had dried up and the nation was in serious debt, estimated at US$ 1 billion. Nkrumah was overturned through a military coup in 1966, and the country entered into an era of political instability.

[16] Some of the more noticeable residential satellites that have sprung up include: Madina, Adenta, Haatcho, McCarthy Hill, Kwashieman, New Achimota, Dome and Ofankor.

Between 1966 and 1981 the country experienced six government changes through military interventions and thwarted democratic elections (Horton, 2001). It is widely recognised that the country's socio-economic policies and administrative performance during this period was marked by inefficiency, mismanagement, patronage, and corruption (e.g. Toye, 1991; Larbi, 1996; Amanor and Annan, 1999; Horton, 2001; Konadu-Agyemang, 2001). Governance and decision making was characterised by tribal and extended family loyalties. Policy decisions were made based on favouritism which invariably resulted in widespread corruption and frustration (Werlin, 1991). In summary, Larbi (1996:194) notes how "*the economic, social, cultural and political development of Ghana before 1983 was characterised by high inflation, a low GDP, a dual economy of an inefficient public sector and an active informal sector, over-regulation by the government (price controls, licensing and administrative allocation) disincentives for production, institutional demoralisation, low incentives for efficiency and hard work and a deterioration of human services*".

When in the early 1980s a series of (additional) external shocks[17] brought the economy to an all time low, the government decided that structural reforms were necessary. In 1983 Ghana embarked upon an Economic Recovery Programme, followed shortly after by a formal Structural Adjustment Programme under the (technical and financial) tutelage of the IMF and the World Bank[18]. The programme was designed to stabilise the economy and address severe economic imbalances in line with the neo-liberal ideology of the World Bank and the IMF.

Since these programmes were introduced, Ghana's economy has experienced tremendous growth. Real GDP has grown at a rate of 4-6% and inflation has declined from more than 130% annually in the early 1980s to 16% in 1998 (Konadu-Agyemang, 2001). Furthermore, there has been a tripling of export goods production and expansion of industrial capacity from about 25% of installed capacity before 1983 to 35-40% in the 1990s (*ibid*.). However, the impacts of the adjustment have been mixed. The radical devaluation of the currency has led to price increases in both imported and domestic goods, including food. Reduced public spending has triggered extensive lay-offs in the public sector and drastic cuts in state services. The introduction of user-pay into health, education, waste collection and other state provided services has re-allocated access. Meanwhile the freeze on civil servant salaries introduced during the restructuring period has resulted in a struggle for people to cope with the price increases and rising cost of living (Konadu-Agyemang, 2001).

Whilst proponents argue that structural adjustment is the best means of coming to terms with hard economic realities, others are more sceptical and take the view that it compounds the economic crisis of the poor, and leaves governments with limited resources to maintain existing infrastructures or to invest in the building of

[17] This included (1) the steadily falling price for cocoa, Ghana's chief export crop, (2) severe drought and accompanying bushfires that swept through the country and (3) the repatriation of 1 million Ghanaians from Nigeria in 1983.
[18] Most countries in the region have had to adopt structural adjustment programmes.

new. In Ghana it is clear that the positive growth performance brought about by the ERP has had its social costs. Songsore and McGranahan (1993) note that whilst the adjustments have led to improvements, it has so far failed to bring economic prosperity back to pre-crisis levels. Larbi (1996:195) goes further and say that "there is economic growth but not development" in Ghana since the adoption of structural adjustment. Briggs and Yeboah (2001) argue that in the African context, it is in the cites, especially the capital cities because of their 'gateway' status, where engagements with SAPs has been most visibly played out and the impacts appear to be the greatest. Human underdevelopment, reductions in the quality of life and mounting inequalities are all visible results of SAP strategies, according to the authors.

### *4.1.5 Urban Planning and Housing*

Accra has grown in a generally unplanned manner, absorbing existing villages in the process (Benneh *et al.,* 1993). The residential areas in the inner city of Accra are made up of a combination of: (1) indigenous single-storey compound housing in dense settlements which were the original fishing villages, (2) old colonial housing, and (3) a range of more modern houses of different sizes and classes. The peripheral residential areas of Accra are characterised by a variety of newer, lower density housing, from low class housing in informal settlements, and middle class houses through to large luxury houses, many of which are being built by expatriate Ghanaians. The rapid growth of Accra in an unfavourable economic climate and under socio-economic mismanagement, has resulted in a fragmented residential structure. There are a few high and middle class areas but the bulk of the population lives in unplanned residential developments characterised by overcrowding and substandard housing and municipal services (Benneh *et al*., 1993). In established residential areas, there has been increased crowding in the form of higher occupancy ratios and building on vacant plots within the settlements (*ibid.*). In addition, developments have sprung up in areas prone to flooding and along drainage ways (such as for example Dzorwulu and Alajo) (Larbi, 1996), whilst urban sprawl and uncontrolled expansion into the peri-urban areas has occurred at a rapid rate (Benneh *et al*., 1993).

The poorly defined nature of land ownership and the tension between land use planning and land ownership are seen as major causes of the *ad hoc* planning and development of Accra (e.g. Larbi, 1996; Fred-Mensah, 1999). Accra has a mix of state and customary land holdings. State and vested land makes up 13% of the total residential area of Accra, with the remaining 87% customary. Customary land (stool/skin/family lands) is held in trust and managed by tribal chefs or family heads on behalf of the subjects of the stool[19] in accordance with customary law and usage. Official planning activity has concentrated on state land; on customary land there has been a gross disregard of official planning procedure and regulations (Larbi, 1996). The development experience regarding customary land has been fraught with land conflicts, with open-ended, often multiple, claims and

[19] The term 'stool' ('skin' in the north of Ghana) is a chieftancy institution and refers here to a community which a chief heads.

hapazardous development without planning for roads, drainage and other infrastructure provision (see for example Larbi, 1996; Fred-Mensah, 1999; Briggs and Yeboah, 2001). There has been a general weakness in the planning system and a failure to implement strategic planning and coordination between different agents and their various functions, e.g. Land Commission, Survey Department, Town and Country Planning, Landowners, and utility providers. There are large numbers of uncompleted houses, subject to land conflict and long-running litigation and/or lack of funds for completion. Interspersed with housing developments are large pockets of undeveloped land, some of which is used for farming.

The Ministry of Local Government groups housing into low, middle and high-income areas.

- The low income areas are of two types; indigenous (Ga settlements) and non-indigenous (mainly migrant) areas[20]. These areas are characterised by poor quality, high density housing with high occupancy rates and inadequate or lacking municipal services, including roads, drainage, water supply, sanitation, electricity and sufficient waste disposal systems. Altogether these areas make up approximately 58% of Accra's population and a large proportion of the informal economic activities (AMA, 1994).
- The middle-income areas, according to the local government classification, are predominately business, administrative and professional income families. Much of the housing has been provided by state, parastatal and private sector organisations and individuals[21]. Within the city these housing areas have generally been planned, but on the fringes of the city such developments are unplanned. Infrastructure provision is limited or lacking. This group makes up approximately 32% of the population (*ibid.*).
- The high income housing is broadly of two types: planned low density areas with adequate infrastructure provision within the city of Accra and low density housing on the fringes of the city[22] where housing developments have sprung up without planning and before infrastructure provision has been put in place. This kind of housing accounts for 10% of the population (*ibid.*).

A similar classification has been made by the Department of Town and Country Planning on the basis of socio-economic dynamics. They have divided the residential sector into eight categories, each with differing population density, ethno-cultural dynamics and amenity provision, as shown in Box 4.1). This box also displays the relative share of households estimated to be residing in each stratum.

---

[20] Examples of such areas under indigenous settlement are: James Town, Osu, Labadi, Adedankpo, Chorkor, Thesie and Nungua. Non- indigenous low-income areas include: Nima, Sukura, Kwashuemen, Odorkor, Bubuashie, Abeka, Maamobi and Ahaiman.

[21] Examples of such areas include: Dansoman Estates, North Kaneshie Estates, Asylum Down, Kanda Estates, Abelenkpe, Achimota, Dome and much of Tema.

[22] Planned areas include: Ridge, Ridgeway Estates, North Labone, Airport Residential Area, Roman Ridge and East Legon. Newer settlements on the fringes of Accra include: Haacho, Adenta, Taifa and Mallam.

*Box 4.1 Residential categories in GAMA*

| Stratum/Sector | Characteristics | % |
|---|---|---|
| High Density Indigenous Sector (HDIS) | These areas are the oldest sections of Accra. They house 'indigenous' communities – mainly the original Ga townships with family compound houses and similar history and culture. Population very dense; growth rate now low. Characteristically low incomes, mainly from fishing. Very poor levels of infrastructure. | 17 |
| High Density Low-class Sector (HDLCS) | These areas are characterised by very high densities; low income population; high proportion of migrant population; ethnically diverse; and with extremely poor infrastructural conditions. High growth rates. Most areas are low-lying, prone to flooding. Housing is sometimes temporary wooden shacking. | 46 |
| Medium Density Indigenous Sector (MDIS) | Houses people who otherwise have been living in the HDIS, but have moved out because their lot improved. Incomes are marginally higher than HDIS and HDLCS. Densities not as high as HDIS. Many migrants also live here. Infrastructure poor to adequate. | 12 |
| Medium Density Middle-class Sector (MDMCS) | Started as LDHCS but have been overcome by rapid urbanisation. Residential quality and services are good. Housing people with primary education or better. Incomes are medium, but slightly low and densities are higher than LDHCS and LDMCS. | 5 |
| Low Density Middle-class Sector (LDMCS) | Started as state-owned estates for government staff. With time the quality of the estates deteriorated. Densities are relatively low, as are growth rates. Population is middle income, infrastructure conditions are adequate. | 11 |
| Low Density High-class Sector (LDHCS) | People living in these areas are of high socio-economic status, with high levels of education and wealth. It has adequate infrastructure and services. | 2 |
| Low Density Newly Developing Sector (LDNDS) | Newly developing settlements usually on the city fringe. Some evidence of lack of basic infrastructure, but housing facilities are usually adequate. These areas are populated by newly middle income groups seeking to develop property. Growth rates are rapid. | 3 |
| Rural Fringe (RF) | Consists of rural settlements nuclei which have been incorporated into the metropolis through an extension of the metropolis's boundary. Large open spaces exist, allowing for peri-urban agriculture. These Ga villages, like most rural localities, are generally lacking service provisions. | 5 |

*Sources: The Department of Town and Country Planning, 1992 in Fobil, 2000; and Benneh et al., 1993*

### 4.1.6 The Informal Sector/Economy

A substantial proportion of the working population of Accra is engaged in the informal sector economy. This sector includes various activities, such as petty commerce (e.g. street vending) and basic low-quality production (in agriculture, artisan and craft work, building materials, waste recycling etc.). The majority of people active within this sector are self-employed operating micro-enterprises, but they may also work as employees or employers (Asenso-Okyere *et al.,* 1997). Income levels vary considerably (Gilbert and Gugler, 1992), but those engaged in the informal sector economy are typically at the level of subsistence, often sourcing household income from a range of activities or resources that are combined for survival (Mead 1998 in Nelson 1999). Because of the very nature of the informal sector, information about it is incomplete and 'informal'. It is not comprehensively reflected in official data and, as argued by Asenso-Okyere *et al.* (1997), the role informal economic activities play in the Ghanaian economy has not been given the recognition it deserves. Government statistics have attempted to estimate the importance of the informal sector in terms of employment. The Core Welfare Indicators Questionnaire Survey (CWIQS) in 1997 estimated that in urban areas of the Greater Accra Region 83 percent of economically active people were engaged in the private sector of the economy (GSS, 1998). In this sector, the proportion of people active in the informal sector constituted 68 percent, far exceeding the formal sector (15%).

The importance of the informal sector for income generation has implications for savings and investment, i.e. the financial sector. Asenso-Okyere *et al*. (1997) point out that whilst formal banking is not very popular, there is a great deal of informal banking through traditional non-bank institutions and thrift societies known as 'susu'. The small-scale urban farmers and vegetable produce traders studied in my own research were all self-employed within the informal economy, and some of them also were employed within the private or public formal economy alongside their farming activities. They did not have access to formal credit facilities. Some relied instead on susu associations, pooling their resources through contributing fixed sums of money on a periodic basis to a common fund that would be rotated to each member in turn, and would have access also to soft loans if a need arose.

## 4.2 Part Two - Solid Waste Management in Accra

This section reviews the nature of solid waste and its management in Accra over the past 20 years. Although the focus is on solid waste, sanitation is also discussed. Recycling - with special focus on the composting activities present in the city, - is given particular attention. Information was gained from SSIs with a variety of stakeholders, including managers in the waste management sector, both private and public, officials in AMA, the health sector and the Environmental Protection Agency. In addition reports and papers have been reviewed.

### *4.2.1 Institutional arrangements*

Waste management has been fraught with difficulties in spite of substantial bilateral support. A major drawback of solid waste management in the metropolis is the chronic financial problems arising from inadequate funding and poor cost recovery. As the city has grown, it has exhausted the capacity of existing traditional disposal sites, (Anku, 1997). The failures can in part be ascribed to weaknesses in the management systems and institutional arrangements. Akuffo (2000:14) reflects:

> "*among the weakest institution that we have in the country are planning and urban management institutions. There has been complete inability of law enforcement in these areas for a long time resulting in haphazardness in urban development programmes*."

Anku (1997:3) takes a similar view and notes:

> *"one of the hindrances to efficient WM in this country is the absence of a clear national policy. As a result programmes and projects on WM improvements have been initiated and implemented in the past on an ad hoc basis without any defined course of action. ….. Additionally, because of dearth of data on WM and lack of qualified staff and training facilities, implementation of WM programmes and projects are haphazardly implemented."*

He further notes:

> *"some of the problems associated with WM in this country, are caused by fragmentation of responsibilities between different Ministries and organisations. In most cases, lines of responsibility are not clearly drawn. E.g., the Municipal/District Assemblies are responsible for clearing roadways and streets, whilst AESC (Hydro) Division of the Ministry of Works and Housing are responsible for construction and maintenance of open drains. Co-ordination between relevant Ministries and agencies such as the Environmental Protection Agency, The Environmental Health Department of the Ministry of Local Government and Rural Development, and the Ghana Water and Sewage Corporation, is also weak. As a result, provision of water supply and sanitation services, for instance, which should be closely linked to solid waste management is ineffective" (ibid.*:5).

In 1988, as part of the decentralisation process under the Economic Recovery Programme, a system of local government through the creation of 110 District Assemblies nationwide was put in place. The Accra Municipal Council was reconstructed as the Accra Metropolitan Assembly (AMA) under the new Local Government Law. The idea behind this was to empower people by "*bringing departments directly under District Assembly jurisdiction, thereby severing long vertical lines of control and enhancing responsiveness to local needs*" (Obirih-Opareh & Post, 2002:98). The AMA acts as the political, planning and management body of Accra District. It has the overall responsibility of the governance and development of Accra, including budgetary control, development of basic infrastructure, provision and maintenance of municipal works and overall improvement and management of human settlements in the district (Anku, 1998; Stephens *et al*., 1994 in Fobil, 2000). In line with this legal mandate, it is the responsibility of the AMA to collect refuse, build and maintain streets, clean drains and pit latrines, operate markets and slaughter houses, issue building permits and other business licences (Anku, 1998).

*Box 4.2 An example of management failure, highlighting the lack of institutional linkages*

At the time of this research there were two major projects under implementation in Accra, both with environmental goals, both under the Ministry of Works and Housing, yet with little collaboration between them. One was the partly UK-funded commission of a new sewage treatment plant to cater for water borne sewage. Located on the edge of the Korle Lagoon in central Accra, the plant was designed to discharge treated clean waste into the lagoon. The other project was a Kuwaiti funded initiative to restore the Korle Lagoon, which is an environmental disaster on a grand scale. The lagoon has served as a cesspool for most of the city's industrial and human waste for years. Its water is thick, black and foul smelling, incapable of sustaining any life. The mangroves that once surrounded its shores are long gone. On one side of the bank there is a large informal settlement that is home to hundreds of migrant families that lack sanitation facilities. One part of the lagoon has partly been filled in with solid waste, which was dumped there in the past when the area was used as a temporary dedicated dumping ground by the waste management services.

Provided the newly commissioned sewage treatment plant is run and maintained according to its designed specifications, water discharge from it should not present a problem. However, in view of the fact that none of the previous treatment plants, nor the composting plant at Teshie/Nungua have been operated as intended, it is quite probable that in the future, water that has not been treated to satisfactory standard will be discharged into the Lagoon, undermining the efforts of the Kuwaiti project. The successful operation of the sewage works depends in part on the functioning of a stirring arm in one of the ponds. Unless maintained regularly this could fail, resulting in turn in failure in the digestion process of the sewage.

Efforts to clean up the Lagoon under the Kuwaiti project are likely to be futile unless there are measures to deal with the large informal settlement (approx 300 000 people) on one of the banks of the Lagoon. Many of its inhabitants are involved in polluting artisan activities such as rubber and battery recycling, engineering and car mechanics. These people either have to be moved to permanent settlements, or provided with appropriate infrastructure to avoid polluting the lagoon, but such measures were not part of the project.

*Source: Interviews with key informants during 2000*

In 1984 the then Accra Municipal Council, had created a Waste Management Department as a separate unit responsible for the handling of solid and liquid (human) waste collection, treatment and disposal. Benneh *et al.* (1993) noted that this institutional strengthening went a long way to stabilise the deteriorating sanitation situation in the city.

In 1992 waste management was further decentralised when the day-to-day waste management operations were transferred to six sub-metros[23] of the Accra

[23] The six sub-metros are: Asiedu Keteke, Ablekuma, Ayawaso, Okaikwei, Osu Clottey and Kpeshie, each of which comprises of around eight residential areas

Metropolitan Area. The sub-metropolitan District Councils, which each comprise around eight residential areas, were put in place to "*respond to the complex and peculiar socio-economic and management diversity of the metropolis*" (AMA, 1994:116) In relation to waste management, each sub-metro were given some resources to carry out their responsibilities of waste collection and waste depot management. However, Obirih-Opareh and Post (2002:99) note that the limited logistics available to the sub-metros meant that this initiative created more problems than it solved. According to the authors, it resulted in "*further complicating an already complex and confusing division in Solid Waste Collection tasks and responsibilities*".

Since 1995, in contrast to most of the other District Assemblies in Ghana, Accra has put in place a set of bye-laws that give the WMD a mandate to: (1) generate revenues through direct user charges, (2) manage a segregated account to utilise these revenues, (3) directly pay the salaries of their staff, (4) privatise selected aspects of their service, and (5) perform vigilance and enforcement of laws which control waste generators and haulers (World Bank, 1996). The WMD however, has only limited autonomy. It is under the supervision and budgetary control of the AMA. Furthermore, it is the AMA that decides on policies and strategy (Obirih-Opareh and Post, 2002).

The waste management challenge in Accra is serious and typical of the situation faced by the majority of cities of developing nations. The city suffers from serious inadequacies with regards to waste management and sanitation infrastructure, and the problem is getting worse as the amounts of waste generated increases. According to the Environmental Protection Agency (EPA) there are two main reasons for the escalating increase in the production of municipal waste. First, demographic changes, with an average population growth rate of 4.3%, have led to the generation of greater quantities of wastes. Secondly, the increase in industrialisation and economic growth experienced since the introduction of the Economic Recovery Programme (ERP) has led to changes in consumption patterns with resulting increases in *per capita* quantities of waste (Anku, 1997).

### *4.2.2 Household Waste Disposal Facilities*

As discussed in Section 4.1, the large population of Accra has brought in its wake overcrowded conditions in the indigenous areas of the city and sprawling suburbs, the majority of which lack basic facilities such as latrines, drains and markets (Awal, 1999). The explosion of satellite communities like Madina, Gbawe, Ofankor and Adenta have made the financing of waste disposal reach crisis proportions. As Anku (1997) points out, The Accra Metropolitan Authority is struggling with the challenge of how to dispose of ever growing amounts of wastes in the face of diminishing available land space for disposal and dwindling budgetary allocations from the government.

Drawing on the findings of an inspection of premises in the city undertaken by the Health Department of the AMA, Awal (1999) notes that about 55 percent of houses in the metropolis have some form of sanitary facilities, whilst the remaining

45 percent have no sanitary facilities at all. The result is that people defecate indiscriminately in drains, beaches and open spaces. Interviews held with waste management professionals during the course of the research revealed that human waste is commonly disposed of in the refuse containers provided for household refuse. Table 4.2 shows the extent of water and sanitation facilities available to different income groups and areas of GAMA in 1991.

*Table 4.2 Water and sanitation facilities in different income groups and areas of GAMA*

| | Wealth index of household | | | District | | |
|---|---|---|---|---|---|---|
| | Low | Middle | High | Accra | Tema | Ga |
| **Principal source of drinking water** | | | | | | |
| Indoor piping | 25.7 | 70.2 | 98.0 | 34.7 | 40.6 | 3502 |
| Private standpipe | 27.1 | 15.3 | 2.0 | 30.9 | 6.3 | 24.3 |
| Water vendor | 32.9 | 8.4 | - | 23.4 | 45.0 | 28.0 |
| Communal standpipe | 9.2 | 5.3 | - | 9.5 | 6.9 | 8.2 |
| Other (e.g. well, open waterway, rainwater) | 5.1 | 0.8 | - | 1.6 | 1.3 | 4.3 |
| **Type of toilet facility** | | | | | | |
| Flush – sewage | 12.3 | 35.9 | 49.0 | 33.6 | 56.9 | 19.2 |
| Flush – septic | 14.1 | 32.1 | 49.0 | | | |
| Pit latrine | 35.8 | 12.2 | 2.0 | 32.4 | 16.3 | 41.6 |
| KVIP (Kumasi ventilated improved pit) | 12.1 | 3.8 | - | 8.3 | 20.6 | 9.6 |
| Pan latrine | 22.1 | 10.7 | - | 23.8 | 2.5 | 16.8 |
| Other | 0.7 | - | - | 0.4 | - | 2.4 |
| No toilet | 2.8 | 5.3 | - | 1.5 | 3.8 | 10.4 |
| **Method of grey water disposal** | | | | | | |
| Same as sewerage | 2.8 | 9.2 | 13.7 | 1.5 | 12.5 | 8.8 |
| Closed separate drains | 4.3 | 16.0 | 23.5 | 6.0 | 11.9 | 5.6 |
| Open separate drains | 46.0 | 42.7 | 54.9 | 53.6 | 40.6 | 9.6 |
| Nearby waterway | 5.9 | 2.3 | - | 6.2 | - | 4.8 |
| Dumped in street | 14.2 | 7.6 | 2.0 | 12.2 | 3.1 | 28.0 |
| Dumped in yard | 26.4 | 21.4 | 5.9 | 20.3 | 31.3 | 41.6 |
| Other | 0.5 | 0.8 | - | 0.3 | 0.6 | 1.6 |

*Source: Questionnaire Survey of GAMA 1991, in: Benneh et al., 1993*

### *4.2.3 Amount of solid waste generated*

Data on the total amount of solid waste generated in Accra are unreliable, partly because of the uncertainty about the size of the population, partly because of a lack of information on the nature of waste generation and recycling among the different income segments. Consequently, estimates vary considerably. Population estimates for Accra District range form the official figure of just under 1.66 million, which was derived from the population census in 1997 (published 2000), through to 3 million (e.g. Awal, 1999). Further, waste is generated not only by the inhabitants of the city but also by a transient population who temporarily spend time within the city; such as those who enter the city in the daytime to work and trade. This floating population is estimated to be anything between 200 000 (Fobil, 2000; Obirih-Opareh and Post, 2002) to half a million (Awal, 1999). Household solid waste generation *per capita* is estimated, by the WMD, to be in the region of 0.55 kg/day (Armah, pers.comm., November 1999). Based on this estimate and on the different population estimates, Accra generates anything between 1050 tonnes/day and 1925 tonnes/day of solid household waste. In addition to this is the commercial solid waste generated by industries, enterprises and public institutions. It was estimated in 1999 that approximately 50-60 percent of the solid waste generated in the city, was collected by the waste management services (amounting to 600 t/day). The remaining 40-50% is disposed of through indiscriminate burning or dumping with resultant health hazards and environmental degradation[24.]

### *4.2.4 Type and composition of wastes*

The types or wastes making up the overall solid waste stream is typically classified into different fractions according to the type of material and the way that the fractions behave in the environment (Fobil, 2000). The classification below is the one used by the WMD. The WMD periodically carry out an analysis of the waste. The constituent proportions of the waste stream for 1995 are given in Table 4.3 along with a waste classification from households in different income groups carried out in 1999 (Fobil, 2000).

A household solid waste characterisation study carried out in different income classes in Accra in 1999 showed that the proportion of organic waste from high income households was higher (approx. 70%) than that of waste from medium (60%) and low income (49%) groups (Fobil, 2000). The waste stream from the lower income groups is of poorer quality with the majority of reusable materials removed. The study revealed that that which is discarded as waste from low income households contains a higher proportion of inert materials (17%) than waste from higher income households (5%) (*ibid*.). See Table 4.3

[24] Waste generated by industries and many institutions (such as the police, army and the University of Ghana, Legon) was not included as they are responsible for disposing of their own waste.

*Table 4.3 Type and proportion of different kinds of wastes of collected waste in Accra*

| Waste type | Characteristics | Proportion of waste stream, 1995 (WMD) (%) | Components of waste from households in different income classes in Accra (Fobil, 2000) (%) | | | |
|---|---|---|---|---|---|---|
| | | | All | High | Medium | Low |
| Organic | food materials, leaves, garden trimmings, animal manure, animal products such as slaughterhouse waste, feathers etc. and industrial waste products from breweries and various food processing plants. | 65 | 65 | 71 | 61 | 49 |
| Paper | newsprints, packaging materials, cardboard etc. | 4.2 | 8 | 10 | 7 | 8 |
| Plastics | plastic bags, plastic containers, rubber and rubber products | 3.5 | 8 | 6 | 9 | 9 |
| Glass | bottles and other glass items | 1.2 | 1 | 1 | 4 | 2 |
| Textiles | discarded clothing and textile material | 1.7 | 3 | 2 | 3 | 8 |
| Metals | aluminium materials, metal cans and tins, ferrous and non-ferrous iron | 1.8 | 3 | 2 | 2 | 4 |
| Inerts | e.g. earth components such as sand and gravel from sweepings, ashes and already decomposed organic component. | 22.8 | 10 | 5 | 12 | 17 |
| Other | e.g. charcoal, bones, shells of snails, hard and treated wood, sawdust, pebbles and ceramic materials | 1.2 | 2 | 3 | 2 | 3 |

*Sources: WMD and Fobil, 2000*

In the Fobil study (2000) the analysis of the fractions of different materials in the waste stream was carried out on waste at the point of being discarded by the household. The constituents of the waste that is collected and eventually ends up at the dumpsite are different as scavenging does take place, particularly in the high-income neighbourhoods where more valuable waste is generated, although Accra does not have large numbers of waste pickers. As such, the proportions of different constituents in the waste stream recorded by Fobil and by the WMD respectively are likely to differ. In spite of this consideration it is noticeable that between the WMD recording in 1995 and Fobil's in 1999, the proportion of plastic in the waste stream increased considerably (from 3.5% to 8%). The increase in plastic waste is a frequent topic of conversation in Ghana, and there is considerable concern about how to handle the problem.

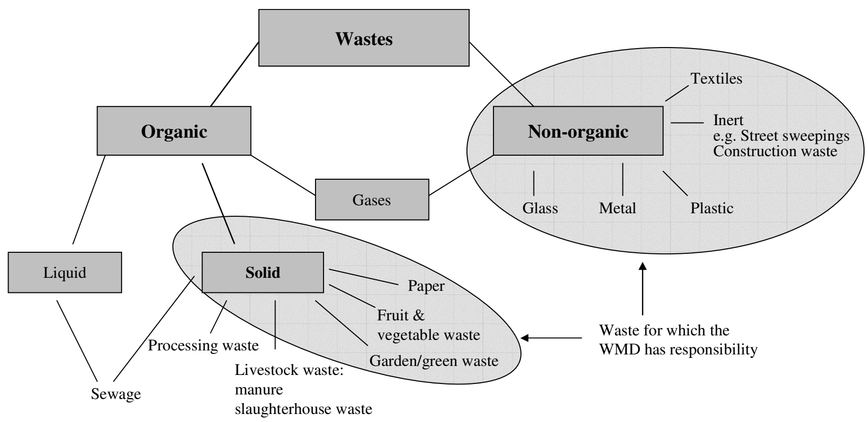



*Figure 4.3 Illustration of different types of urban waste and the ones for which the WMD has responsibility*

*Source: This thesis*

### *4.2.5 Sources of solid waste*

In terms of the waste source, the following broad classification of solid waste is used by the AMA

- *Domestic Waste*

Waste arising from household activities. This is typically made up of left-overs from food preparation, sweepings, fuel burning, garden waste, and discarded items such as old clothing, furniture, packaging, newsprint. Because of the lack of sanitation facilities, the domestic waste also includes faecal matter. The domestic component is by far the most sizeable, accounting for approximately 95% (AMA, 1994). According to Mr Armah, the manager of Accra WMD until 2000, sewage treatment does not represent a major problem in Accra. As the majority of toilets are not water closets, there is relatively little sewage in Accra, and the nightsoil from the pit latrines is relatively uncontaminated. At the beginning of this research, responsibility for wastewater treatment was not under the AMA's, but during the research The Ghana Water and Sewage Co-operation was transferred to the AMA. Mr Armah foresaw that sewage treatment could become a major and costly problem in the future (interview November, 1999).

- *Commercial Waste*

Waste from shops, offices, restaurants and markets. This typically consists of packaging material, food waste and street sweepings. The composition of this waste does not differ much from domestic waste except that the paper and plastic content is higher. Approximately half of commercial waste is produced by the markets. The market waste has a high proportion of organic material (70-90%).

- *Institutional Waste*

This is waste from establishments such as government buildings, schools, hospitals, military bases and religious buildings. Generally its composition is similar to that of commercial establishments, but it can also contain hazardous wastes. Some hospital wastes in particular are of this nature. Wastes from hospitals and laboratories that can contain dangerous pathogens (e.g. human parts, cotton wool, syringes etc.) are disposed of on site by burial or incineration (AMA, 1994). Many other institutions are not serviced by the WMD but manage their own waste through burial or incineration, including the university, the police and the army.

- *Industrial Solid Waste*

This waste varies considerably in composition and volume depending on the industrial activity undertaken. It may be waste from breweries, sawmills, mining, construction, and food processing. Much is similar to the waste generated by the commercial sector, involving organic waste, plastic, metal and paper items. Some industrial wastes arise from chemical processes and mechanical operations and fall into the category of hazardous waste. AMA does not have responsibility for collection or disposal of industrial wastes and there is limited information with regards to extent of, nature of and responsibility for hazardous waste. (AMA, 1994)

### *4.2.6 Waste collection*

Two systems of household waste collection operate in the city: a door-to-door service collecting directly from the households, and a communal container collection (CCC) service whereby people have to carry their own waste to a container or designated dump depot. Door-to-door collection is used in high-income, low-density areas and some middle-income areas. In Accra, the majority of residents live in densely populated , low-income areas for which CCC service is both technically and economically most appropriate. The door-to-door service is operated in approximately 30% of the areas that receive waste collection, with the CCC system covering the remaining 70% (Obirih-Opareh and Post, 2002). According to a World Bank estimate, in 1996 the cost per household for CCC is roughly 25% of the cost of the door-to-door service. However, even though considerably cheaper, the cost represents a substantial amount of the disposable income of low-income families and is not affordable by many.

There have been attempts by the WMD to collect user charges for services to waste generators receiving CCC, but the cost recovery has been poor[25] and at the time of this research the service was operated free of charge. In the 1980s a pay-as-you-dump (PAYD) policy was introduced whereby people were made to pay a small fee for dumping their waste in the communal containers or at designated dumpsites. However, Obirih-Opareh and Post (2002) note that although the local authorities earned some revenue, the policy was counterproductive as it led to illegal dumping of waste because people attempted to avoid paying, leading to environmental degradation and public health hazards. The controversial policy was abandoned in 1991 by order of the central government. Similar experiences of indiscriminate dumping following the introduction of dumping fees or environmental taxes have been observed elsewhere, for example, in the UK where the car scrapping charge has resulted in people abandoning their unwanted vehicles along roadsides.

The communal containers, or the depot sites which lack containers, are emptied daily. However, lack of adequate equipment, spares, fuel and maintenance systems have often resulted in inadequate service. Overflowing waste sites with smelly, highly unsanitary conditions are commonplace, which in turn dissuades people from taking their waste to the designated sites. The door-to-door collection service is operated on a weekly basis. This service does cover its costs through user charges[26]. In fact, it generates surplus revenue which is used to cross-subsidise the CCC and other waste management costs.

In spite of the door-to-door collection system generating a surplus, it accounts only for approximately 11 percent of the total cost of solid waste collection in Accra (World Bank, 1996) and overall cost recovery is poor. Waste management, and collection of solid waste in particular, represents a significant expenditure for local governments. AMA has always struggled to meet the funding requirement for the service and as a result, the WMD has been in a situation of having to operate under severely constrained financial conditions. Accra has received considerable external support for collection systems in the past, in the form of vehicles, containers, spare parts, training and technical assistance (World Bank, 1996). For example, the German Government (through GTZ and GOPA[27]) were (actively) involved in supporting waste management in Accra , both technically and financially, during the 1980s and 90s. However, the rapid increase in waste volumes coupled with inadequate budgetary funding for maintaining services that have been put in place, has rendered the WMD unable to provide an adequate service. There has been a chronic lack of funds to maintain, repair and fuel equipment and to allow for sufficient staff. In 1996 vehicle downtime was reported

[25] According to the WB, in 1996 the total cost for CCC was 85.9 million Cedis (£9000) per month and total billings were 2.3 million Cedis (£240) per month.

[26] In 1996 the city-wider costs for door-to-door service was 10.2 million Cedis (£1070) per month and the total billings 22 million Cedis (£2315) per month, with 80% of bills being paid (World Bank, 1996).

[27] Gopa is a German consultancy firm, sub-contracted by GTZ to manage the administrative part of the Accra Waste Management Project.

to be 60 percent (World Bank, 1996) and many of the vehicles in the workshop have been seriously cannibalised for parts. Under these conditions staff morale is low.

**A move towards a public-private partnership in solid waste collection**

The waste collection system in Accra has undergone many changes since the creation of its Waste Management Department in 1984. A whole range of different collection and financing systems have been tried with varying degree of decentralisation and level of private-public partnerships.

In addition to the use of sub-metros for aspects of the collection service and local waste management, as mentioned above, isolated examples of private collection initiatives have existed over the years. The use of donkey cart collection in the area of Apenkwa-Tesano-Abeka in the late 1970s is perhaps the best known example. However, until 1994 solid waste collection was the sole responsibility of the WMD.

In 1994, in line with the wider policy of decentralisation and privatisation under the SAP, and in response to the failure of the public waste collection service through the WMD, a move towards partial privatisation of the service was made. The lack of funds within AMA to operate waste collection to a satisfactory standard, reinforced the case for private sector involvement (Obirih-Opareh and Post, 2002). Having proven successful in pilot studies, this arrangement was formalised in 1995 when AMA adopted an official policy of partial privatisation of waste collection. This is in line with current privatisation, decentralisation and deregulation debate within the fields of waste management and urban development and relates to the neo-liberal doctrine that has prevailed since the latter half of the 1990s. The general arguments for privatisation is that the private sector is better suited to provide workable waste collection since the system can be made more flexible, with smaller operations designed for different circumstances, and for their ability to ensure more complete cost recovery.

Obirih-Opareh and Post (2002) report that the WMD privatisation campaign aimed at bringing 80 percent of the collection operations under private sector responsibility by 2000. Under this system private franchisees worked under three-year agreements to provide collection in a selection of mixed income areas. The World Bank-sponsored Urban Environmental Sanitation Project, which became effective in 1996, was influential in promoting and supporting the development of a private waste collection system. The city was zoned into different areas according to criteria such as accessibility, income category, transportation etc., and franchises given to different private contractors, according to their level of technology and equipment (Anku, pers. comm., June 2000). The franchisee contracts included both door-to-door and CCC service. Those operating in door-to-door collection areas were required to cover their costs through collection of user charges which were established by the AMA (UESP, 1996). They then had to pay a fee to the AMA for dumping their truckloads at the designated dumpsites (Obirih-Opareh and Post, 2002). The contractors operating in the CCC areas would be reimbursed by the AMA since the CCC service does not carry a user fee. Payment was done on the basis of recorded trips to the dumpsites and the certification by the assemblyman in the area that the contractor had performed the service in a satisfactory manner (Obirih-Opareh and Post, 2002). In 1999, at the start of this research, there were eleven sub-contracting private contractors in total. Together with the collection operated by the WMD regular collection was provided in approximately 60 percent of the city, with the remaining areas receiving no collection service at all. It was estimated by the WMD that 50-60 percent of all solid waste was collected.

Although partial privatisation of waste collection had resulted in some improvements, both in terms of coverage and volumes collected, waste management was still beset by serious problems and large amounts of waste was still left uncollected and mounting waste piles of indiscriminately dumped waste was a common feature of the city landscape. There was a growing feeling that the private collection system was failing to provide a satisfactory service. Several reasons for this failure can be identified:

- The private contractors were poorly equipped and the payments they received from collection charges (in the case of door-to-door collection) or dumping fees (in the case of CCC) were not sufficient for upgrading or renewing the equipment. The only way to make the contracts financially viable was to use old dilapidated vehicles. Collection was frequently failed because of vehicle breakdown.
- Late payment by AMA was common and resulted in disruption of service. Obirih-Opareh and Post (2002) cite this as the most important financial problem and cause of poor results in the privatised CCC service.
- The contractors operating in areas with door-to-door collection received their payment directly from households through collection charges. Under this arrangement they were required to pay a dumping fee to the WMD at the dumpsite. In order to avoid this expense and to save fuel costs in driving to the dumpsite, some private contractors would indiscriminately dump their waste loads along roadsides, in river valleys or on the beach.
- The waste collection fees recovered from households were for private collectors to cover their costs for transportation of waste to dumpsites. They did not contribute towards the costs of waste disposal, i.e. operation, maintenance and development of landfills. As such the system did not provide the WMD with working capital to maintain and improve WM.

These problems coupled with the fact that the waste volumes continued to grow, overstretched the waste management apparatus.

**From decentralised private collection to a private monopoly**

In August 1999, contrary to the idea of devolution the central government intervened and entered into a contract with a Canadian company called City and County Waste (C&CW) to take over the running of waste collection in the city. The AMA/WMD became relegated to operate under the management of C&CW, as did the private contractors. According to this contract new equipment (containers, vehicles etc) to the value of US$8.3 million (£4.55 million) was brought in  to the country funded by a Canadian loan (Alimi, 2000). AMA was to pay C&CW a guaranteed 22.5 billion cedis (£2.37 million) for the first year, a substantially higher amount than previously spent on waste management in general, let alone waste collection. This figure was derived from the estimated amount of waste that would be collected. Under the contract C&CW would get paid for every tonne collected and delivered to the dump site. Considering that AMA's budgetary allocation on waste management in the preceding year (1998) was 2 billion cedis (£210 000)[28], serious questions arose as to how Accra would be able to afford this kind of waste collection service. Even at the cost of 2 billion cedis, AMA was running at a deficit, and struggling, often failing, to pay the private CCC contractors for their services. This deficit was in part due to poor cost recovery of collection fees. It was envisaged that through expanding and increasing waste collection charges and through a concerted effort to actually recover them, a substantial proportion of the contract cost would be covered. In addition, the government decided to provide national budgetary support through its National Environmental Sanitation Policy (Ahowi, 2000 in Obirih-Opareh and Post, 2002).

The whole issue became a 'political hot potato'. Some felt that this decision on the part of the central government killed the initiative of the private sector waste collectors. The system had not been in operation for long enough to be truly tested. The collectors were still 'finding their feet' operating under conditions of under-funding and with insufficient equipment to enable them to provide an effective service. There was a general feeling amongst many people within the waste management sector in Accra that had the government been willing to pay a fraction of the money they paid to C&CW for each tonne collected to the private enterprises, these would have been able to upgrade and maintain their equipment and provide an equally good service. Furthermore, this would have been at a fraction of the cost of the contract with C&CW. The private contractors had been paid 10 000 cedis (£1) for every tonne weighed in at the dumpsites whilst the government agreed to pay C&CW 211 000 cedis per tonne (£22). There was a certain amount of discontent and talk of ulterior motives and corruption behind the scenes in association with the deal with the Canadian firm. Residents receiving door-to-door collection were questioning the introduction of vastly increased fees (from ¢10 000/month (£1) to anything between ¢25000 (£2.6) and ¢60 000/month (£6.3), depending on the neighbourhood), with some refusing to pay.

Notwithstanding the increased spending on WM and arguably the inappropriateness of opting for such a 'Rolls Royce' solution to solid waste collection for a city like Accra, the collection service did improve substantially under the management of C&CW. The amount of waste that was weighed in at the dumpsites doubled from 600t/day to 1200t/day over a period of eight months. The CCC containers were emptied on a more regular basis than before and the sites were kept clean and, with that, people started to use them more (Marquis, pers. comm., June 2000). C&CW also cleared old piles of indiscriminately dumped waste across the city, contributing to creating a cleaner city appearance. C&CW

[28] Excluding the costs incurred by private door-to-door collectors who financed their operations through household collection fees.

was only obliged to operate on roads accessible to the company's vehicles and as such many outlying and poorly accessible areas remained unserviced (Obirih-Opareh and Post, 2002). Being paid on the basis of the amount of waste weighed in, C&CW had a financial incentive to maximise the amount of waste that they took to the dumpsites. Consequently, this payment policy did little to encourage waste minimisation and recycling. It was an expensive, knee-jerk measure aimed at superficially cleaning up the city, without much thought given to sustainability issues, or even to where to put the waste once collected.

**And back again ….**

Eight months into the contract, it became clear that AMA was unable to pay the agreed sum (of 1.8 billion cedis a month) of money to C&CW. Following the presidential election in 2000 and subsequent change of government, the contract with C&CW was cancelled. The equipment, paid for by the government loan from Canada, remained in the country and became available to the AMA and its WMD and the private contractors. With the improved equipment available to them, the system of collection by private contractors works better than before, and whilst the situation is far from perfect, the city's collection service is greatly improved from the situation some years back (Klaassen, pers. comm. October 2000).

### *4.2.7 Waste and Waste Disposal*

The solid waste that is collected is disposed of by open-air dumping at publically owned and managed sites. Typically low-lying areas and disused quarries within the built-up area have been used. At the time of this research AMA had two official dump sites. One at Mallam and one in Teshie/Nungua as depicted on the Map in Figure 4.5. Both these sites had exceeded their lifespan; they were overflowing with waste causing nuisance, pollution and environmental degradation. No soil was applied to cap the waste and fires regularly burnt, fuelled by the methane produced within the waste mounds. Pay loaders and bulldozers were used to spread and grade the waste and make room for the waste collection vehicles. However, machinery breakdown and fuel shortages were commonplace and frequently the waste collectors were forced to dump the waste by the entrance to the sites causing a back spill of waste onto the roads surrounding the sites.

The main site at Mallam is an old quarry within an established residential settlement. At the time of this research it had been in use for five years and was getting overfull. It received 80 percent of the collected waste which equated to 580t/day at the onset of the research and 1000t/day towards the end of the research period when C&CW operated the collection service. What had been a deep hole in the ground had become a mountain reaching up above the rooftops of the surrounding houses.

The other, minor site at Teshie/Nungua was originally designed as a composting and night soil treatment plant with open-air dumping of the non-compostable fraction of the waste. As will be reviewed later in the composting section below, the composting operation has not functioned properly and the site at Teshie/Nungua has effectively been used as an open-air dump. This site too is overflowing. Waste collected from a 10 km radius was delivered to the site, representing approximately 20% of the total solid waste collected. (120t/day in 1999 and 200t/day in 2000/1). When the site was developed and first brought into use in 1980, it was situated within an area of undeveloped land between Accra and Teshie/Nungua. Now sprawling residential settlements/housing have expanded to completely encircle the site. The roads to the site are unmade and dust clouds are constantly hanging over the houses as the rubbish collection trucks make their way to the site across these dirt roads deep in pot-holes.

Plans were underway to develop a sanitary landfill site in Kwabenya 40 km outside Accra, with financial support from the British Government (DFID). At the time of this research a suitable site had been identified, but the project was severely delayed. There were a number of reasons for this. Firstly, the initial projected cost was underestimated and negotiations for agreement to more than doubling the funding delayed progress. Secondly, until AMA had identified a site where land could be secured on a permanent basis, with the agreement of the local people and without causing displacement of people and the social effects of that, DFID did not agree to release the money. Similarly, a source of clay for lining the landfill needed to be secured by the AMA before funds would be released and construction could commence. Once the site had been commissioned and the two makeshift sites within Accra had been closed down, the transportation component of the overall waste management bill would increase substantially because of the considerably increased distance between the point of waste generation and waste disposal.

No provisions exist for disposal of hazardous and industrial wastes.

### *4.2.8 Waste Treatment and Recycling*

Policies aimed at minimising waste generation and, with the exception of composting, of encouraging recycling are lacking. A significant portion of the reusables in the solid waste stream are, however, recovered and by the time the waste arrives at the dumpsite there is little waste of recyclable value left. There are different people involved in the domestic waste recycling process including the householders, initial waste buyers, the street scavengers, the waste collectors, the waste traders and dealers, and, at the last port of call, the dumpsite scavengers. Curiously and contrary to may other cities, the numbers of the latter (i.e. dump site scavengers) are relatively limited in Accra, possibly due to effective waste recovery on route to the dumpsites. Initially it was envisaged that the views of scavengers would form an integral part of the research. However, the discovery of the limited scavenging activity at the Accra dumpsites (this research; Marquis, pers. comm., June 2000; World Bank, 1996) resulted in this aspect of the research being cancelled.

The social groups involved in industrial waste recycling are somewhat different. Recovery of such wastes typically involves recycling within the industry itself or in a commercial link between a waste generator and a more formal waste dealer or a producer using a waste or by-product as an input in their manufacturing (e.g. brewery waste in poultry feed production).

Whilst there are no public recycling ventures, nor policies or strategies to stimulate this, in spite of the high cost of industrial raw materials and dwindling foreign exchange, there are several private recycling enterprises, some producing finished products, others raw materials for industries. Therefore, by the time the waste becomes a waste, so to speak, much of the useful materials have already been removed. There is or course, great variability between areas in the city, with more valuable waste in the high-income areas than in the low income ones, as discussed above (Table 4.3).

Some of these private recycling enterprises are small-scale, operating within the informal sector (such as scrap metal recyclers/merchants by the Korle Lagoon), others more formalised establishments. Figure 4.4 depicts recycling enterprises in Accra that have been documented (Meynel, pers. comm., June 2000) as existing in Accra at the time of the research. These are described below.

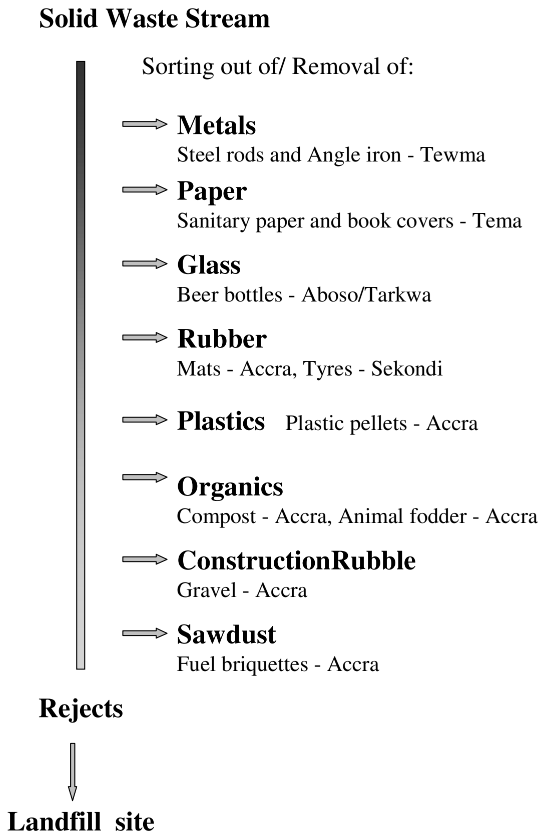



*Figure 4.4 Existing solid waste recycling enterprises in Accra and the greater region*

*Source: Meynel, pers. comm., June 2000 and this thesis*

**Scrap Metal**
There are two factories with steel melting furnaces in Ghana, both of which are located in Tema. They produce metal rods and angle irons. Scrap metal has become something of a scarcity and there is a good market for recycling. At the time of the research the factories were even importing scrap metal from neighbouring countries.

**Paper**
The Super Paper Product Company in Tema recycles paper into sanitary paper and covers for school exercise books. At the time of the research they were operating at half their production capacity (Meynel, pers. comm., June 2000) as the supply of waste paper was insufficient. The SPPC have their own collection trucks and pay 25000 cedis per tonne (£2.5).

**Glass**
There is a glass factory at Aboso near Tarkwa, which recycle clear, brown and green glass into beer bottles. This enterprise is run by a Ghanaian/Togolese company called Tropical Glass under an American managing director. Since its refurbishment it has been in full operation since 1996, which has led to a great increase in glass recycling countrywide (Meynel, pers. comm., June 2000). There is very little broken glass to be found on waste disposal sites. In Accra there is a glass collection depot located in Achimota. The factory pays well (¢75000-160000/t, £8-17) for glass delivered to their factory and there is potential for small-scale collection point operations to encourage further recycling.

**Rubber**
There are two enterprises in Ghana that deal with rubber recycling. One is the AKOTO Enterprise, which is located in Accra. They produce mainly doormats from waste rubber from other factories and from rubber collected from the waste stream. Rubber is one of the materials collected by scavengers at Mallam open air dumpsite. The other company, The MACAL Tyre Re-threading Company, is located in Sekondi and is remoulding used tyres.

**Plastics**
At the onset of this research plastic recycling in Ghana was limited to one company, Polymers Ltd., which recycled their own, clean plastic. Efforts were under way in Accra to establish plasic recycling and at the end of the fieldwork period a private enterprise was operational, turning waste plastic into pellets for use by plastic factories. The plastic handed is bought at a price of 400 cedis/kg (£0.04) and the market value for plastic pellets at US$0.4-0.5/kg (£0.22-0.27); the business has proven successful and has expanded its operation (Klaassen, pers comm., October 2000).

**Organics**
Much of the organic waste is utilised at the household level as animal feed. Some is even recycled commercially whereby householders sell vegetable peels etc. to livestock keepers. A small proportion of the organic waste that end sup in the solid

waste for collection is composted. The composting operations that exist in Accra are described below.

**Rubble**

A Construction firm called Billfinger and Berger has set up a recycling unit for construction rubble in Accra. The Recycled material is produced in two different gravel sizes. The quality of the recycled material is very high and has a market value of US$30/tonne (£16). The high value is in part because comparative material in Accra has to be transported a long distance, from locations as far as 50 km away.

**Sawdust**

Since 1996 a small company has existed in Kaneshie in Accra that turns Sawdust into fuel briquettes. Firewood is very cheap, so there is no economy in paying for or transporting sawdust for the purpose of recycling. The briquette production needs to be located near a sawmill for it to be cost effective. Apart from private households, the manufacturers sell briquettes to ceramic, brick and tyre factories.

**Composting of solid waste**

Whilst the vast majority of collected household waste is disposed of through open air dumping, Accra has a relatively long history of composting MSW. At the time of the research there were two composting operations in the city (Figure 4.5):

1. A large-scale public composting plant in Teshie/Nungua on the eastern outskirts of Accra.
2. A small scale NGO initiated community project involved in neighbourhood household waste collection and composting in James Town, a densely populated part of central Accra.

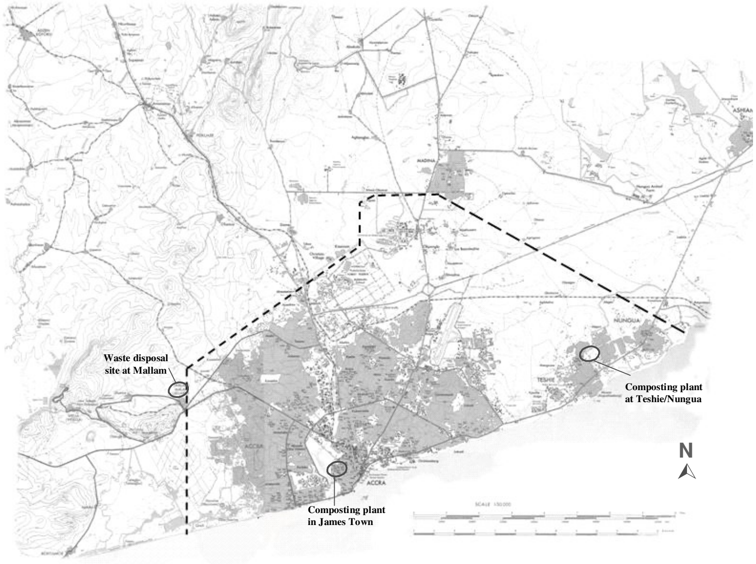



*Figure 4.5 Location of the two composting sites and the Municipal landfill site at Mallam*

*Source: Adapted from survey map of Ghana, The Survey Department, Ministry of Lands and Mineral Resources of Ghana.*

**The Teshie/Nungua site**

This plant was designed and built by a Swiss company in 1979 and became operational in 1980. Incorporating mechanical screening of mixed waste, composting and faecal treatment in the form of a series of stabilisation ponds for night soil and septage, it was designed to receive and process a substantial amount of the waste generated within the city of Accra.

Ambitious in design, the plant relied on sophisticated engineering for sorting the mixed waste. Grab cranes and feeding hoppers were used to move the mixed waste into a hammer mill through a chain conveyor, into a screening drum and then onto a belt conveyor with an overband magnetic separator for removal of metallic components. Having gone through this process to remove non-organic components and mill the waste to aid decomposition, the resulting organic waste is ready for composting.

The method employed is co-composting with digested sewage sludge in an open-air windrow system whereby the organic waste is laid out in windrows and capped with a mixture of sewage sludge and sawdust from the adjoining faecal treatment plant. The temperature (initially 50°C rising to 70°C to kill of pathogens) and moisture (approx 50 percent) content is monitored to ensure optimum conditions for decomposition and pathogen destruction. Liquid waste from the waste stabilisation ponds is used to water the windrows to ensure that the compost becomes too dry. The household waste and faecal material is composted for a period of 12 months during which time it is turned four times using a pay loader (turning machine). The first half of this process is done in the open, the second half in a shed.

The original design of the plant included a fine milling and screening line through which to pass the compost once it had stabilised and matured, to break up any lumps, mill and screen the compost, and produce a high quality final product ready for use in horticulture, agriculture and landscaping.

However, whilst this describes the system that the plant was designed to operate, what happened in reality was very different. As discussed in Chapter 1, there are numerous examples where large-scale high-tech mechanical composting plants like this have run into difficulties in developing countries (Asomani-Boateng and Haight, 1999: Furedy *et al.,* 1997; Ali, 1997; Lardonis & van de Klundert, 1994), the outcome being that some facilities closed, others were scaled down and many operate well below the planned capacity. The Teshi/Nungua plant is no exception. In fact, it provides a case example of the failure of transfer of technology where the installations are too expensive, too complicated and not appropriate to local conditions. At the time of this research the plant was akin to a graveyard of broken down machinery and equipment without the resources to do the necessary maintenance and repair to make them operational.

From conversations held with a number of people who were or had been involved with the Teshi/Nungua composting plant at different times throughout its life, it became clear the it had never been operated according to its design specifications, it had often been non-operational and it had always been operated below its planned capacity. It has been fraught with difficulties and disruptions caused by machinery breakdown and shortages of spare parts and fuel, and (in spite of considerable cash injections and managerial support from GTZ/Gopa once they became involved in the waste management in Accra,) the plant was never run effectively.

It was not long before the waste separation and screening facility ceased to work and this critical sequence in the operation was abandoned. Instead the mixed waste was composted without prior separation, which had negative consequences for the compost quality. The composting was carried out according to the intended procedure described above whereby the waste was co-composted with sewage sludge/sawdust at a ratio in the order of 1:4, moisture and temperature monitoring and regular turning. Once the material had stabilised and was judged to be mature, it was passed through a mechanical sieving drum, separating out any components larger than 10 mm. Any large non decomposed organic material and most of the inorganic components were removed at this point. However, because of the mixed waste composting method used, the end product still contained a rather high proportion of inert contaminants, particularly small fragments of glass and plastic.

At the onset of this research project the Teshie/Nungua plant was just starting up their compost production after having been closed down for almost two years. They had suffered operational constraints and the windrows had been left for long periods of time, exposed to sun and rain, without being turned. When the production was reassumed compost was produced by simply sieving out the organic, decomposed fraction of the old windrows. The compost used for the on-farm trial and the vegetable growers' experiments was produced in this way. During this two-year period, potentially toxic elements (PTEs) from ferrous metals, batteries, plastics, various dyes etc. had plenty of time to contaminate the organic fraction of the waste and most of the nutrients present were likely to have been washed out or volatised through exposure to sun and rain. Furthermore, the windrows had been left to dry out and consequently caught fire during this time, causing organic matter and nutrient losses. In fact the material produced at this time was more akin to black soil than compost.

Whilst the composting operation was shut down the amount of both municipal waste and night soil delivered to the site remained unchanged. At the onset of the research, a daily 120 metric tonnes of solid waste collected from a 10 km radius was delivered to the site. At the time, this represented 20 percent of all waste collected in the Accra Metropolitan Area (i.e. 600 t/day). During the year 2000, once C&CW had taken over the contract for waste collection in Accra and vastly increased the amount of solid waste collected across the city, the amount of waste taken to the Teshie/Nungua site increased by 60 percent, to 200 metric tonnes per day, representing 16 percent of total collection (1200 tonnes/day).

When the waste treatment plant was designed, a land area for disposal of the inorganic fraction of the waste was allocated. A large, unlined trench was dug for this purpose when the site was built in 1979. Considering that the composting plant has always been operated below its capacity[29] and has been closed down for extended periods of time, yet the waste collection and delivery to the site has carried on regardless, the dumpsite was overflowing with waste even before the increase in waste volumes. To make matters worse, the ancient diggers and front loaders used to move the waste tended to be either broken down or out of fuel. Waste arrived at a much faster rate than the site staff were able to shift it. Many of the drivers of the waste collection trucks operated by the private companies sub-contracted to collect waste, resorted to dumping the waste outside the gates to the site, or simply disposing of their loads elsewhere.

The river running in a hollow alongside the edge of the site is in a vulnerable location in terms of receiving the leachate from the unlined rubbish dump, and as the dump has become overfull, the river itself has been used for dumping. Furthermore, the wastewater stabilisation ponds were not functioning properly (Marquis, pers. comm., June 2000) and the water discharging into the river was not clean enough to be safe for being emitted into a surface water body. The Teshie plant was an environmental disaster in the making, which is likely to cause serious problems in the future. Having been built

[29] On the days that they did sieve out any compost from the existing windrows they were running at a dramatically reduced rate at approximately 4-6 tonnes per day. Assuming an organic fraction of 30 percent and a volume reduction of 50 percent, then with a daily 200 metric tonnes received at the site and a sewage sludge to waste ration of 1:4, the demand level would be to compost 37t each day. The plant was designed to cope with that (Marquis, pers. comm., June 2000)

outside Accra on undeveloped land on the northern outskirts of Teshie back in 1979, it is now situated in the middle of a residential area. Sprawling housing settlements have been expanding in an unplanned manner and the site is now surrounded by houses. The environmental implications, both for people working at the site and for those living in the vicinity are considerable.

The compost that has been produced and the Teshie/Nungua plant over the years has mainly been utilised for landscaping, by AMA itself as well as hotels, embassies and the like, by large-scale fruit and vegetable producers, by private gardeners, and occasionally by various research projects. Marketing and project quality development has never been a major priority. The main objective of the operation has been waste treatment, with the assumption that there would be a market for the end product. Since the production has always been much lower than planned and designed for, the compost produced has had an outlet. However, obtaining payment for the compost has been a different matter. Much of the compost produced has been used internally by the AMA and pricing the compost to cover costs of production has not been possible. Marketing and quality controls to develop a viable market has not been given priority.

*Photo 4.1 Finished compost at the Teshie/Nongua plant*

**The James Town site**

In addition to the large-scale public composting plant at Teshie/Nungua, was a small-scale NGO/CBO run waste collection and composting operation. It was initiated and supervised by a local NGO, GROWTH Integrated Development Programmes, and executed and operated by a local CBO known as The Ashiedu Keteke Community Participation Project (AKCPP). The area they were operating in was on of the densely populated indigenous parts of central Accra known as James Town within the Ashiedu Keteke sub-District of central Accra.

The project was set up in response to a desire to clean up the streets within the community, thus the driving force was health and sanitation rather than composting. Initially it was set up as a waste collection service only whereby householders would pay a collection fee in return for daily door-to-door collection service. Any household that opted to participate in the scheme were given buckets in which to keep their household waste.

GROWTH secured the support and involvement by the AMA whereby they got access to land for a waste depot between the timber market and the Korle Lagoon in James Town, and the use of a container for the non recyclable waste fraction which would be emptied periodically for landfilling by the WMD. Initial funding was obtained from the German Government, through GTZ and Gopa which were the implementing partners in Germany's bilateral support of waste management in Accra. A small tractor and trailer for collection, suitable for navigating the narrow streets of James Town, and initial costs for salaries etc. was supplied from GTZ/Gopa. Later further funding was obtained from UNDP and another two tractors and trailers were purchased.

Not long into the project it was found that the WMD could not manage to keep up with the waste removal from the depot and as a result a local composting operation was set up in 1996.

The quality of waste that is collected from this low-income neighbourhood is not particularly good. Most of the nitrogen and moisture rich materials are removed at source and used for animal feed. When the composting operation was first set up the project tried to access high quality waste from one of the major markets in the locality. They talked to the Market Queen[30] and got agreement to collect waste from the market, but the AMA did not permit it.

The waste, made up of mixed household waste and street sweepings, which arrived at the site, was sorted and the organic fraction put into piles and capped with digested sewage sludge from the local sewage plant at Dogo, at a rate of 1:4. The piles were then turned regularly (supposed to be every three days). Once the material had decomposed it was left to mature for a period of five months, after which it was sieved in a hand turned drum. The compost was then sold either in 50 litre sacks or in bulk. In 1998 they produced 150 tonnes of compost.

---

[30] Market Queens (also called Queen Mothers or *ohemmas*) are traditional leaders who control the market trade associations. See Section 4.3.3.3 for more on this.

Following a successful start, the project has not been running entirely smoothly. At the time of the research they were going through a transition process of having had external funding and support to becoming self-sufficient. The motivation of the people involved was waning, rooted in a feeling of lack of ownership. There appeared to be a number of reasons for this, some of which relate to technical constrains, others of a more managerial and socio/cultural nature. Project management and the waste collection side of the operation was done by indigenous Ga people, whilst the waste separation and composting activities were done by hired in migrant labourers from the north of the country. There were undertones of mistrust and jealousy with affected the project.

One important reason for the lack of motivation was that the compost marketing side had never been prioritised leading to a situation of excess production in relation to sales. The business model of the project was set up for the waste collection activities, covering their costs through household waste collection fees, whilst the operating costs for the composting should be covered through compost sales. Hire of land and capital investment was not taken into account as these were subsidised, and, according to the coordinator of GROWTH, would need to be so for the model to be viable (Klaassen, pers. comm., June 2000). Providing the organic fraction of the collected waste is converted to compost and the compost is sold, the costs should be covered. However, although there was demand for the compost, mainly from the expatriate community for gardening and landscaping, sales had been insufficient. The composting site is tucked away in a densely populated part of the city from where it is problematic to market the compost, partly because it is difficult for people to find, partly because some people are reluctant to visit that part of town.

Production tended to be intermittent, consumers never knew if they would be able to get any compost if they did go through the trouble of going to the site and this further constrained the potential for sales. At the time of the research the business suffered also from the site being overfilled with non-recyclable waste. The container that the WMD, and later T&CW had undertaken to periodically empty was overflowing and waste was beginning to crown the whole depot. They have also suffered from security problems at the site. The depot is unfenced and tends to be used at night, and some of the waste piles have been fired. During the period that this research was done, compost production was suspended. The staff felt that they did not want to work unless the site was cleaned up and they could sell the compost. The composting enterprise clearly suffered from a ‘chicken and egg’ situation with regards to the production and sales relationship. Since my own research ended the project decided to cease compost production. The waste collection and recycling of the more profitable non-organic wastes are continuing (Klaassen, pers. comm., August 2001)

*Photo 4.2 Sieving drum at the James Town plant*

## 4.3 Urban Agriculture

### *4.3.1 Introduction*

This section provides a descriptive overview of urban and peri-urban agriculture in Accra. It examines the types of agriculture commonly found, the soil fertility management practices employed, the people who are involved in agricultural activities and their access to resources such as land, water and extension support. The importance of urban agriculture is examined in relation to other occupational activities, income generation and food security both on a city and household level.

The information presented in this section are based on:

- The findings from a Baseline survey carried out Aug/Sept 1999
- Close work with vegetable growers throughout the fieldwork period (1999-2001)
- Interviews with market women (Autumn 2000)
- Interviews with poultry farmers and poultry farmers associations (Summer 2000)
- Direct observation
- Secondary data

This section is in two parts. The first part presents a general overview of UA in GAMA and draws, to a large extent, on secondary data. The overview is followed by a more detailed report on selected aspects of UA and vegetable marketing, based on findings from empirical work carried out as part of this research, in particular the baseline survey. The focus of the work is placed on cropping, and in particular the situation of the commercial small-scale urban vegetable producers, as this was the type of farmers that the research focussed on following the initial baseline survey.

### *4.3.2 General Overview*

**Importance of UA**

As in most cities of developing countries a variety of agricultural activities are present in the urban and peri-urban parts of Accra. Both livestock-keeping and cropping are widespread and at the time of this research intensive commercial vegetable production was on the increase. Various studies of urban agriculture (Cencosad, 1994; Armar-Klemesu & Maxwell, 1998; Obosu-Mensah, 1999; Obuobie, 2003), and related topics such as food supply and distribution (Argenti, 1996), urban poverty (Norton 1995), urban environmental deterioration and human health (Benneh *et al*., 1993), and land rights (Kasanga *et al*., 1995; Flynn-Dapaah, 2001) have been undertaken in Accra in the past. Studies to ascertain the importance of UA for food nutrition, income generation and livelihood security within the urban economy are, however, limited. The most comprehensive study of this nature was carried out during 1997 by the Noguchi Memorial Institute for Medical Research with funding form IDRC (Armar-Klemesu & Maxwell, 1998). It was undertaken as part of a larger study of urban (food) nutrition in Accra in collaboration with the International Food Policy Research Institute of Washington DC. The findings of this study were important in informing this research. The Noguchi study was based on a survey of 559 households in 16 enumeration areas of Greater Accra and subsequent farmer case studies and group interviews. This study found that just under 14 percent of 559 households surveyed were engaged in some form of agriculture in the immediate urban and peri-urban area of Accra, (excluding fishing) (Zakariah *et.al.,* 1998) (and that the importance of this in terms of household food nutrition or food provision on the city level was relatively unimportant). According to the Ghana Living Standards Survey (2000) the proportion of urban dwellers engaged in agricultural activities is higher. "*Although farming and keeping of livestock is predominately a rural activity, a significant number of urban households reported that the own or operate a farm or keep livestock; around a third (32%) in urban areas have some involvement in agricultural activities*" (GSS, 2000b:53) However, this figure is an average for urban dwellers throughout Ghana as opposed to Accra specifically. Furthermore, it does not distinguish between agricultural activities practised within the urban area and those on a family farm in the rural hinterland. It is not uncommon for people who have migrated to the cities to retain some degree of stake or active involvement in the farming activities of their rural village.

On a household level, engaging in agricultural activities provides access to food, cash income and, in the case of livestock, a strategy for asset accumulation. With the exception of commercial poultry production and possibly the cultivation of traditional leaf greens at certain times of the year, it is unlikely that agricultural produce from within the urban Accra contributes to any significant extent to the overall food consumption of the city.

The Noguchi study (Zakariah *et.al.,* 1998) found that, in contrast to many other African cities, UA in Accra is not particularly integrated into other livelihood strategies. For example, farmers rarely process and/or market their own produce. Spouses seldom work together to integrate the farming and marketing activities through street food vending and petty trade. This research supports these findings. Whilst agricultural activities are common across GAMA, it appears that there is untapped potential in terms of enhancing its impact of livelihood security.

**Types of UA farming systems**

Farming takes many forms in GAMA and a wide range of plant- and animal-based agricultural activities exists. This range from large scale poultry production, through to snail rearing and from rainfed staple crop production to specialised exotic vegetable and flower production. Whilst not impossible to provide precise farming system classifications, these would be complex and fragmented and as such of limited value. However, some general typologies can be identified based on common practices. Box 4.3 below outlines the farming systems classification used in the Noguchi study.

*Box 4.3 Seven farming groups identified in the Noguchi study*

1. *Seasonal crop farming* – rainfed, seasonal agriculture, relying on informal land access, with produce mainly for home consumption.
2. *Customary land rights systems* - rainfed agriculture with some dry-season irrigation, on La stool land between Labadi and Teshie, practiced by La residents for both market and home consumption.
3. *Vegetable growing* – irrigated market oriented production of vegetables, relying on informal land access, usually along main drains and streams in Accra.
4. *Small ruminants and poultry* – raising of small livestock in densely populated areas, sometimes with market orientation, but more frequently as an investment or asset strategy.
5. *Backyard gardening* – small-scale gardening on own land or on rented compound, usually for home consumption.
6. *Commercial livestock* – usually poultry, with few examples of pigs, raised on medium to large scale for sale to urban market.
7. *Miscellaneous* – export crop production, micro-livestock, snail farming, bee-keeping, large ruminants etc.

*Source: Armar-Klemesu & Maxwell, 1998*

Drawing on the Noguchi work, five farming system categories with some distinguishing characteristics and commonalities were identified for the purpose of this research, as outlined below[31].

**Irrigated vegetable growing** – carried out at different scales in both urban and peri-urban locations where there is a water source nearby. It is a commercial activity characterised by intensive, continuous cultivation of crops such as lettuce, cabbage, pepper, spring onion, onion, cauliflower, cucumber, and traditional soup greens such as jute amaranths and selenium. Very little of the produce is kept for home consumption. Peri-urban vegetable growing tends to be located near rivers with access to irrigation. Urban vegetable growing is on a smaller scale on 'spare' land near wastewater drains. Land in the peri-urban areas is typically rented or share cropped, whilst in the urban areas the (small scale vegetable) production is carried out on land under informal arrangements, usually without any payment. Growers involved in vegetable production derive much of their income from this activity and, whilst many have other jobs, for some it is their sole occupation. Of the different urban cropping activities commercial vegetable growing is the most common. This group of farmers is dominated by men, many of whom are relatively young in comparison with farmers involved in growing more traditional crops. All ethnic groups are represented.

**Seasonal farming** – rainfed agriculture, primarily in peri-urban areas, although small patches of land are also used for this activity within the city itself. Traditional staple crops such as maize, tubers, beans and groundnut and traditional vegetable crops notably, tomatoes, okra, garden egg and pepper are most commonly grown, sometimes in various intercrop arrangements. The produce is mainly used for home consumption with some surplus being sold. Land use is primarily informal, however rented or owned land does exist in the outer-lying peri-urban areas. The farm size is typically 3 acres (1.21 ha). Many of these farmers have other occupations, typically in the civil service, and do not derive their main income from farming. Most of these farmers are men, many are migrants from northern Ghana and the Sahel.

**Mixed farming** – farming with some land allocated for irrigated vegetable production and some for seasonal rainfed production of traditional crops such as maize, tubers and okra. Livestock keeping is also a common element in this farming category. This kind of farming system is found in peri-urban areas and in one location within urban Accra, namely the La stool land in eastern Accra. This is a large area (in excess of 400 ha) of undeveloped land under traditional Ga chieftaincy and subject to customary land rights. Like the seasonal framers, these farmers tend to farm areas of around 3 acres and the land is either customary owned or rented (see section on land access below). For most farmers in this category farming is their sole occupation and the main household income is derived from it. There is a clear difference between irrigated vegetables and rainfed staple crops, with the majority of vegetables sold whilst the staple crops are kept

[31] The sample in the baseline survey was made up of 112 farmers. For analytic purposes a more detailed typology was considered inappropriate.

for home consumption. There are more women in this group than in the previous categories but men still dominate. Within this group of farmers it is not unusual for men and women to share the farming activities and work together.

**Livestock keeping** – at different scales of operation is common in and around Accra. Non-commercial rearing of a small number of chickens, ducks, goats or sheep is common throughout the city and especially in low-income migrant communities (Zakariah *et.al.,* 1998) In the middle/high income, lower-density areas livestock keeping is typically combined with cropping in a backyard gardening system, whilst in the low-income, high-density neighbourhoods livestock keeping is the only farming activity. For the non-commercial livestock keeper the livestock provides supplementary food, income and, importantly a form of asset which can be turned into cash should the need arise (*ibid.*). This type of livestock-keeping is carried out by both men and women, but women dominate. Most have other jobs.

Commercial livestock keeping is primarily concentrated on poultry and pigs, mainly in the middle/high income communities, and mainly on the outskirts of the city. However, some smaller scale commercial poultry keeping is located within Accra and in lower-income neighbourhoods pigs and even small ruminants are raised commercially (Zakariah *et.al.,* 1998), in spite of by-laws in place to control and limit the practice within the city. Commercial livestock keeping is primarily carried out by men, and all ethnic groups are represented. It is common for commercial livestock farmers to hire labour. It is noteworthy that cattle and milk production is not an important activity in Accra

**Backyard gardening** – small scale cropping and livestock keeping in back gardens or on land adjacent to the dwelling, which may be owned or informally used. The farmers are normally the owners or tenants of the homes. Both staple crops and vegetables are grown and they may be rainfed or irrigated. Fruit trees such as citrus and mango are also common as are plantain and banana. The production is generally non-commercial with the vast majority of produce kept for home consumption. Backyard gardeners tend to be in the middle class sector of society, with income from non-agricultural activities. The poorer fraction of the urban population do not tend to have any land for backyard gardening; however, livestock-keeping does exist in the poorer, densely populated communities. Both men and women are involved in this type and it is common for the whole family to be involved.

**Access to resources**

**Access to Land -** GAMA consists of a mixture of public, private and customary (stool) land. With the exception of most backyard gardeners and commercial livestock producers, the vast majority of urban and peri-urban farmers rely on informal access to land. It may be in the form of customary land tenure as is common in the peri-urban areas and in La. Non-customary land tends to be owned by the national government, municipal authority or private individuals. Those who farm under non-customary land arrangements in the peri-urban areas, tend to either opportunistically farm government land without paying a fee, or have been given permission, or have some form of informal rental arrangement with the landowner. Rents are usually in the form of sharecropping, but some degree of cash rental also exists. In urban areas, by contrast, a fee is almost never paid for access to land. Whether farmers farm with or without permission, land access is almost always insecure and farmers may be moved on, sometimes without any notice given, as land is put to other uses (Zakariah *et al.,* 1998). While land remains undeveloped, landowners are happy for the land to be cultivated as it keeps it clean and free from weeds as well as prevents it being squatted or used for rubbish dumping (Obuobie *et al*., 2003).

Which type of land people utilises has implications for what they grow and the way they manage their cropping system. Cultivation is broadly practised on three different kinds of land:

1. Land that has long been under agricultural production and which has not (yet) been put under urban development. This kind of land is mainly present in the peri-urban areas, but does also exist in clearly urban areas (notably La stool land). This kind of land is typically informally rented, share cropped or farmed under customary access/tenure arrangements.
2. Small patches of public and privately owned land which is opportunistically farmed, typically along rivers and drains, under power lines, on undeveloped building plots, on institutional land around public institutions etc. This land is mainly in densely urban areas, but also in the interface between the urban and peri-urban. It is typically informally used without any payment for rent and often without permission.
3. Backyard gardening on land which belongs to a property or which is immediately adjacent to a property, such as the road verge just in front of a house. This land tends to be either owned or informally used.

**Access to Water -** With the bimodal rainfall pattern in Accra water is in short supply for large parts of the year. Access to water resources is of critical importance to farmers and a determining factor in the type of farming activity that can be engaged in. Those with access to low-cost water are able to grow vegetables during the dry season, thus maximising commercial viability. In the urban areas vegetable growers use either drain water, streams, pipe borne water or hand-dug wells. In the peri-urban areas stream water is the most common source and vegetable production is primarily located along rivers and streams. Backyard gardeners rely mainly on pipe-borne water and grey water from the household. Pipe-borne water is recognised as being of higher quality and the use of waste water is discouraged. However, for most small-scale urban vegetable growers it is unaffordable and the majority rely heavily on polluted surface water for irrigation. As such, vegetable production is located close to surface water sources where watering cans are used to fetch water on a first come, first served basis. The rivers and open drains flowing through Accra receive both industrial and domestic effluents and contain pollutants of different kinds including heavy metals and faecal contaminants. There is considerable concern about the practice of wastewater irrigation in Accra, especially in relation to the potential threat to consumer health. In response to these concerns, the AMA has enacted a by-law to restrict the use of drain water for food crop irrigation. However, resources are lacking to enforce the by-law and the use of wastewater irrigation remains widespread and unregulated. The marketing survey carried out as part of this research (2000) revealed that sometimes market women were reluctant to admit to selling produce from Accra because of consumers' concerns with regards to wastewater irrigation.

**Access to Extension Services -** The political climate and legal framework in Accra is generally favourable for UA. However, UA is recognised more in terms of needing regulation than for its importance for food provision. This is particularly the case for animal husbandry, which raises more concern than plant cultivation does. Within professional agricultural circles it is not perceived as 'proper' farming, but rather referred to as gardening. This is for example reflected in the fact that urban farmers do not have access to credit. Nevertheless, UA receives official recognition and both policy and plans have been put in place to develop local capacity for public support and management of various UA activities. The District Agricultural Development Unit under the AMA has identified the most common agricultural activities and offers extension service to urban farmers and fishermen. Within Accra there are 50 Agricultural Extension Agents (AEAs) whose role it is to offer support to farmers in the form of teaching, demonstration and over-seeing to the implementation of new scientific and technological agricultural, veterinary and fisheries practices (Sackey, 1998). The agricultural extension service follows the transfer of technology (ToT) model whereby new, improved technologies developed by research are adapted by Subject Matter Specialists (SMS) before being disseminated to farmers by the AEAs. The AEAs are expected to inform the SMSs about farmers' problems, and the SMS to pass these back to the research institutions (Ministry of Food and Agriculture, 1999). Whilst all the vegetable producing areas within Accra are covered by an AEA, it appears that the extent and quality of the assistance given to farmers is variable, and frequently deficient. During the course of this research, with the exception of one area, the extension agents were never seen nor reported to have visited the farmers. In a baseline study on vegetable production in Ghana, Nurah (1999:82) points out that "*it is generally known and agreed by extension officers that extension in Ghana gives very little advice on vegetable production*".

Farmer to farmer exchange of ideas and knowledge appears to represent farmers' most important source of information and technical advice. They also gain technical advice from sellers of seed and chemicals.

During the late 1990s Farmer Field Schools (FFS) were introduced and piloted as a farmer education initiative that complements the ToT extension system, in a few selected areas within Accra. Initially used exclusively to tackle IPM (integrated pest management), the FFSs have broadened their focus to include soil fertility management and the management of the whole farming system. The initiative has been externally funded (FAO). It was implemented in conjunction with the extension service, but it so far has not been adopted as part of the mainstream farmer education and extension provision.

A number of farming associations exists in the city including a Vegetable Growers Association, a Commercial Poultry Farmers Association and the La Farmers Association which operated in the Labadi area.

### *4.3.3 Selected findings from the Baseline Survey*

This section presents selected findings from the baseline survey. It also draws on interviews with vegetable produce marketers, poultry farmers, poultry farmers associations, and on information gained from the urban vegetable growers during the course of the experimental research period. The objectives of the baseline survey were to gain an understanding of:

- ongoing farming activities in Accra, with particular focus on cropping
- current soil fertility management strategies employed by farmers.

Two considerations guided the sampling procedure:

1. To ensure that all the farming types engaged in cropping activities identified in the Noguchi study were represented in the sample (see Table 4.4).
2. To ensure a good geographical spread from the heart of the city centre through to peri-urban villages with many rural characteristics.

In total 112 farmers (of which only 14 were women) in 11 different areas were interviewed during August/September 1999. (See Table 4.5, Figure 4.6 and Figure 4.7 for information about the location and classification of the farmers interviewed). The research team consisted of the researcher and two Ghanaian assistants form the University of Ghana, Legon. All the researchers had previous experience of social surveys and interviews. One of the assistants was particularly familiar with the area researched, as she had been the main research assistant in the Noguchi study. All three surveyors were female.

*Table 4.4 Spread of respondents in accordance with the Noguchi-study classification*

| **Farming type** | **No of farmers interviewed** |
|---|---|
| Seasonal crop farming | 33 |
| Customary land rights systems | 24 |
| Vegetable growers | 46 |
| Backyard gardening | 13 |
| Small ruminants and poultry | 51 |
| Commercial livestock | 5 |

*Note: Many farmers fell into several of these farming types. For example, small ruminants and poultry were always combined with some kind of cropping activity.*

*Source: This research*

*Table 4.5 Geographical spread of respondents*

| **Very Urban** | **Intermediate** | | **Peri-urban** | |
|---|---|---|---|---|
| Marine Drive[1] | La[3] | | Pokuase[2] | |
| Korle Bu[1] | Legon: | University area[2] | Abokabi[2] | |
| Dzorwulu[1] | | Anomele[2] | North Legon: | Atomic Energy[3] |
| James Town (Mudor)[4] | | Kisseman[2] | | Agbogba[3] |
| Golden Tulip[1] | | | | |
| Abose Okai[2] | | | | |

1 = Exclusively commercial vegetable growing, 2 = Predominately seasonal farming,

3 = Predominately mixed irrigated vegetables and seasonal farming, 4 = Exclusively pig rearing

*Source: This research*

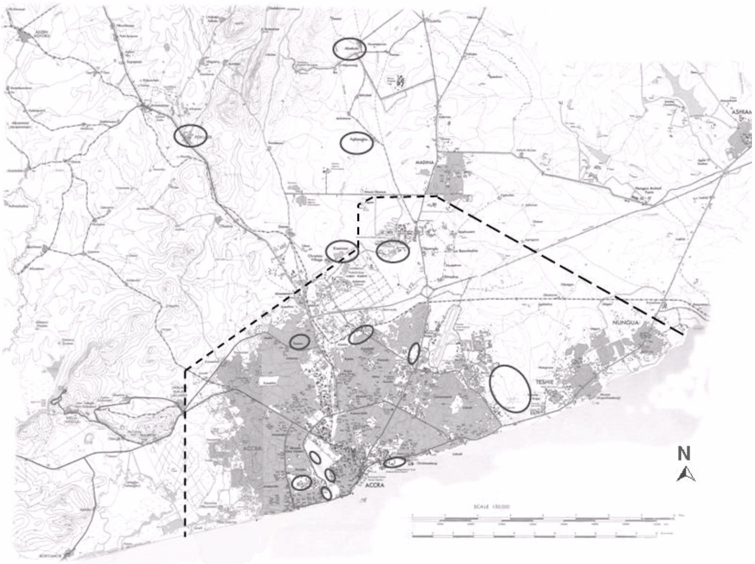



*Figure 4.6 Location of the areas included in the survey and the two composting sites in Accra[32]*

*Source: Adapted from survey map of Ghana, The Survey Department, Ministry of Lands and Mineral Resources of Ghana.*

[32] At this stage of the research the study focussed on GAMA. Four sites outside AMA itself were included in the baseline survey to explore the peri-urban farming systems as well as the more urban ones.

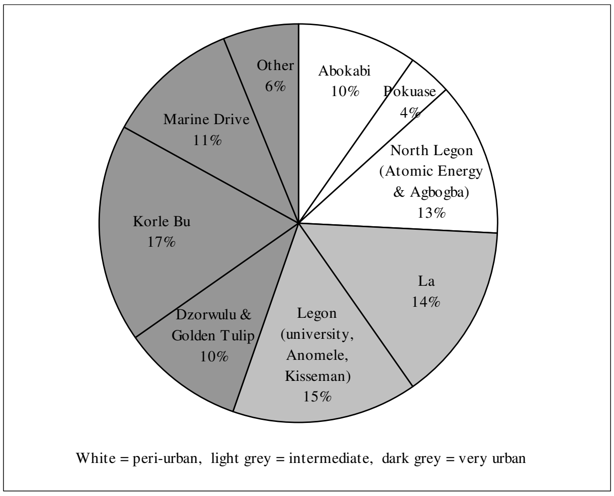



*Figure 4.7 Proportion on farmers interviewed in each location, (n=112)*

*Source: This research*

The interviews were carried out on an individual basis, usually on the farmer's land. Farmers were selected while walking along a transect across the farming areas. In two areas (La and Abokabi) prior arrangements were made whereby several farmers met with the members of the research team at a pre-arranged time and place.

A survey questionnaire was pre-tested (see Appendix A); in the final version the questions were grouped into the following categories:

- Personal details (name, age, gender, education)
- Occupation (primary, secondary and tertiary income sources, main household income source)
- Family details (size of household, household members' occupation)
- Land access (owned, rented, informally used, squatted)
- Land size
- Land use (crops grown, cropping patterns)
- Livestock (type, number)
- Marketing (extent of, where, how, transport)
- Soil fertility (fertiliser, organic inputs, cultivation methods, transport of inputs)
- Compost awareness and use (general knowledge of it, knowledge of the existence of municipal compost, ever used or considered using urban waste)

Farmers' responses were recorded and entered into a Microsoft Excel database for analysis. For analytic purposes the farming systems were classified into five groups as described above in Section 4.3.2. These were broadly similar to the classification used in the Noguchi study, but as the sample was only made up of

112 farmers, a more detailed break-up seemed inappropriate. In Figure 4.8 the proportion of farmers interviewed in the different categories is given.

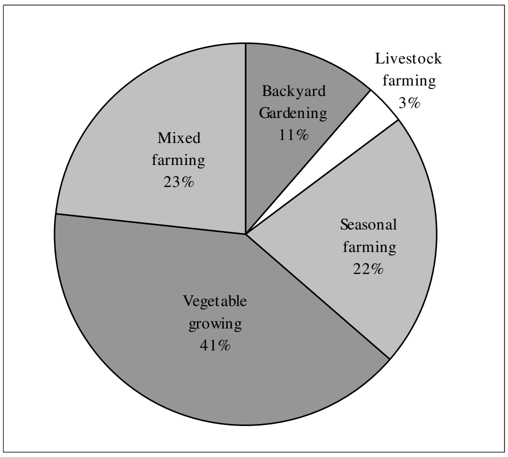


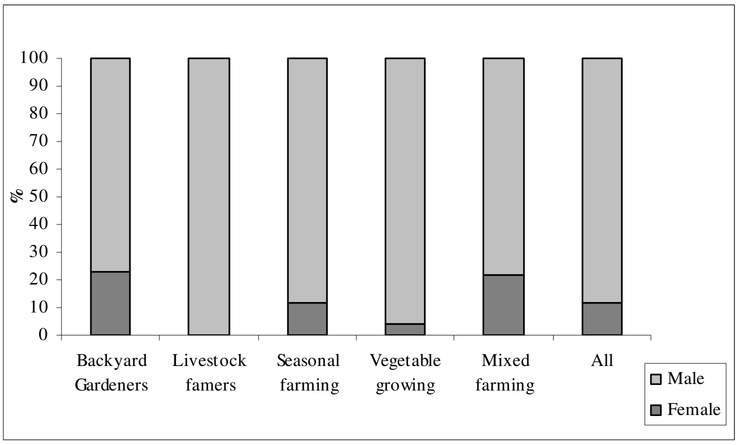

*Figure 4.8 Proportion of farmers in the different farm type categories, (n = 112)*

*Source: This thesis*

### *4.3.4 Study Findings*

#### *4.3.4.1 Characteristics of the farmers*

The average age of all farmers interviewed was 43 years. Differences were found in the age of farmers engaged in different types of farming activities, with commercial vegetable growers clearly younger (average 34 years) than seasonal farmers (54 years). The age of the 14 women interviewed was slightly higher (47 years) than that of the men (42 years). Whilst many studies of urban agriculture have highlighted the dominant role that women play in urban food production, this seems not to be the case in Accra. This study, along with others (e.g. Armar-Klemesu & Maxwell, 1998; Obosu-Mensah, 1999) found that the vast majority of urban and peri-urban farmers in Accra are men. This is particularly the case for intensive vegetable production, which is the most common form of urban agricultural activity. Out of all the farmers interviewed, 87.5 percent were men. Of the vegetable growers as many as 95 percent were men. Most of the farmers (79%) reported themselves to be the heads of households, (64% of the women).

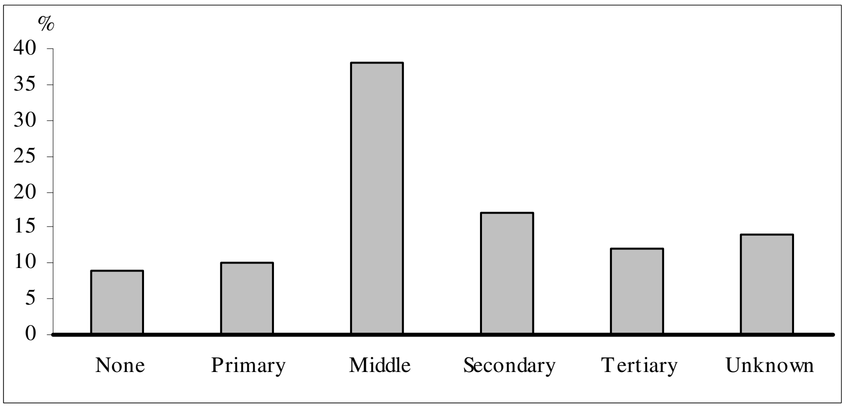



*Note: there are 115 respondents in this graph. This is because three of the backyard gardeners also farmed other land, thus are represented in two categories.*

*Graph 4.1 Proportion of men and women interviewed, (n=115)*

*Source: This research, baseline survey*

The level of education varied greatly. People with all different education levels were involved in urban agriculture. Most farmers had middle school education, but some had tertiary education whilst some did not have any formal education. There were no clear correlations between education level and age, gender or type of farming activity. People with tertiary education level were less dependent on farming for income than the other groups. 45 percent of people with tertiary education reported to have farming as their primary occupation, compared with 67 – 83 percent for the other education levels.




*Graph 4.2 Education level*

*Source: This research, baseline survey*

Some had farmed for many years. However, there was great variation ranging from as long as 60 years to 4 months. 57 percent had farmed for more than 10 years. Again there were clear differences between farmers engaged in different types of farming. Commercial vegetable growers and backyard gardeners had been farming the shortest with and average of 11 and 9 years respectively. 26 percent of the vegetable growers had been farming for more than 15 years. 61 percent of seasonal farmers and 44 percent of farmers in the mixed farming category had farmed for that length of time. On average seasonal farmers had been active for 21 years, almost twice as long as the vegetable growers had.

The majority of farmers interviewed had access to some form of irrigation. However, 38 percent of the farmers relied entirely on rainfall. These farmers were mainly in the peri-urban or intermediate areas. The urban vegetable farmers used water from the storm drains and the Odaw River to irrigate their vegetables, which enables them to crop all year round and make a living out of very small plots of land. Some farmers (19 %) reported to have a mix of irrigated and rainfed land. They would typically grow vegetables for the market on the irrigated land next to a drain or river and grow maize, tubers or okra on the rest.

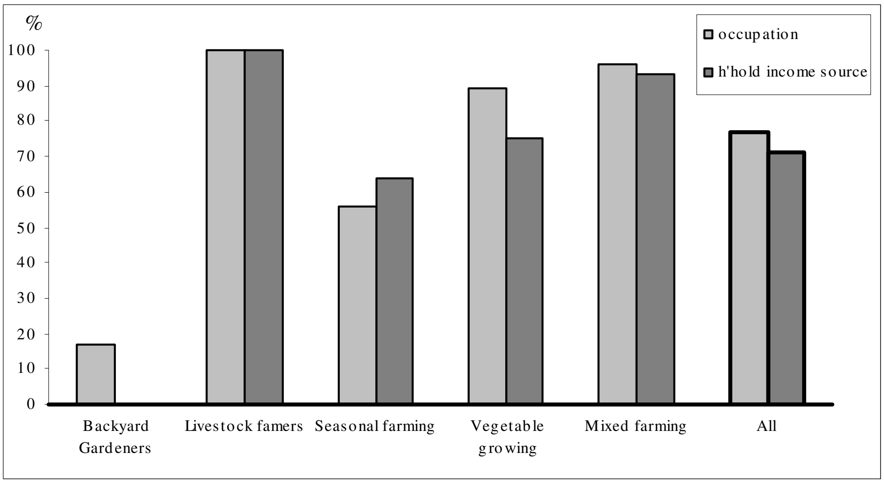
**Importance of farming**

Farming was the primary occupation of the majority of people interviewed. Overall 77 percent of interviewees reported that farming was their primary income source and 71 percent that it provided the primary income source for their household. Some had secondary occupations but for many farming was their sole occupation. Farming tended to be the primary occupation for vegetable growers (89%), farmers in the mixed farming category (96%) and for commercial livestock farmers (100%). Livestock farmers and mixed farmers also reported that farming was the main income source for their household (Figure 6). This was not the case for vegetable farmers, which can be explained by the fact that a higher proportion of these farmers were not heads of household (65% compared with 79% for the overall sample). Backyard gardeners in particular, but also many of the seasonal farmers (44%) had other occupations from where they derived the main household income.

*Table 4.6 Importance of farming*

| | Proportion of respondents with farming as: | |
|---|---|---|
| | Primary occupation | Sole occupation |
| All | 77 % | 45 % |
| Vegetable growing | 89 % | 54 % |
| Seasonal farming | 56 % | 28 % |
| Mixed farming | 96 % | 56 % |
| Backyard gardening | 17 % | 0 |
| Commercial livestock farming | 100 % | 50 % |

*Source: This research, baseline survey*




*Graph 4.3 Proportion of farmers with farming as primary occupation and household income source*

*Source: This research, baseline survey*

The importance of farming to household income was also explored with the small-scale urban vegetable growers during the course of the research. In Marine Drive 63 percent of growers were farming full time. The proportion of full time farmers in Dzorwulu was higher at 90 percent, whilst in Korle Bu the reverse was true. The majority of the people farming within the Korle Bu Hospital compound were labourers at the hospital and only 10 percent did not have any other job. These growers had night-work, which enabled them to farm during the day[33].

During meetings in two of the vegetable growing areas (Marine Drive and Dzorwulu) farmers were asked to estimate the proportion of their overall household income that came from farming, in relation to other work they did and the income brought in by other household members. This was done with the aid of a PRA exercise, which involved 40 farmers in total. For 21 percent of growers in Marine Drive and 17.5 percent in Dzorwulu farming provided the sole income source for the whole household.

**Urban vegetable growers' reasons for farming**

During the course of the research discussions were held, accompanied with a PRA exercise, with vegetable growers in the three experimental sites, to gain an insight into people's reasons for farming. A number of themes emerged from this. Many talked about a sense of enhanced control of their life through the vegetable

[33] A word of caution about the respresentativeness of this information is however, worth noting: many farmers who had day-jobs would not have attended meetings when these issues were explored, thus introducing potential bias, with a higher importance being attributed to farming than is perhaps the reality.

production. Many growers (53 % of the vegetable growers interviewed[34]) did not have any other jobs. For them the reason for farming was clear cut as they did not have any alternatives and it provided their sole income and, for some (15 %) even the sole household income. Other growers with farming as their sole occupation had positively chosen this and talked of the freedom to do your own thing as a major benefit and reason for farming. They felt that providing it was done well, farming pays better than a government job. Whilst many of the farmers had other jobs the role of vegetable production and sale as a supplement to their income was of prime importance. Those on a government minimum wage struggled to make ends meet and found that the steady trickle of income from farming made a big difference in surviving between the monthly salary payments. Some of the younger men farmed in order to pay their school fees and be able to carry on with their education. On the other end of the age spectrum were the retired who farmed for something to do as well as to supplement the household income.

Surprisingly few farmers spoke of the role of farming in supplementing household food needs or enhancing the family's nutrition. In fact, it was not unusual that crops that had not been sold were not taken home but rather left to waste on the beds. Within the three experimental sites, this was particularly the case in Marine Drive. By contrast, farmers in Korle Bu grew a higher proportion of indigenous crops and they did talk about the value of having access to food.

Some of those who came from a farming tradition said that they farmed because it was what their family had always done and it was what they knew. One farmer said that the growing of food is a necessary activity fundamental to the maintenance of life and that as such farming gave him a sense of pride. He said that "*if you farm people bless you*" (Abass, pers. comm., 2000). This sense of job satisfaction was common amongst the farmers and many indicated a sense of enjoyment from farming.

Another kind of enjoyment came from just spending time in the gardens. One farmer, who worked as a night guard, said that it gives him something to do during the day when he is not at work. A similar sentiment was echoed by many of the farmers. The farmers in Korle Bu frequently got together in groups to play board games when not working on their plots. Some of the younger farmers in Dzorwulu had allocated an area near their plots where they got together to listen to music and lift weights. For those farmers that did not rush down to their plots at 5 am to water their plants before going to work in the morning, spending time in their gardens was not just work, but also associated with a certain amount of recreation, social interaction and relaxation. Over the time spent in the vegetable growing areas, the sense of community spirit and friendship amongst the farmers was noticeable, perhaps more in Dzorwulu and Korle Bu, than in Marine Drive.

---

[34] Again, the growers who had other jobs may not have been able to attend the focus group discussions which would have influenced the sample and thus the results. In Korle Bu, since the majority of growers had night jobs they were present during the day.

The aesthetic value of the garden areas was noted by some of the farmers. A view expressed was that whereas an area of wasteland would be used for rubbish dumping and could attract criminal elements, by turning it into vegetable gardens it not only provided an income generating opportunity for people, but also served to beautify the city.

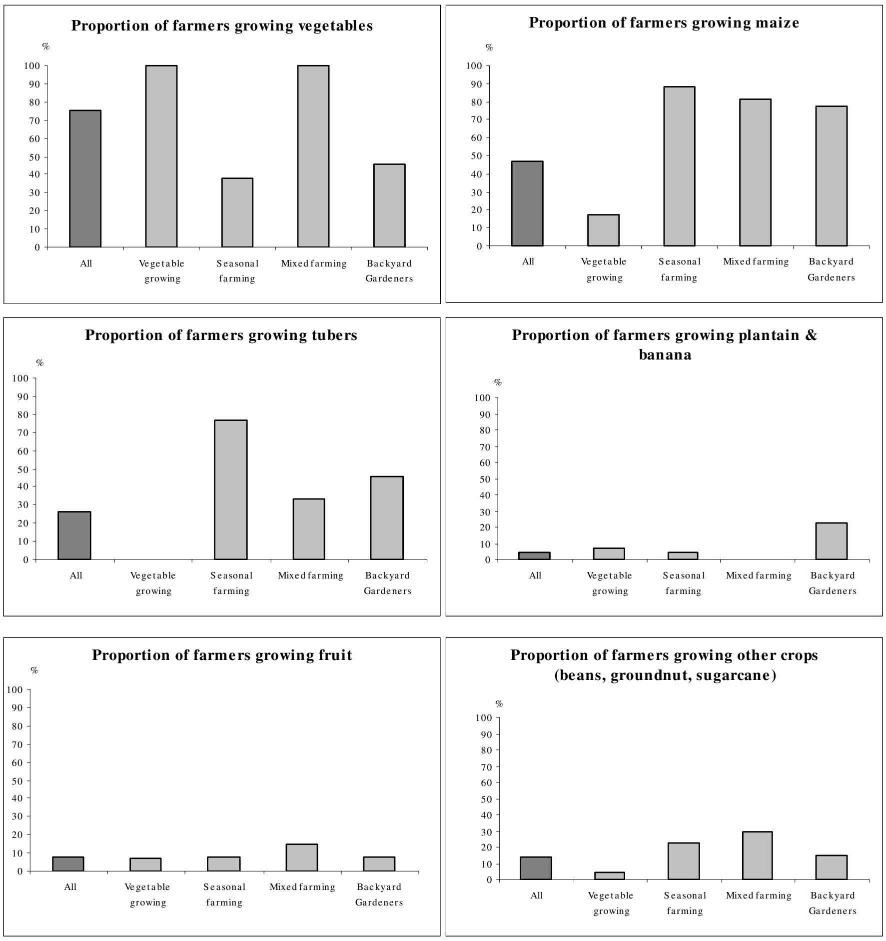
### *4.3.4.2 Characteristics of the farming systems*

**Crops grown**

Vegetable production was a very common cropping activity with 79 percent of all respondents reporting the growing of vegetables (Graph 4.4a); 38 percent of farmers interviewed grew exclusively vegetables. A whole range of traditional and exotic vegetable crops were grown. The most widely grown 'traditional' crops were tomatoes, sweet pepper, okra, garden egg (eggplant), onion and various green leaf vegetables, such as jute (ayoyo), solanum (bouma) and amaranthus. Common exotic crops included lettuce, cabbage, cucumber, carrots and cauliflower. Maize was the second most common crop (grown by 56% of farmers), followed by tubers, mainly cassava (31%), but also yam and sweet potato (Graphs 4.4b&c).

It was very common to grow several types of crops. For example, only 27 percent of the farmers who grew maize did not also grow vegetables. Of the tuber growing farmers, 63 percent grew vegetables and almost all also grew maize (94%). It was uncommon for farmers to grow exclusively maize or tubers; only 6 and 2 farmers respectively did so. These were farmers who cultivated land with no access to water for irrigation and who did not make a living out of farming. Only a few reported growing plantain, banana, fruits or other field crops such as beans, groundnuts and sugarcane.

Intercropping was relatively uncommon. However, some examples of sequential sowing and intercropping were encountered. These were beans intercropped with okra or pepper and vegetable crops such as pepper and lettuce, cabbage and lettuce, and cabbage and onion grown together on the same beds.



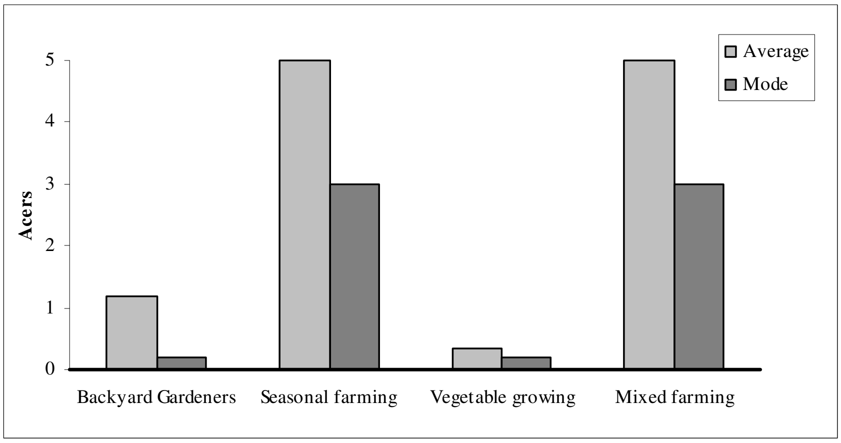

*Graphs 4.4 a-f Proportion of farmers in the different farming categories and the total sample growing different crops, (%) (n = 108)*

*Source: This research, baseline survey*

## Land size and access

There were large variations in the amount of land people farmed, ranging from 0.02 to 25 acres (0.008 – 10.12 ha), with an average of 3.7 acres (1.5 ha). Half the farmers (53%) farmed less than one acre. Seasonal and mixed farmers had substantially larger land areas (mode of 3 acres/1.21 ha) at their disposal than did vegetable growers and backyard gardeners (mode of 0.2 acre). Intensive vegetable growers in the built-up urban areas operated on the smallest land areas. It was unusual for these growers to know how much land they cropped; they most frequently gave an estimate or the number of beds they had. The number of beds ranged between 6 and 45 with an average of 24 beds. A bed would typically be 1.5 by 8 metres, although considerable variation existed beyond this range. Even though the vegetable growers had very little land, a high proportion of them had farming as their primary occupation (89%) and main household income source

(75%). Vegetable growing is done intensively and there is generally a good market for the produce, although farmers would complain that they sometimes faced problems selling the crops when they were ready for harvest and that it was not uncommon for whole beds to go to waste.




*Graph 4.5 Average and modal land size farmed by people in the different farming categories, (n = 108)*

*Source: This research, baseline survey*

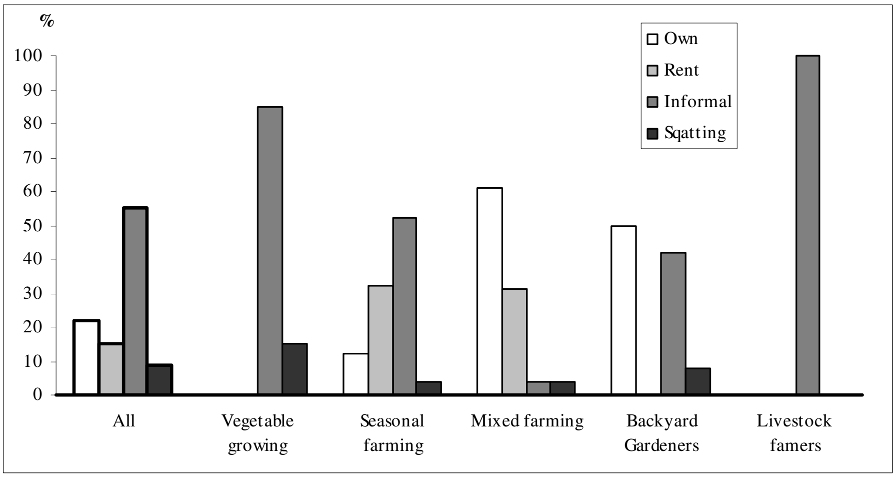
Informal land use was by far the most common (55%), particularly amongst the urban vegetable growers where 85 percent relied on informal land use and the remaining 15 percent reported that they were squatting. This uncertain lend tenure also accounts for the fact that people were unable to say how much land they farmed. People who owned or rented always knew how much land they had. All four commercial livestock farmers interviewed housed their animals on land which was informally used. However, with only four farmers interviewed it is not possible to say whether or not this is a representative picture.

Twenty-two percent of the farmers interviewed reported that they owned the land they farmed; these farmers were mainly found in the mixed farming and backyard gardening categories. La was the area where people had the most secure land rights. Here as many as 87 percent owned[35] the land, representing 54 percent of total respondents reporting to own the land they farmed. Seasonal farmers mainly relied on informal land use (52%) followed by renting (32%). Renting of land tended to only occur in the peri-urban areas.

The fact that people had informal land access did not necessarily mean that they felt insecure about their land rights. Many vegetable farmers, for example, had farmed the same plots for long periods of time and examples were given where

[35] Land owned in this context refers to traditional land ownership, i.e. secure land rights to stool land.

these plots had been inherited. The land at Marine Drive, for example used to be parkland, because the municipalities lacked resources to maintain the park farmers were allowed to crop the area. The farmers are seen as providing a service to the municipality in keeping the land neat and tidy. Similarly in the Dzorwulu Plant Pool area under the power cables, the land is owned by the government. Many of the farmers used to be employed by the Ministry of Agriculture and are allowed to farm the land to keep it clear from shrub vegetation and squatters. By contrast, people cropping (mainly maize) on University land in Legon felt less secure, as did the vegetable growers within the Korle Bu hospital complex. The university and hospital were expanding and farmers were unsure if they would be able to carry on cropping from one season to the next. Some farmers who cultivate privately owned plots of land which have not yet been utilised for building, also feel insecure and are aware that their livelihood from farming may come to an end at any time. For example, a group of vegetable growers interviewed behind the Golden Tulip hotel had permission from the landowner to cultivate the land free of charge 'until further notice', to avoid the establishment of squatter settlements.




*Graph 4.6 Land access, (n = 112)*

*Source: This research, baseline survey*

**Labour**

It is common for farmers to hire labour at times of high labour demand or for particularly time consuming or strenuous work. Half of the farmers interviewed hired labour occasionally, primarily for weeding and land preparation. 67 percent of the labour hired was for weeding and 33 percent for land preparation. Planting (13%) and harvesting (13%) were also activities for which it was relatively common for farmers to hire help. Other work-tasks mentioned were selling, spraying and animal care.

Farmers in all categories would hire labour, although it was less common amongst the vegetable growers where only 30 percent reported to ever hire help. In the other three categories hiring labour was equally common with 72 percent of seasonal farmers, 70 percent of mixed farmers and 69 percent of backyard gardeners reporting to do so. Farmers would mainly hire men. 79 percent reported to only hire men whilst 21 percent would hire both men and women. No one said that they only hire women. Women are mainly hired for harvesting and planting, and, albeit less commonly, for weeding.

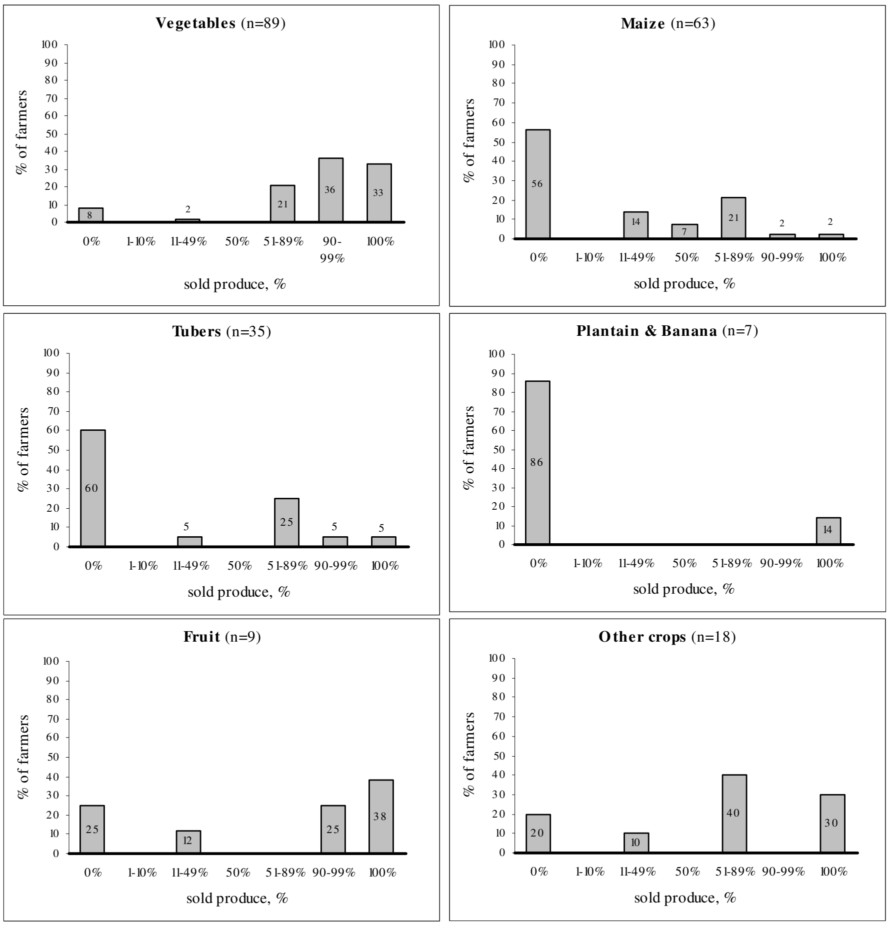
Hired labour is paid per day, week or month depending on how long they are hired for, or per bed or acreage prepared, weeded or planted. Farmers typically reported that they paid between c2000-5000 (£0.2-0.5), or between c30 000-50 000 (£3-5) per acre for weeding. The only job-share practice encountered was amongst the small-scale urban vegetable growers where growers would help each other out with harvesting.

#### *4.3.4.3 Marketing*

**Sales by producers**

This section draws on the baseline survey findings, but also on interviews with 30 market women (Autumn 2000) and the experimental work with the vegetable growers (during 2000-2001).

A high proportion of the crops grown in and around the city of Accra are sold. Vegetable production in particular, is a largely cash driven activity, with little of the produce being used for home consumption. 69 percent of all farmers interviewed who grew vegetables reported to sell 90 percent or more of their produce and as many as 33 percent of them sold all their produce (Graph 4.7a). Maize, tubers, plantains and bananas were mainly grown for home consumption, although some of these crops were also sold. 56 percent of farmers growing maize, 60 percent growing tubers and 86 percent of those growing plantain and banana kept all the produce for home consumption (Graphs 4.7 b-d).




*Graphs 4.7 a-f   Proportions of produce sale and kept for own use, (% of respondents growing the crop in question)*

*Source: This research, baseline survey*

Backyard gardeners tended not to sell any of the food crops produced. One respondent reported that he sold 95 percent of the cassava produced, but that was the only example of any sale in this farming category. Half of the backyard gardeners interviewed grew vegetables. All of them reported that it was exclusively for home consumption.

Vegetable growers and farmers in the mixed farming category sold the great majority of the vegetables they produced. 67 percent and 65 percent of farmers in these groups respectively sold 95 percent of more of their vegetable produce. Whilst the mixed farmers tended to sell most of the vegetables and fruit they grew, they kept the majority of the rainfed crops for home consumption. Vegetable growers tended to grow very little but vegetables. With the small-scale commercial urban vegetable growers lettuce is the most widely grown crop. With its short growing cycle it is popular with growers as it ensures quick return on money invested and, similarly, is a low risk crop in case of a failed harvest, compared with a crop that is in the ground for several months.

The urban growers have access to water either from drains or standpipes and crop all year round. There is, however, a certain degree of seasonality in the crops and the urban growers' advantage is in the dry season when there is less produce from elsewhere and prices are high. In fact, because of low prices during and just after the rainy season there is a glut in the market which leads some urban growers to concentrate on growing traditional crops for home consumption on some of their beds, instead of the market-oriented crops. Lettuce in particular is produced purely for sale and, although grown all year round, there is a drop-off during the rainy season. The peak of production for lettuce is around Christmas when lettuce is in high demand and the prices can double. Similarly, onions are mainly planted in August/September for a November/early December harvest when the price for locally produced onions is best. At other times of the year, better quality onions can be obtained from the north. The prices for vegetable produce in the city start to increase in August to reach a peak around Christmas. The prices begin to fall again in late April/May when produce from the wetter upland hills and the Kumasi region has been harvested following the rains.

Those of the seasonal farmers who grew vegetables tended to divide the produce between sale and home consumption. The same was true for their primary crops, maize and tubers. 36 percent of farmers in this category growing maize and 17 percent of those growing tubers did not sell any produce at all. The rest would sell some and keep some for home consumption.

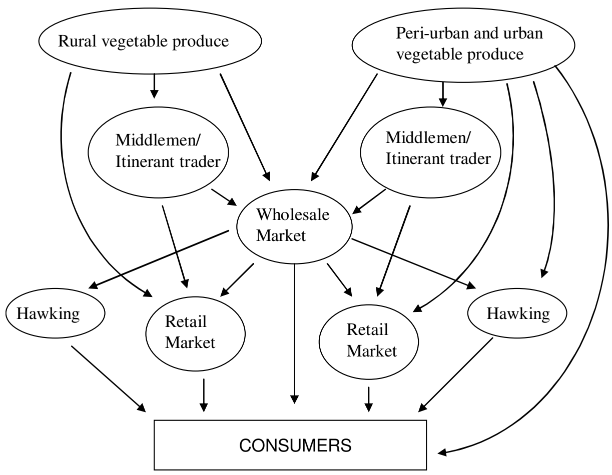
**The role of market women**

Whilst the production end of the urban food industry in Accra is dominated by men, women clearly dominate in the area of food trade. Marketing of vegetable produce is done almost exclusively by women. According to Duncan (1997, in Ministry of Food and Agriculture, 1999), women constitute 90 percent of the labour force involved in the marketing of farm produce. They may be involved with direct marketing either at market places or through hawking, or indirectly by acting as 'middlemen'. Retail trade in general is predominately carried out by women. The 1997 Ghana Core Welfare Indicators Survey showed that in the urban parts of Greater Accra 68 percent of women were involved in the retail trade, compared to 14 percent of men. Furthermore, 80 percent of women were involved in the informal sector, 35 percent men.

As with most marketing systems, the marketing of vegetable produce in Accra involves a series of agents who operate at different scales and who intervene at differing levels in the marketing chain. Figure 4.9 illustrates the various routes that the vegetable produce takes from the producer and the consumer[36]. There are 51 markets where vegetables are sold throughout Accra, all expect two of which are managed by the AMA through the Metropolitan and District Assemblies (Sackey,

[36] Marketing of vegetable produce also occurs in shops and supermarkets, but it constitutes such a small proportion that it has not been included here.

1998). The market trade is controlled by crop specific trader associations, which are led by so called Market Queens (or *ohemmas*) who apply and enforce restrictions on entering the market. The Market Queen ensures that no produce is sold outside their various networks, thus they carry a lot of power. The appointment of Market Queens and the structures of the trade associations are organised according to traditional leadership structures (Lyon, 2000). The role of the trade associations is to control the market spaces, settle disputes, lobby local government and help reduce traders' transactions costs (*ibid*.). However, they have also been criticised for using their power to create oligopolies, with associated profits (Lyon, 2000; Dozeyem, 1998).



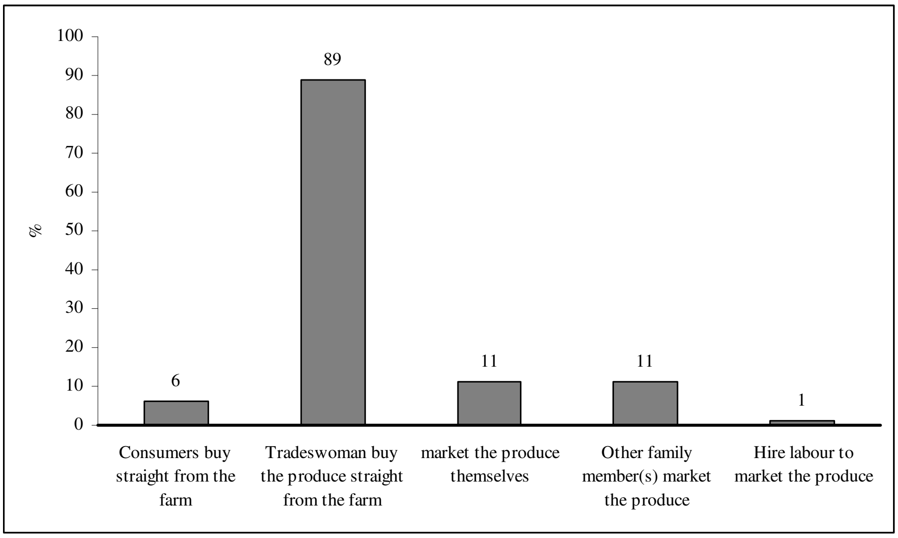

* A market woman may be either a retailer or a middleman depending on what she does with the produce once she buys it off the farmer.

*Figure 4.9 Marketing routes of vegetable produce in Accra*

*Source: This thesis*

In addition to the retail trade at the markets, foodstuffs such as fruit, vegetables, yam, plantain and smoked fish are sold by hawkers, stall and pavement retailers along many of the principal streets in Accra. This kind of informal trade is on the increase.

Vegetables produced in the urban and peri-urban areas are generally sold to market traders and middlemen who come to the farms, but produce is also taken by the farmers themselves to wholesale or retail markets. In some cases crops are sold directly to local consumers. In the three study areas (experimental sites) direct marketing to consumers was observed only in Dzorwulu. The baseline survey showed that although some farmers reported marketing their own produce, selling directly to consumers at the farm, or asking another family member market the produce, the vast majority (89 %) of farmers who market their produce sell it on to women traders (Graph 4.8). If the female farmers are removed from the study sample, 92 percent of the farmers interviewed sold their produce to market women.




*Graph 4.8 Means of marketing produce, (n=98, of which 88 male and 10 female)*

*Source: This research, baseline survey*

As can be seen in Graph 4.8, farmers in Accra tend not to market their produce with the help of family members. From the respondents in the baseline survey, only 9 percent of the male farmers who sold their produce reported that another family member does the marketing. Of the few female farmers interviewed who sold their produce (only 10), 30 percent had other family members do the marketing. It was also more common for female farmers to market their produce themselves; 40 percent did so, compared with 8 percent of the male farmers. Interestingly, women would generally not market their husbands' produce. The explanation given for this was that by so doing, they would not have control of the income from the sale. Consequently tradeswomen preferred to purchase farm produce independently from other farmers, even if their husbands were farmers.

The vegetables produced in urban areas constitute a small proportion of the total market. However, during the dry season when the traditional green leaf vegetables (e.g. jute, solanium and amaranthus) are in short supply, the produce from Accra was of importance (this research, marketing survey, 2000).

The marketing chain of the vegetables produced within Accra is not necessarily more direct than that of the rural produce, but a larger proportion is marketed through a shorter chain. The marketing women visit the urban vegetable growing areas regularly and negotiate with the growers to buy the crops while they are still in the ground. The crops are commonly bought on a whole bed basis before they are ready for harvest and subsequently harvested as and when the market woman needs them. If she is operating on a relatively large scale and sells on the produce to the wholesale market, she will harvest the whole bed, or several beds, in one operation. However, many of the market women are hawkers (*stall or pavement retailers*) operating on a small scale and it is common for them to harvest a bed sequentially as and when she sells the crops, only removing what she can carry in a head pan.

Prices are negotiated between the farmer and the market women on the basis of a number of influencing factors, of which seasonal price fluctuations in accordance with the seasonality of production is clearly the most important. There is not a set price for a bed. The bed sizes vary and the timing of harvest, quality of the crop, and outlays incurred by the farmer all influence the agreed price.

It is common for growers to have long-standing arrangements with a few regular market women based on trust and mutual negotiation. These relationships are often accompanied by credit arrangements. Sometimes the market woman may pre-finance the production and as such have sole right to purchase the crop. Under such arrangements the market women have considerable power in price negotiations and in dictating which crops to grow and the time to sell. In studying tomato production, financing and marketing in Ghana, Lyon (2000) found that traders charge an implicit rate of interest through offering the farmers lower prices. During the course of this study's experimentation with the vegetable growers, it emerged that the market women carried a lot of power in the price negotiations and frequently controlled the timing of harvest. It was not uncommon that they changed the date of harvest from that previously agreed.

At times the farmers give the market women credit, and thus get paid only once the market women have sold the produce. This is particularly common during times of glut when the farmers have limited bargaining power but, according to Lyon (2000), also when traders have made a loss in previous transactions and request help to build up their capital again. This type of credit arrangement was frequently observed during the course of the research. Farmers were only willing to enter into such an arrangement with market women with whom they had a well established relationship and whom they could rely upon to be trustworthy and reliable.

Through discussions with farmers and PRA exercises with the vegetable growers, it was clear that the market women consistently emerged as the most important institution for the growers. They represent their link to the market and provide them with critical information such as price fluctuations and consumer demand.

#### *4.3.4.4 Livestock keeping*

This section draws on the findings from the baseline survey (1999) and on interviews with 20 poultry farmers and the two major poultry keepers associations (2000). The focus for the baseline survey was to explore cropping systems and thus farmers exclusively engaged in livestock keeping were not included in the sample.

Livestock keeping is a common agricultural activity in Accra. Although the baseline survey focussed on crop farmers, half (49%) of those interviewed reported that they had some kind of livestock. The type of livestock systems that occur range from the very small scale, with people keeping a few chickens and goats, through to large scale commercial operations.

Poultry is by far the most commonly kept livestock in Accra, followed by small ruminants and other fowls. According to the Ghana Living Standards Survey, 2000, more than four-fifths of a million (812000) households raise goats, half a million households raise sheep, and more than a million (1,164,000) households raise chickens (GSS, 2000b). Eleven percent of all chickens are owned by households living in urban areas. However, the full extent of livestock keeping is not fully known and knowledge about the numbers of livestock kept is a very grey area (Aggreyfin, pers. comm., October 2000). An educated guess by MOFA is that there are about 17 million chickens in Ghana, 80% of which are in the Ashanti, Great Accra and Brong Afaso Regions. Of these 30%, i.e. 4.2 million, may be in Accra; a substantially higher figure than that reported in the Ghana Living Standards Survey, 2000. Apart from poultry and small ruminants, cattle and pig production also occurs. In fact, commercial livestock production is mainly made up of poultry and pigs (Maxwell *et al.*, 1998).

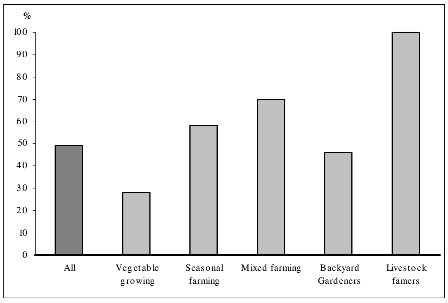
In the baseline survey, livestock keeping was most common amongst farmers in the mixed farming category. This group was largely made up of farmers in the La area, where livestock keeping is very common. Here 70 percent had some kind of livestock, compared with the much lower proportion of 28 percent amongst the vegetable growers (Figure 4.9)

Chickens were by far the most commonly kept livestock (79%), followed by goats (34%) and thirdly sheep (22%) (Figure 4.10). Chicken and goats were the only types of livestock kept by farmers in all categories. Sheep were particularly common amongst the La farmers. Cows and pigs were seldom kept. The rather high proportion of pig keeping farmers (9% of those with livestock) recorded in the survey is because three commercial pig farmers were interviewed in the Mudor area next to the Korle Lagoon, which is an area characterised by this activity. Apart form these three farmers, only two others in the sample kept pigs. Similarly, out of the 112 farmers interviewed, only two reported having cattle. Both these farmers were in La.

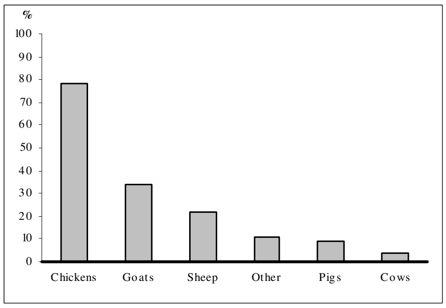
Chickens were kept by all backyard farmers with livestock. Of the farmers with livestock in the seasonal and mixed farming categories chickens were also very common, with 87 and 84 percent of farmers reporting keeping chickens respectively. Out of the vegetable growers with livestock (28%) only 62 percent reported haveing chickens. This group of farmers also had fewer chickens than farmers in other categories. On average they had 10 heads compared to 14 for seasonal farmers, 18 for backyard gardeners and 26 for the mixed farmers.

The widest range of livestock were found in the mixed farming category, whilst vegetable farmers only reported keeping chickens, goats and sheep. In backyard gardening systems chickens, goats and other small livestock such as ducks and rabbits, were common.

Goats were most commonly kept by seasonal farmers (60%) followed by vegetable growers (38%). On average farmers would have 10 heads. There were no differences between farming systems in the number of goats kept.




*Graph 4.9 Proportion of farmers with livestock*




*Graph 4.10 Type of livestock amongst livestock keepers – proportion for the whole sample*

*Source: This research, baseline survey*

There are by laws in place regarding livestock keeping in Accra. For example, following an outbreak of African Swine Fever in 1999, pig keeping was completely banned within Accra. With regards to sheep and goats, each household is allowed to keep 10 heads only. It is permitted to keep poultry in any numbers providing there are no complaints from neighbours. These by-laws were introduced for health reasons, but also because roaming animals do not mix well with motor traffic. In Ghana it is traditional to let animals roam in search of their own food. The practice of cutting and carrying food is not popular (Sackey, pers. comm., October 2000)

**Poultry production and poultry producers**

Poultry manure is used extensively by vegetable producers in Accra. Because of the size of the commercial poultry production industry in Accra, the manure constitutes an urban waste. Thus, in the context of this research, following the baseline survey, poultry production in Accra was explored further. Since poultry manure is the most important nutrient input used by urban and peri-urban farmers in general, and by commercial vegetable growers in particular, it became relevant to collect information on the extent of poultry farming in and around the city in order to ascertain the amount of poultry manure available to farmers in the city.

In order to gain information in this area, two poultry breeders associations were consulted, 20 poultry farmers were interviewed through SSIs, and in-depth discussions were held with staff of the Livestock Information Unit and the Statistical Research and Information Directorate of MOFA[37].

There are two poultry farmers' associations, with whom the majority of commercial producers are members since they obtain poultry feed through them. These are:

- The Poultry Farmers Association (PFA) which aims to cater for large scale producers. In order to register as a member of this association, the production capacity needs to be in excess of 10,000 birds with a production not falling below 5000. The largest producers have in the order of 80-100,000 birds. This association has 13 members within Greater Accra/GAMA (i.e. 50 km radius of central Accra)
- The Greater Accra Poultry Farmers Association (GAPFA), which caters for the more common medium and small scale producers. This association has a membership in the order of 300. A bird population size of 2000-5000 birds per member is typical.

Based on data collected from these two associations, information about the size and location of poultry farmers was gained. Each association totals approximately 300,000 birds amongst their members.

MOFA uses nominal sizes to grade poultry production units: small scale <2000 birds; medium scale 2000-10000 birds; large scale >10000 birds. The vast majority of commercial poultry farmers operate on a small scale, as illustrated in Graphs 4.11a&b. These are the production units from which urban vegetable growers mainly source their manure. The large-scale poultry farmers are located on the outskirts or outside Accra. The medium to small-scale producers tend to be more urban based. The greatest potential for manure utilization by urban vegetable growers lie mainly in association with the medium size farms that because: (1) they produce enough manure to make it worthwhile harnessing, and (2) their operations are located close enough to the urban farmers to make collection feasible. Manure from the large scale producers on the outskirts of Accra is mainly utilized by larger scale commercial vegetable producers in the peri-urban fringe.

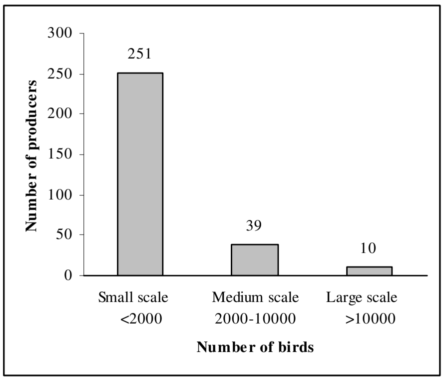
In addition to the registered commercial poultry producers, there are non-registered poultry keepers as well as the numerous chickens that are kept free range within households (so called scavenging birds). According to information held by the agricultural extension service of AMA, it is estimated that commercial poultry producers not registered with either GAPFA or PFA constitute an additional 30-

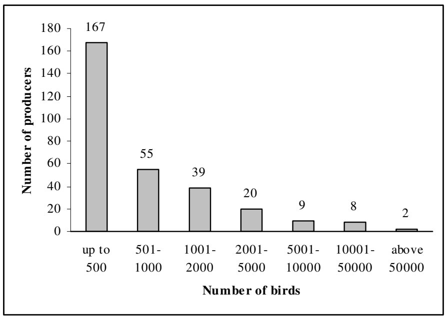
[37] Discussions were held with Dr Alorvov of the Livestock Information Unit of MOFA and Mr Aggreyfin, Acting Director of the Statistical Research and Information Directorate of MOFA.

40% (Alorvov, pers. comm., October 2000). According to the service's own 1997 figures, the number of poultry producers in the size categories ranging from less than 500 birds to 10,000 birds were 489. Whilst full knowledge of the number of commercial poultry producers and, in particular the number of birds that are kept within Greater Accra, is not available and different agencies have different information, the estimates used by the various parties are close enough to indicate that they may be moderately close to the real situation.

When it comes to the scavenging bird population, the picture becomes considerably more blurred. There is no official estimate of the scavenging bird population in the city, but it is known to be considerable. An educated guess by The Livestock Information Unit of MOFA is that there are about 17 million chickens in Ghana, 80% of which are in the Ashanti, Great Accra and Brong Afaso Regions. Of these 30%, i.e. 4.2 million, may be in Accra. In terms of manure utilisation the scavenging bird population, although substantial, may be disregarded as manure is not collected from these birds. They do, however, contribute to urban pollution.

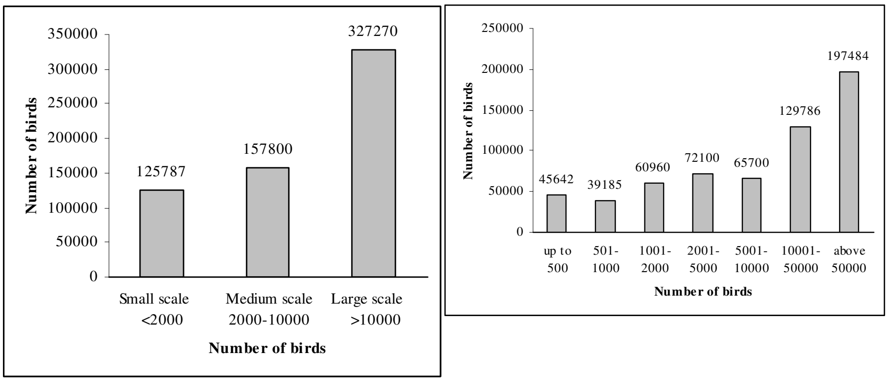
Graphs 4.11-4.12 show the number of poultry producers and the number of birds in Greater Accra that are registered with the two poultry farmers associations. Graphs 4.11a and 4.12a display the data according to the size categories used by MOFA, whilst 4.11b and 4.12b display the same data graded into a larger number of categories which further illustrates that the majority of producers operate on a small scale.




*Graphs 4.11 a & b   Number of registered poultry producers in different size categories in Greater Accra*

*Source: Tabulated data obtained from PFA and GAPFA*




*Graph 4.12 a&b Number of registered birds in different size categories of production in Greater Accra*

*Source: Tabulated data obtained from PFA and GAPFA*

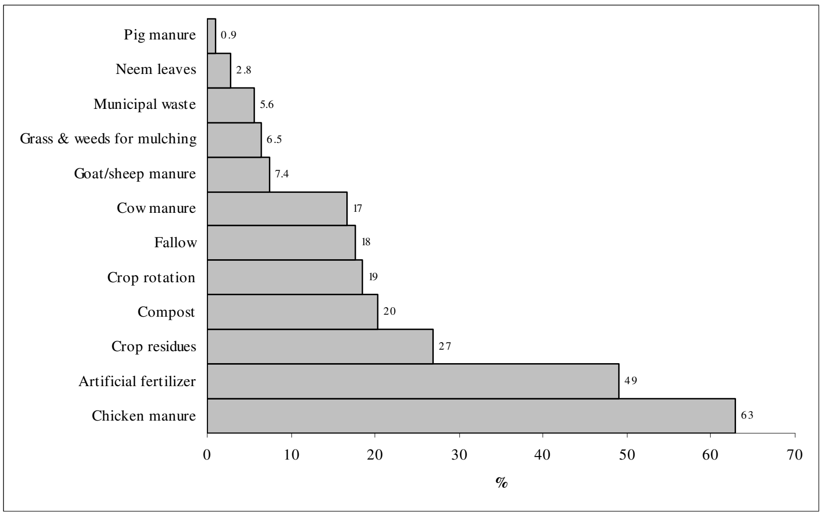
Based on an estimated feeding requirement of 100-130 g feed/bird/day and an excretion rate of 20 percent (Euroconsult, 1989; MOFA), each bird produces 20-26 g manure/day or in the order of 0.0084 tonnes manure/year. However, poultry manure rarely contains concentrated droppings but is mixed with a bedding material such as woodchips or sawdust. Where layers are kept in cages, the manure is often scraped out without mixing with woodchips or sawdust. Such manure is very strong and, according to the manager of one of the largest producers in Accra, not very popular with farmers. The most common form of manure and the type vegetable growers tend to use is deep litter, in which the excreta is mixed with woodchips or sawdust. Therefore, an estimate of the amount of poultry manure produced needs to take into account the bulking material and a subsequent reduction as the manure decomposes. According to estimates by IBSRAM derived from a detailed study of one of the major poultry producers in Kumasi, broilers produce 0.018t/ manure/bird/yr and layers 0.01t/manure/bird/yr (Drechsel, 1996). Using this estimate and assuming a commercial bird population of 825000 birds (this excludes the substantial population of scavenging birds from which manure is not harvested), a rough estimate of 11,500t potentially harnessable poultry manure is produced annually within Greater Accra. If vegetable growers apply chicken manure at a rate of 20-25t/ha and apply this amount 4 times a year, the manure produced within Accra would be able to fertilise 115-144 ha of land used for the type of intensive vegetable production which is prevalent in Accra. Another way of viewing this is to look at how many urban vegetable growers that can satisfy their soil fertility inputs through chicken manure. If a typical land holding of an urban vegetable grower is 300 square meters, then approximately 4000-5000 growers would be able to satisfy their requirement from the existing sources of poultry manure.

This rough calculation reveals that with the kind of intensive fertilization regime used by the small-scale commercial vegetable growers of Accra, all the manure produced could easily be utilized. Current use of poultry manure is mainly by vegetable growers (both urban small-scale and peri-urban larger scale), but some usage is also reported with food crop producing farmers (see Section 4.3.4.5). In spite of the fact that the majority of poultry manure is given to farmers free of charge and it is effective and popular with farmers, it is not fully utilized. Interviews held with poultry farmers in Accra revealed that much of the manure produced is not collected by farmers. The frequency with which poultry farmers empty the sheds or pens typically ranges between 4-8 weeks. Unutilised manure is haphazardly disposed of either on the poultry producers' own land, or in the cases where they do not have access to land, indiscriminately dumped on roadsides or on wasteland. When large amounts have accumulated without anyone claiming it, it is not unusual that the manure is set on fire.

**Cost of and access to chicken manure**
Yet growers reported that poultry manure is sometimes difficult to get hold of in sufficient quantities and that they often have to make do with inferior quality manure, i.e. manure which is fresh or immature, or with very high concentrations of sawdust in it. Growers get manure from a variety of poultry houses within the city, at varying distance from their land, depending on availability. Generally farmers do not have to pay for the manure providing they come and collect it, particularly if they clear it out of the poultry houses themselves. Lately, as poultry farmers have come to realise that there is a demand for this waste material amongst the vegetable growers, they have started to bag the manure and sell it. It is, however, more usually obtained free of charge and the cost for the growers lie in the transportation. The manure is transported to the farms either by means of walking and by carrying sacks on their heads, or by handcarts, tro-tros (minibuses used as local buses), hired taxies or pick-ups, or large tipper trucks, depending on the distance and the amount needed. It is common for growers to co-ordinate their purchase and hire a truck. Prices are very variable depending on the driver and the distance to the poultry house. Farmers commonly reported paying between 20 000-30 000 cedis (£2-3) for the transport of about 10-20 bags and between 70 000 – 80 000 cedis (£7.3-8.4) for the hire of a tipper truck. If farmers go for the more expensive option of buying manure ready bagged form a middleman who delivers the manure to the farm, the price is about 3000-5000 cedis (£0.3-0.5) per bag.

#### *4.3.4.5 Soil fertility management*

Most farmers interviewed in the baseline survey did something to maintain the soil fertility of the land they farmed, through techniques such as fallowing or crop rotation, or by the use of external inputs. Chicken manure and NPK fertilisers were by far the most commonly used fertility measures (Graph 4.13). Other common practices were the use of crop residues, compost derived from farm and household waste, crop rotation, fallowing and cow manure. Use of manure from sheep, goats and pigs was relatively uncommon. A few isolated cases of farmers using grasses, weeds and neem leaves for mulching, and municipal raw or composted waste, were also found. 10 percent of the farmers interviewed did not use any soil fertility maintaining measures whatsoever. The majority of these (64%) were backyard gardeners.



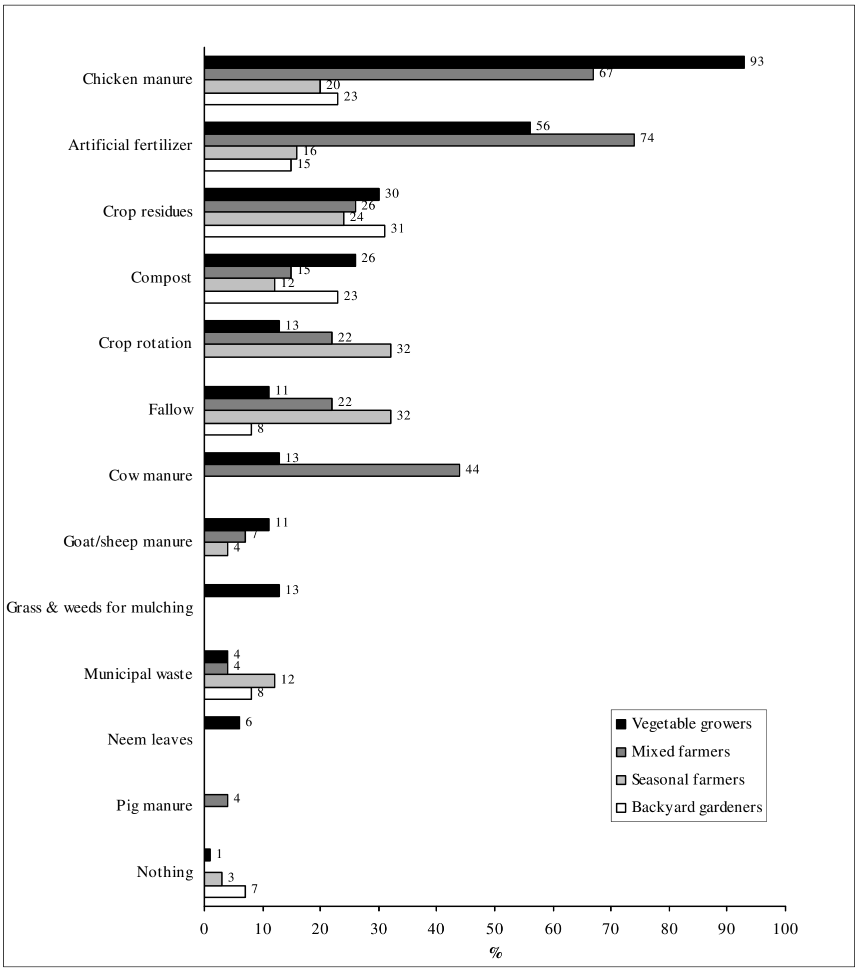

*Graph 4.13 Soil fertility management and inputs used by farmers, (n=108)*

*Source: This research, baseline survey*

There were clear differences in the type of soil fertility management used in the different farm categories (Graph 4.14). The seasonal farmers relied on traditional low external input measures such as fallowing, crop rotation and crop residues with some limited input of artificial fertiliser and chicken manure. Other manure use in general was low amongst this group of farmers.

The vegetable growers relied heavily on external inputs for soil fertility maintenance. Almost all (93%) used chicken manure and over half (56%) used artificial fertilisers. Although these two inputs were by far the most widely used amongst this group, vegetable growers used a whole range of other techniques and it was common for individuals to use a combination of 3-5 techniques. By contrast the seasonal farmers would typically use 1-2 different techniques (See Table 4.7).

The mixed farmers also relied heavily on external inputs of artificial fertilisers and chicken manure. A large proportion (44%) of farmers in this category also used cow manure, particularly in La where cattle are kept by several farmer, and thus growers have access to this manure. Lack of access to cow manure was the most commonly mentioned reason why farmers did not use it in other areas.




*Graph 4.14 Soil fertility management and inputs used by farmers in the different farming categories, (%)*

*Source: This research, baseline survey*

*Table 4.7 The number of different soil fertility inputs or management techniques used by farmers*

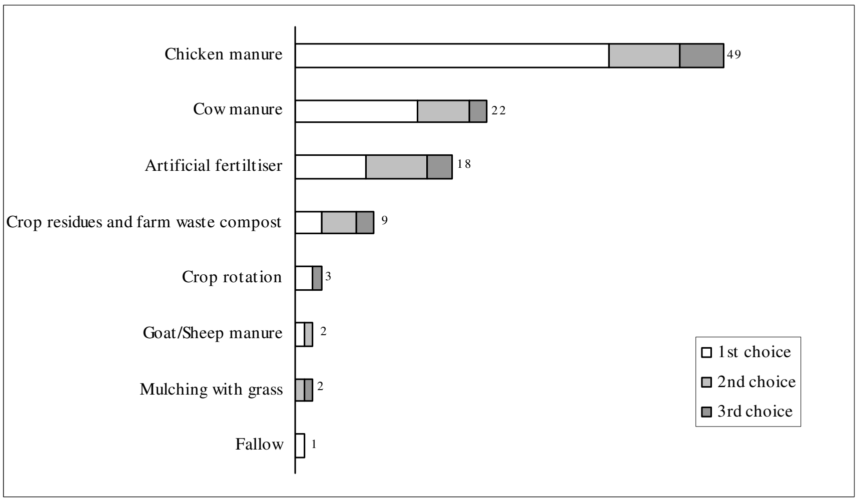
| No of soil fertility measures used | No of respondents | Comment |
|---|---|---|
| None | 11 | Mainly seasonal farmers |
| 1 | 24 | Mainly seasonal, some mixed farmers |
| 2 | 30 | Mainly vegetable growers, some mixed farmers |
| 3 | 24 | Mainly vegetable growers and mixed farmers |
| 4 | 9 | Vegetable, mixed and seasonal farmers |
| 5 | 6 | Mainly vegetable growers |
| 6 | 1 | Vegetable grower |
| 7 | 1 | Vegetable grower |
| 8 | 1 | Vegetable grower |
| 11 | 1 | Mixed farmer |

*Source: This research, baseline survey*

Twelve percent of farmers reported using different soil fertility inputs on different crops. Several of them said that they would use fertiliser or manure on the vegetable crops but not on the maize or okra. The few farmers that grew legumes did not use any fertility inputs on them either.

Farmers tended to prefer what they knew and were familiar with and felt reluctant to speculate about techniques and materials about which they had no knowledge and experience. As such when farmers were asked which soil fertility techniques or inputs they preferred or would prefer, they tended to mention the same ones they used. The vast majority of farmers who preference ranked fertility management techniques and inputs perceived that chicken manure was best (Graph 4.15). They were happy with the quick response to crop growth when applying chicken manure and that it is relatively easy to get hold of at an affordable price. Some farmers said that the effect only lasts a short time and were of the opinion that cow manure was better.

The experience with cow manure was generally limited and the opinions about the effects of using this manure tended to be polarized. Many were of the opinion that it is the best of all fertility inputs and mentioned the following major benefits of cow manure: it lasts a long time in the soil, it gives good structure to the soil and it is not too strong for the plants. Other farmers did not like to use cow manure, claiming that it is not very effective. Some even said that it impairs crop growth because it is salty. Another negative aspect mentioned was that it contains weed seed from the diet of the cows. Many farmers said that they did not know enough about the properties of cow manure to comment. They said that it is very difficult to get hold of and it generally costs more than chicken manure. Several farmers said that as the chicken manure is so readily available they do not even try to get hold of anything else.




*Graph 4.15 Soil fertility techniques and inputs mentioned as first, second and third most preferred, (number of mentions)*

*Source: This research, baseline survey*

Artificial fertilisers were not very popular, but some farmers did like to use them, primarily because of their fast acting properties and convenience. It was a commonly held perception that crops grown with artificial fertiliser are of inferior quality in terms of taste, texture and shelf-life. The market women often complained about vegetable produce grown with fertiliser and the growers generally tried to avoid using them. However, several vegetable growers said that if they wanted a quick harvest, because they needed money or wanted to harvest a certain crop before the market price collapsed, they would use artificial fertiliser to boost the growth. They would not use artificial fertilisers alone, but combine the use with chicken manure or other inputs such as crop residues or grass mulching.

Sheep and goat manure was used only by some farmers. It was a commonly held view that this manure is salty and not very good for the soil and crop growth. Pig manure was equally disliked, but for reasons that were not explained. However, many of the vegetable growers interviewed were Muslims and would not use any product from pigs for religious or cultural reasons.

**Knowledge of and attitudes towards compost and wastes**

When asked if they knew what compost is, about half of the farmers instantly said yes. When the interviewers probed further, it became clear that the majority of farmers realised that compost is in fact just decomposed organic material. What was not as widely known, however, was that composted vegetative matter is good for the soil and crop growth. The use of compost was not common amongst the farmers surveyed, with only a few examples of farmers composting their farm waste. Those that did tended to mix it with chicken manure in the compost heap. The general practice amongst the vegetable growers is to leave the crop residues and other plant material to dry out and then to burn it. Seasonal and mixed farmers tended to leave crop residues on the field to decompose between cropping cycles. There were no examples of farmers using their household waste on the land.

Only 18 percent of the farmers interviewed knew about the existence of municipal composting either at Teshie/Nungua or James Town. This in spite of the fact that compost has been produced at the Teshie/Nungua site for 18 years. Out of this 18 percent, only 21 percent had ever used or considered using this material on their farms. There was a general perception amongst those farmers that knew anything about it that the municipal compost is too expensive and difficult to get hold of (transportation). Many farmers sounded interested to know more about this material and expressed interest in trying it providing they knew more about its properties and performance.

**Constraints to using soil inputs**

Seasonal farmers were using less fertility inputs per unit of land than the commercial vegetable growers and the mixed farmers. Because most seasonal farmers are operating in the peri-urban areas, crop larger land areas, and do not produce for the market, they generally felt that they could not afford to use external fertility inputs. Transportation and the cost of buying the inputs were voiced as the main constraints.

A lot of the vegetable growers did not feel that getting the fertility inputs that they needed was a problem. A common response was that “it is all a matter of being willing to spend money. If you are willing to pay, access to fertiliser and manures is not a problem as such. If we want to get a good crop we have to used some kind of fertility input.” There was also a general perception that although they had to pay for the transportation of chicken manure; the cost was not beyond what they could afford.

Others had a different view. Out of the sample of 108 crop growing farmers (4 were livestock farmers), 30 mentioned some constraint(s). 17 of these only mentioned one thing, was transportation. The cost of transportation was ultimately the root cause of the difficulty, but farmers mentioned that getting access to transport was difficult. However, when probing this issue, it was not getting access to transport *per se* that was the problem, but rather affordable transport.

Availability of soil inputs was the second most serious constraint. This could either be a complete shortage, or lack of availability at a low enough price. Availability of manures did not appear to be related to seasonality. The heavy users of chicken manure are the farmers that crop all year and the poultry houses are in operation all year round and regularly clean out the poultry houses. The fact that use of soil fertility inputs requires labour was also mentioned as a constraint by some farmers. This was the case for artificial fertilisers as well as organic inputs. Other constraints mentioned were that organic inputs are not very effective, lack of knowledge about how to use organic fertilisers, the high cost of artificial fertilisers and that organic manures are unpleasant to handle.

## 4.4 Summary

This chapter has presented the fieldwork site and explored the situation in Accra with regards to waste management and urban agriculture. The key findings from this study, particularly in relation to the potential for linking urban waste to agriculture, are summarised below.

- Accra is faced with waste management challenges typical of most cities in developing countries; growing waste volumes and insufficient funds, infrastructure and governance structures to tackle this problem. Different decentralisation policies have been implemented over the past 20 years with varying degrees of success.

- Composting has been a feature of waste management in Accra since 1980 when a high-tec, publically run composting plant was commissioned. This operation has suffered continuous problems over the years, but was still operational at the end of this research, albeit to a limited extent. In addition, a small-scale CBO operated composting operation was present in Accra at the time of this research.

- Both composting operations had neglected the marketing side of their enterprises and consequently had limited commercial outlet for the compost produced. This in turn, affected their motivation for production, particularly so in the small-scale enterprise.

- There is no source segregation of waste and the general opinion amongst waste management professionals and public sector officials interviewed was that Accra is not ready for that. The appreciation for it among the general public and the funds required are lacking.

- Urban and peri-urban agriculture is common in Accra and a multitude of different types of farming systems exist. In the urban areas commercial small scale vegetable production, seasonal rainfed traditional crop production and backyard gardening are the most common systems.

- The use of different kinds of soil fertility inputs is limited amongst farmers and growers. Use of chicken manure and artificial fertilisers dominate. The primary traditional system for fertility management in Ghana is shifting cultivation. As such people have limited history and knowledge of using fertility inputs. The baseline survey indicated that the commercial vegetable growers are using inputs (mainly chicken manure and artificial fertilisers) and are willing to spend money on it. Seasonal farmers, on the other hand, are generally not.

- Farmers and growers are generally not using organic city wastes, other than chicken manure, in their cropping system. The small-scale vegetable growers did not even recycle crop residues, weeds and other farm wastes.

- Only a limited number of farmers and growers interviewed knew that urban organic wastes were being composted in Accra and even fewer had ever tried or considered trying this material.

- Having explored the composting operations and the farming systems in and around Accra, the decision was made to concentrate the experimental work to working with small scale commercial urban vegetable growers. The next two chapters focus on the experimental work with urban vegetable growers to test the use of CMW in local cropping systems.

# CHAPTER FIVE – THE EXPERIMENTS

## Introduction

This chapter presents and discusses the choices made in the design and implementation of the experimental work to test the effect of using MCW in vegetable production systems. The work consisted of:

- Vegetable growers' experiments
- An on-farm trial
- Soil, compost and manure analysis.

The research process followed during the collaborative experiments is introduced and discussed. The chapter concludes with a reflection on the researcher's role in process management.

Two complementary experimental designs were used:

- Informal experimentation by small-scale urban vegetable growers: groups of farmers in three different locations in Accra compared compost with chicken manure. In these experiments there were no replication within the farm, there was less structure than in the on-farm trial, and less control by the researcher.
- The on-farm trial: this was conducted on a farmer's field and managed jointly by the farmer and the researcher. It had a randomised block design which enabled the generation of hard data that could be analysed statistically.

## 5.1 The vegetable growers' experiments

Informal experiments with small-scale, urban, commercial vegetable growers in three different locations in Accra were run for one year. Following the baseline survey and on the basis of the farming systems typologies that emerged from the survey, the decision was made to work more closely with this group of farmers. Mettrick (1993:202) notes that "*collaborating farmers can be identified from the diagnostic survey, by the extension service, or on the basis of the researchers' increasing knowledge of the farmers in the area*." A combination of these approaches was used in identifying growers for participation in the informal experimentation. The reason for choosing to work with the small-scale commercial urban vegetable producers was made because, along with the backyard gardeners, the urban vegetable growers appeared to have the greatest potential for the utilisation of composted urban waste. Specifically:

- They crop commercially and are able and willing to spend money on soil fertility inputs. The peri-urban farmers who practice seasonal agriculture are less willing to invest in soil fertility improvements than the vegetable growers who produce high value crops.

- They cultivate intensively very small land parcels and cannot afford to let any land lie fallow. They have to use some kind(s) of external inputs to maintain production.

- Because of the practice of continuous cropping, they sometimes experience problems when applying chicken manure just before planting, or to juvenile plants. The chicken manure is rich in nutrients and can be too strong for crops. Comments such as "The chicken dropping burns the plants if I put on too much or too often" were common. As a result, the addition of sufficient organic matter to maintain soil structure becomes problematic for these farmers. It was considered that compost amendments could provide a source of soil improvement without causing damage to the growing crops.

- Because these growers cultivate urban land, transportation costs are lower than to the peri-urban farmers.

- These growers had a perceived problem with soil fertility and were willing to participate in experimentation using composted city waste.

In addition, working with these growers was ideal for the purpose of the research as they had access to irrigation, allowing continuous cropping. Because the time in which to carry out the experiments was limited it was considered important to work with growers who could crop continuously in order to ascertain any changes resulting from compost amendments.

The basic idea behind this part of the research was to help the growers gain access to municipal compost and to try it out in a way that made sense to them within their current cropping system. The compost could be compared alongside current farmer practices and assessments of performance based on both the researcher's and growers' criteria. It was considered critical to allow the growers to have a stake in the experimental work. The main role of the researcher was to facilitate the growers in their experimentation, monitor what they chose to do, and record their conclusions about the performance of the compost. Emphasis was placed on co-learning, using an action research approach to the work. The processes that took place as the farmers entered into experimentation and learning were monitored and represent a research result in their own right.

Three of the urban vegetable growing areas that had been included in the baseline survey were selected for growers' experimentation (see Figure 5.1). These areas were chosen because they were typical for areas where vegetables are grown in Accra, yet displayed certain agronomic and socio-economic differences, thus encompassing the range of growers and situations in the city. The areas chosen were:

1. Marine Drive in a part of the city called Osu. This is a small. cultivated area by the sea between the Independent Square and the Presidential Castle, which used to be parkland. The municipality experienced difficulty in maintaining the park and it fell into decay. Permission was given to people to cultivate this land some 20 years ago. The area is made up of a series of shallow terraces and the raised beds are shaded by trees. Water is accessed from a large drainage channel which discharges into the sea just beyond the cropped area. This drain frequently dries up and the area regularly suffers water shortages and

subsequent crop failure. The growers who crop in Marine Drive are Ga people and most of them live in Osu or in Accra Central. They are not cultivators by tradition and for the majority of growers, their knowledge of farming is limited to the vegetable growing system that they are engaged in here. The majority of the growers here are male, and they are predominately Christians.

2. An area under vegetable production inside the grounds of Korle Bu Teaching Hospital. This is a low-lying area, which once used to be under water, located close to the Korle Lagoon. The crops are irrigated with wastewater from the hospital and associated accommodation blocks, which is carried in a series of varying size drains criss-crossing the area. The water used for irrigation is very polluted. During the drier parts of the year, the ditches are coated with a brownish/blackish slime and the whole area is polluted by a foul smell. Most of the growers work as labourers at the hospital and grow vegetables for the market to supplement their incomes. Many of them are migrant workers from Burkina Faso and Niger. Some of them had prior knowledge of farming from the rural areas of their origin. All the growers in this area were male, the majority Muslims. Of the three areas, this was the most commercially marginal.

3. Dzorwulu Plant Pool, which is an area of cultivated land under the power cables and along the Odaw River between Pig Farm, Dzorwulu and Nima. In this, the largest of the three areas, the growers had access to piped water for irrigation, as well as water from one of the major storm drains (subsidiary to the Odaw River) that run through Accra. The fact that farmers irrigate their crops with clean water here has helped the marketability of their produce (and some farmers sell directly to consumers). Many of the people who crop here are ex-employees of the Ministry of Agriculture who were laid off as a result of the structural adjustment that Ghana underwent. The land belongs to the Government and the redundant workers were given the right to cultivate the area. Many have cultivated here for a long time (30 years). Even though the land belongs to the Government and the land-use is informal, it is not unusual for the current growers to have inherited the right to use the land from parents or other family members. Most of the people who farm in Dzorwulu Plant Pool live in Pig Farm or Nima. Some are immigrants from the north or Burkina Faso, but most are Ga people. There is a mixture of Muslims and Christians. Although the majority of growers are men, this area has more female growers than the other two areas. The Dzorwulu Plant Pool farmers are organised in a farmers' association. They meet regularly and have an area of land which they have allocated for experimental purposes. The association was established two years ago when the extension services set up an integrated pest management (IPM) farmer field school in Dzorwulu Plant Pool as part of a countrywide initiative.

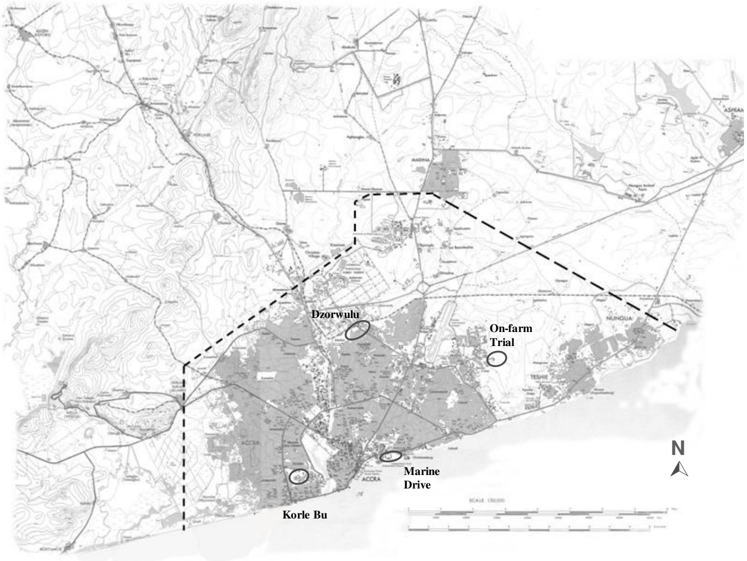



*Figure 5.1 Location of the on-farm trial in La and the vegetable growing areas where growers' experiments were carried out*

*Source: Adapted from survey map of Ghana, The Survey Department, Ministry of Lands and Mineral Resources of Ghana.*

Preliminary open meetings were held with growers in each of the three areas to ascertain the potential interest in the research. People who attended the meeting and expressed an interest in participating in the experimentation were selected as volunteers on the basis that effective collaboration is driven by enthusiasm (Farnworth and Jiggins, 2003). Mettrick (1993:202) notes that "*a balance has to be struck between representativeness, willingness to cooperate, and awareness of and interest in the particular problem being researched.*" According to Werner (1993) willingness and ability to participate and communicate with the researcher(s) are more important than representativeness. During the course of the year, some growers dropped out whilst others joined in. In general there were a range of 6-12 farmers participating in each area at any time. Whenever planning and evaluation meetings were held additional farmers joined in to learn about the outcomes.

The vegetable growers have very little land at their disposal. With an average of 24 beds and a typical bed size of 10-15 $m^2$, a vegetable grower will typically have about 300 $m^2$ on which to crop. To carry out trials with many different replicated treatments would therefore prove difficult within this pattern of land allocation. Also, it was considered that complicated research designs for the purpose of the generation of statistically reliable agronomic data is not desirable in this kind of on-farm experimentation. Werner (1993:127) notes that "*the more valuable type of replication is that across farms as it helps achieve good representation of different farmers' views and of the usually heterogeneous environmental and management conditions*." He further notes that the higher the number of replicates within a farm the less the farmer will be able to understand the trial and draw his or her own conclusions. With these considerations in mind, the experiments were designed in such a way that each grower compared compost as an input alongside his/her normal farm practice, and each grower represented a replicate in the overall experiment.

There was consensus amongst the growers in all three areas that they could afford to allocate two adjoining beds for experimenting and that they wanted to compare compost with chicken manure. They could not afford to have a no input control treatment. Instead, the growers' conventional practice (i.e. chicken manure) was used as the control treatment. This is in line with the design of much other on-farm research. Werner (1993:126) writes that when designing on-farm experiments "*farmers' practice is always the control treatment*" since "*it is not the purpose of an on-farm trial to prove the superiority of a proposed innovation over an artificial standard but rather over the real, unfortunately highly variable, farmers' practice. It is therefore recommended that each individual farmers' practice be used as the control treatment*."

By placing the conventional practice (i.e. chicken manure) and compost treatment side by side the growers were able to continuously monitor and analyse the experiment. As pointed out by Hagman and Chuma (2002) this leads to an understanding of the processes and factors than influence the performance of technologies, (learning by experimentation). Also, because of the variability in soils within and across the cultivation areas, the use of adjoining beds for the experiments ensured that soil differences were minimised.

During the experimental design meeting, the growers agreed to all grow the same crop; lettuce was by far the most preferred choice. Some growers had lettuce plants on the go in their nursery beds and would be ready to plant within one to two weeks, others needed to sow before they could start their experimentation.

Following the first crop of lettuce, the variation in experimental management between growers increased. There was a whole host of environmental and management-related variations between the experimental beds (see list in Box 5.1 below). Some growers continued to grow lettuce whilst others opted to grow other crops, either solely or as an intercrop. All growers planted a second crop without adding any further compost, as they wanted to test the effect of compost over time. One of the perceived disadvantages of chicken manure is that it does not last long in the soil. Later many growers grew a third, or even fourth crop without adding further compost, whilst others supplied more. Some left the land uncultivated periodically due to factors such as water shortage, lack of chicken manure, seeds or ready seedlings, or because work or private commitments elsewhere took them away from the cropping activities for a period. Other growers kept cropping continuously with only days in between harvesting and transplanting.

Figure 5.2 shows a cropping and compost application calendar for each grower who participated in the research. Box 5.1 shows sources of variability between farmers. In addition, transplant sizes and planting densities varied from time to time and between beds. This had implications for the growth and uniformity of plants. The variability between farmers and, from a statistical point of view, the relatively small database, had implications for the type of analysis that could be made and the conclusions that could be drawn from the assessments done. However, the focus on this part of the research was to allow growers to test the compost in a way that made sense to them within their cropping system. To monitor growers' opinions and reactions, the interest amongst the surrounding growers and any learning that took place during the course of the research, were the primary objectives.

*Box 5.1 Sources of variation between different growers' experimental beds*

- Three different locations
- Different soil types between and within locations
- Different timing of operations
- Amount of chicken manure used varied
- Quality of chicken manure varied
- Method of chicken manure application varies
- Watering and weeding differences
- Some areas periodically ran out of water
- Different crops grown
- Different varieties used
- Some have used their beds as nurseries
- Some left gaps between planting. Consequently, the rest period between crops and the weathering time for the applied compost varied.
- Some intercrop
- The number of crops grown without further compost application varied

*Source: This thesis*

Figure 5.2 displays each crop grown by each farmer in the three areas during the experimental period. The fields which do not have a black border represents crops that failed. The white blocks show where farmers used their compost beds for nursery production. The arrows denote timing of compost application. Chicken manure was applied to every crop thus not marked on the calendar.

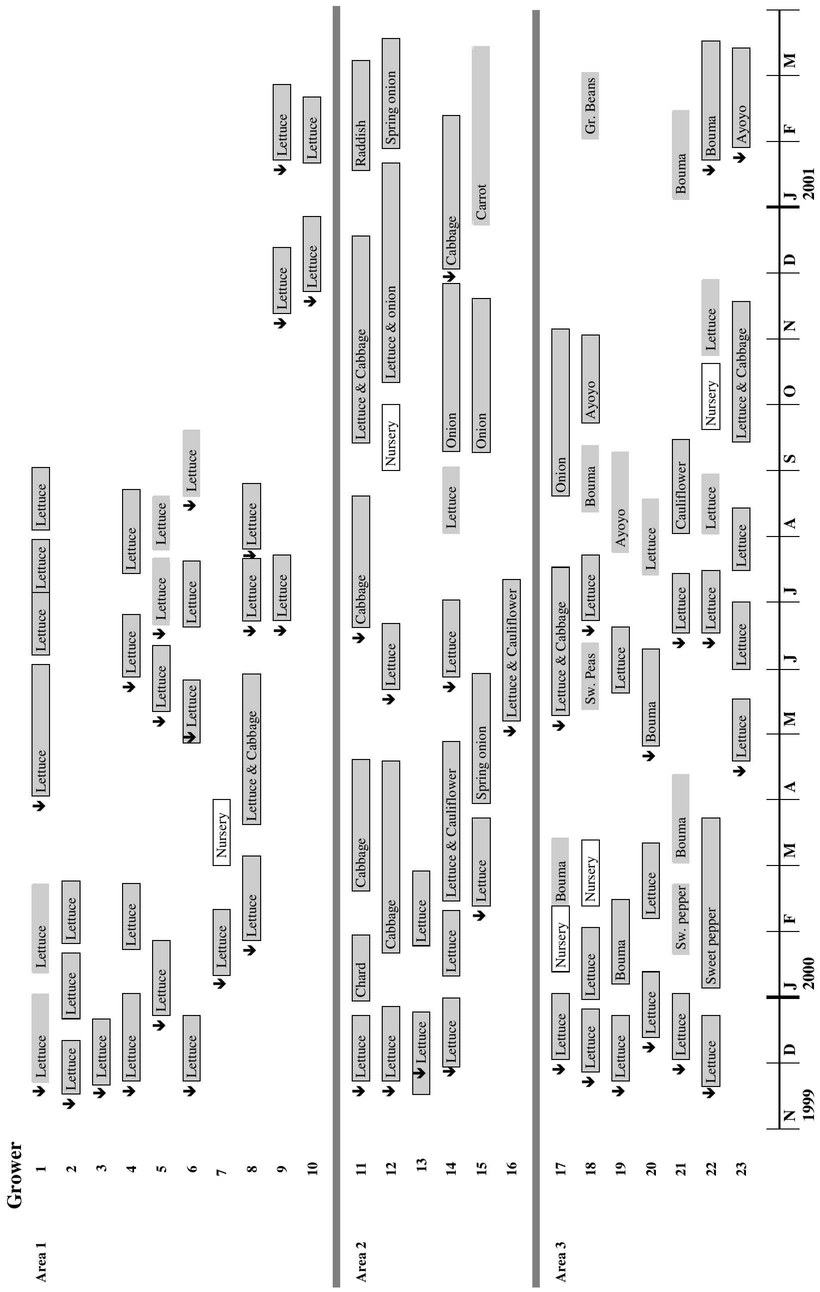



*Figure 5.2 Cropping calendar for the vegetable growers, ( ➔ = compost application)*

*Source: This thesis*

### 5.1.1 Composts and manures

As mentioned in Chapter 4, there are two urban waste composting operations in Accra. A relatively large-scale operation in Teshie/Nungua which has been running since 1980, and a small-scale CBO initiative located in the densely populated, indigenous part of central Accra known as James Town (see Section 4.2.5 and Figure 4.5).

For the first application, compost from the Teshie/Nungua plant was used. However, the results of chemical analysis of the compost (Chapter 6) revealed that the quality of this material was inferior to that produced at the small-scale operation in James Town. The level of heavy metals and inert contaminants, such as glass and plastic, was higher and the nutrient content (particularly nitrogen and phosphorus) was lower. Consequently adaptations were made and subsequent compost was obtained from the James Town site.

Chicken manure was used as the grower practice treatment, with which the compost was compared on separate beds adjacent to the compost amended beds. It was obtained by the growers themselves and came from a variety of sources. The nature and quality of chicken manure tends to be variable, depending on degree of maturity, bedding material used (sawdust or wood chips) and degree to which chemicals are used in the poultry production system. Undiluted manure from cage birds (layers) is very strong as is much of the manure from broiler houses as the sheds are emptied with every batch of birds and thus the manure is fresh. Conversely, if the manure is stored in the open once cleared from the sheds, exposed to sunlight and rain, it can lose much of its nutrients. Well-rotted manure is preferred, but sometimes there is a scarcity and growers are forced to use manure that has just been removed from the poultry houses. With regards to bedding material, some growers had no preferences whilst others expressed a preference for one or the other. Some liked the sawdust mix best and said that this manure is more potent whilst others preferred the manure mixed with woodchips as it lasted longer and provided some structure to the soil. No concerns regarding any chemicals that might be contained in the manure were expressed by growers.

The determination of desirable and actual application rates proved to be something of a challenge. It is a well-researched and documented fact that there are agronomic benefits to composted materials (Shiralipour *et al.*, 1992). However, a review of past work on the use of compost as a soil improver in agricultural systems reveals that the rates used vary considerably and that the determination of a suitable rate is something of a hit and miss affair. Bearing in mind that the properties of compost are highly variable (depending on the waste material that went into making the compost, the composting process used, the environmental conditions during the composting and subsequent storage, and the maturity of the compost), and the fact that soil and climatic conditions vary, it is hardly surprising that results vary from case to case. Quite apart from the scientific considerations regarding the determination of an appropriate application rate, compost availability, cost, labour constraints are also important determining factors for the appropriateness of a certain application rate. However, these issues will be discussed elsewhere, and in this section the focus is placed on the environmental and agronomic criteria.

According to Hyatt (1995) research also seems to indicate that increasing compost application rates shows diminishing returns to plant growth, with optimum rates ranging between 50-100 t/ha. My own review of research on compost use in Europe and USA revealed that rates ranging between 5 and 100 t/ha were common.

The determination of the application rate for compost in theory can be done on the basis of several criteria including:

- Safe loading rate
- Nutrient supply equal to conventional or normal farm practice
- Amount of organic waste available
- The cost of organic waste

In relation to the points above, a rate may be set whereby a satisfactory crop response in achieved with the minimum application level, i.e. it is a question of how little one can get away with. In relation to waste-derived materials applied to agricultural land, the focus in the literature is primarily on safe loading rates. The rates here are set in relation to estimates of plant nutrient uptake, in order to maximise production whilst minimising environmental pollution through various nitrogen losses. In addition to plant uptake, the nitrogen and phosphorus present in the inorganic and organic fractions in an organic waste material, are subject to volatilization, denitrification, immobilization, mineralization, leaching and surface runoff. The extent to and rate at which such processes occur is determined by factors such as weather conditions in terms of temperature and precipitation, and soil conditions in terms of soil moisture, aeration, pH and amount microbiological activity. There is no simple and reliable way of predicting the rate and extent of nutrient release from organic materials.

Recommended loading rates for applying organic wastes such as manures, poultry litter, slurries and composts to agricultural land are usually based on the nitrogen content of the waste (Edwards *et al*., 1995). For example, guidelines in the Code of Good Agricultural Practice issued by the Ministry of Agriculture in the UK stipulate that applications of organic manures should not exceed 250 kg total N per hectare in any 12 months. In Sweden the rate is lower at 150 kg N/ha (Hogg *et al.*, 2002). Nitrogen is used as the determining nutrient partly because it is the most unstable nutrient, and the problem of nitrate leaching from agricultural land is well documented, and partly because it is the most important nutrient for crop growth. The justification for setting N loading criteria is to minimise nitrate leaching to groundwater (Polprasert, 1996). Increasingly, however, the problem of excess phosphorus leaching into waterways and coastal environments has become a concern (Edwards *et al*., 1995; Heckrath, 1998).

Limits to application rates can also be set based on the loading rates of potentially toxic elements. In relation to sludge, for example, Polrasert (1996) notes that application rates on agricultural land should be at a rate equal to the N uptake rate of the crop, unless lower application rates are required because of heavy metal (e.g. Cd) limitations. As discussed further in Section 5.3.1, Chapter 6 and Appendix B, the legislation and guidelines of different countries differ substantially with regards to the maximum permissible concentrations of heavy metals in organic soil amendments and/or maximum permissible annual loading rates to soil.

As discussed further in Section 5.3.1, most of the nitrogen present in mature compost is not in a form available for plant uptake. In fact, nitrogen is less readily available from composts than other organic amendments (HDRA, 1998). A widely agreed estimate, for temperate climates, is that of the total N present in mature compost, 10% becomes available for plant uptake during the first cropping season following application to land. In the following crop 5% of the remaining nitrogen will become mineralised, and 2% in the subsequent seasons (Hyatt, 1995). Considering that mature compost typically contains in the order of 1% total N, most of which is unavailable to plants, application volume, or weight, needs to be quite high in order for it to have an impact on plant growth. In the tropics where the temperatures are high all year round, the mineralisation rate is faster (Greenland *et al.*, 1992). In irrigated farming systems where several crops are grown in a year, nutrient release, and removal through crop uptake is likely to be faster, necessitating more frequent compost and/or manure applications for optimum growth.

In this research, the compost application rates were set partly in relation to the manure application rates recommended by the local extension services and those used locally by the growers, partly based on other research into the use of composted waste in agricultural production systems.

The manure application rates used by farmers and vegetable growers locally tend to vary. However, a rate of approximately 20-25 tonnes/ha was common. This is also the application rate recommended by the agricultural extension services. A compost application rate of 50 tonnes/ha was used in the initial trial. See Section 5.2 for the rationale for this decision. The determination of application rate for the vegetable growers' experiments was informed by the on-farm trial. Preliminary results from the on-farm trial with tomatoes on the La farm site indicated that this rate gave a good response. Also, compared with the chicken manure application rate used by the vegetable growers (in the order of 20-25 t/ha, although variations were large between areas, farmers and cropping cycles), this seemed to be appropriate to start off with.

For subsequent applications the rate was lowered to 25 t/ha. The findings from both the on-farm trial and the early outcomes from the vegetable growers' experiments indicated that a lowered rate, to maintain the effect of compost amendment, was appropriate, (again, see Section 5.2 for the rationale for this choice). Chicken manure was applied to every crop in accordance with normal practice whilst compost was applied to every second, third or even fourth crop depending on the wishes of the grower. (See cropping calendar, Figure 5.2).

The growers' reasons for deciding when to apply more compost were governed by a number of factors:

- A wish to monitor the durability of the compost (i.e. its residual effect in subsequent crops following application). The potential for compost to provide a long-term effect on soil fertility and as a source of slow-release of nutrients was seen by the growers as a benefit compared with chicken manure, and the growers wanted to explore this.
- The nature of the crops grown (e.g. nutrient demand and length of growing cycle). The nutrient demand and the length of growing period varies between crops and consequently the frequency of application of soil inputs is to some extent determined by the crop choice.
- Seasonal considerations. The growers came to discover that crops grown in the compost-amended beds did not perform well unless they were well watered. Over time, many of the growers came to be of the opinion that compost was better in the wet season than in the dry, particularly as chicken manure is not considered suitable during the wet season (see Chapter 6, Section 6.3.3 for more on this).

The corresponding volumetric application on each bed was worked out by calculating the bulk density of the compost and measuring the square meter area of each vegetable bed. The compost was spread evenly on the surface of the already prepared beds, prior to transplanting or sowing, and not incorporated into the soil surface. Growers varied the method used when applying chicken manure. The most common method was to apply it 7-10 days after transplanting and to leave it on the soil surface without incorporation. Occasionally farmers would add chicken manure to the beds prior to transplanting. If so, they would usually incorporate the manure lightly into the soil surface.

With the principle objective of testing the compost under as normal a situation as possible and to minimise the risk of biases (Werner, 1993), each grower followed his or her own practices with regard to field operations and crop management. Choice of crops, chicken manure application rate and method, weeding, watering, determination of the need for and timing of spraying, timing of harvest etc. was all left to the growers according to their normal practice. For the same reason, compost was the only input provided by the researcher to the growers for use on the experimental beds. Apart from this the growers provided all the inputs as part of their normal cropping practice.

## 5.2 The on-Farm Trial

The on-farm trial was set up to test the effects of using MCW under real farming conditions yet with an experimental design and degree of researcher control that would provide quantitative data that could be statistically analysed. Run in parallel with the less formal experimentation by vegetable growers, it was anticipated that the findings from the two types of on-farm research would validate each other.

The on-farm trial was designed, managed and monitored jointly by the researcher and the farmer. Therefore, the experimental design was kept simple so as to interfere as little as possible with farm management. The trial ran for 21 months, during which time five completed and one failed crop were grown, with four compost and manure applications (approximately every 6 months). The compost was compared with kraal manure from the farmer's own cows and a 'no application' control. Later the farmer decided that he also wanted to add a chemical fertiliser treatment to the trial. Soil samples were taken four times to monitor any changes in the chemical composition of the soil.

Initially there were two on-farm trials with two different farmers, one urban, one peri-urban. The trial located in a peri-urban setting was the largest of the two and included more treatments (e.g. chicken manure, NPK from the onset, and different rates of compost application). However, as a result of a series of unfortunate circumstances, this trial suffered a number of setbacks and had to be abandoned before any useful results could be produced. This work is not reported in the thesis.

The farmer whose trial was run to completion was experienced and had comprehensive knowledge of the local area. His farming system comprised seasonal cropping of traditional crops and livestock rearing. Tomato and okra, and to a lesser extent chilli pepper, were crops with which he was familiar. He had no experience of growing lettuce and cabbage. In fact, learning about growing these more exotic vegetable crops was seen by the farmer as one of the benefits of the experimentation.

The site for the trial was just behind Burma Camp, situated within an area (in excess of 400 ha) of undeveloped Ga stool land stretching between Labadi and Teshie. This area is known as the La stool land. Although located within the Accra Metropolitan Area (see Chapter 4) and surrounded by urban settlements, it has remained undeveloped because of a strong will on the part of the chief and local elders to retain this area for traditional farming under customary land tenure arrangements. Rainfed agriculture with some dry season irrigation is practised here by La residents for both market and home consumption (Armar-Klemesu and Maxwell, 1998; baseline survey in this research). Whilst located within the central parts of Accra, because of its particular circumstances, this area is in many ways similar to a peri-urban setting in terms of the type of agriculture that is practised here.

The trial was conducted on an open field that had been cropped annually for the previous three years. The experimental field sloped slightly to the south (2%). It was located adjacent to a small stream, enabling irrigation and continuous cropping to take place throughout the year.

At the time this research was initiated an international workshop on urban agriculture was held in Accra. As a result of this workshop the head of Agriculture Food and Fisheries within the AMA, Dr Daniel Sackey, became convinced of the importance of cycling urban waste to agriculture and decided to carry out some experiments with a couple of local farmers. Since this initiative was already underway, the decision was made to join forces with Dr. Sackey and the two farmers that he had selected for the experimentation[38]. It was felt that this would be a more appropriate approach and a better use of resources than duplicating the work. Contact was made with the farmers who at that point had already planned what they were going to do but were willing to make some modifications, such as the inclusions of blocked replicated treatments needed to make the results scientifically reliable. However, which treatments to include and crops to grow had already been determined prior to my own involvement.

The trial was based on a randomised block design with four replications. Each plot was 20 $m^2$ and was located one metre into the field in order to minimise any edge effects. Compost amendments were compared with cow manure and a no application control. In the second, and all subsequent crops a fertiliser treatment was added to the trial[39]. Only one application rate was used, in order to not make the design too complicated and to keep the trial area to a manageable size.

The researcher and the farmer together discussed and designed the trial. The farmer selected the trial location within his farm whilst the experimental layout was done by the researcher. Treatments, application rates and assessments were decided upon jointly. The farmer wanted to use cow manure and NPK as these were inputs he was familiar with from before and wanted to compare against the compost. This was particularly the case for cow manure as the farmer kept a number of livestock and used kraal manure from his cows on his fields. Consequently, this was the farmers' 'normal practice' with which compost was compared. Crop choice and decisions about day-to-day management of the crop were left entirely to the farmer to ensure that the research had relevance and fitted with local practices. However, the importance of treating each plot equally in terms of watering and weeding etc., was stressed by the researcher and fully appreciated by the farmer. Assessments and recording was done by both the farmer and the researcher, sometimes together, sometimes separately. Soil, compost and manure sampling was solely done by the researcher. The underlying idea was that the farmer would farm as usual with the only difference being the use of compost as a soil improver, within an experimental design. Therefore, the farmer would decide if and when to water, weed, spray etc.

Initially the field within which the trial was incorporated was ploughed with a tractor two months prior to setting up the trial. Beds were then constructed by hand and all subsequent cultivation was done by hand using hoes and machetes. The cropping history of the field used for the trial was recorded and is displayed in Table 5.1.

---

[38] The collaboration with one of the farmers selected failed before the first crop was harvested.

[39] The fertiliser plots were slotted onto the outer edges of each block; thus this treatment was not randomised.

*Table 5.1 Cropping history of the field prior to the initiation of the trial*

| **Crop** | **Time** | **Inputs used** |
|---|---|---|
| Tomatoes | late May/early June 1998 to late October 1998 | artificial fertiliser only |
| Maize | April 1997 to late September/early October 1997 | artificial fertiliser only |
| Tomatoes | late May/early June 1996 to late October 1996 | artificial fertiliser only |

*Source: This research*

During the lifetime of the trial compost and manure were applied to the beds four times (Figure 5.3). A total of five completed and one failed crop were grown. The cropping calendar below displays the cropping sequence and the time of soil sampling and compost and manure applications.

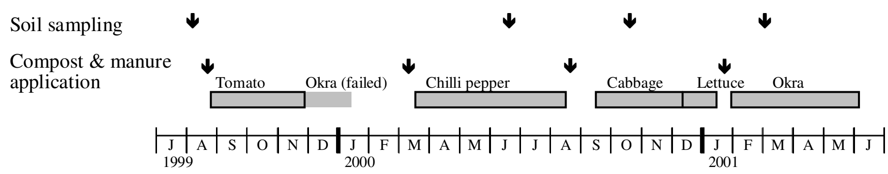



*Figure 5.3 Cropping Calendar for the on-farm trial, ( ➔ = soil sampling and compost and manure application)*

*Source: This research*

*Table 5.2 Application rates used at each of the four application occasions in the different treatments*

| | **Compost** | **Cow manure** | **Fertiliser** | **Control** |
|---|---|---|---|---|
| 1st application Tomato crop | 50 t/ha | 20 t/ha | not used | no application |
| 2nd application Chilli crop | 25 t/ha | 20 t/ha | 12 g/plant at 10 days after transplanting | no application |
| 3rd application Cabbage crop | 20 t/ha | 30 t/ha | 15g/plant at 14 days after transplanting | no application |
| 4th application Okra crop | 20 t/ha | 30 t/ha | 15 g/plant at 1 month after sowing | no application |

*Source: This research*

The cow manure used in the on-farm trial came from the farmer's own kraal. His cattle were roaming the La stool land during the day and locked up in the kraal at night. The manure was left out in the sun and rain until used. Consequently, the age and quality varied.

In line with the manure application rates recommended by the agricultural extension service, cow manure was applied at a rate of 20 t/ha for the first two applications in the on-farm trial. Later, however, the farmer wanted to increase this rate to 30t/ha as he did not feel that the results achieved were satisfactory. The higher application rate of 30t/ha was used for the third and fourth applications.

As mentioned above (Section 5.1.1), it was decided that a compost application level of 50 t/ha (5 kg/m$^2$) would be used at the first application. It could be argued that this rate is too high in view of limitations on resources such as capital, labour, transportation and organic waste availability. However, it was set on the basis of the following:

- Review of research carried out on waste derived compost use, mainly in Europe and USA (e.g. HDRA, 1998; Wallace, 1996; Stoppler-Zimer *et al.,* 1992), showed that rates ranging between 5-100 t/ha have been used. It was therefore considered appropriate to base the rate somewhere in the middle of this range.
- The animal manure application rate recommended by the agricultural services and used in local intensive crop production systems, such as the ones researched, ranges around 20-25 t/ha. Considering the very low concentrations of nitrogen in the compost (0.1-1.1%) and the fact that its bulk density is higher, the researcher and growers alike agreed that this seemed a reasonable estimate. When spread evenly on the soil the farmers thought that this application level seemed reasonable in comparison to their normal application levels of cow and chicken manure. Some growers commented that they did not think that the amount, when spread on the land, looked sufficient.
- Growers in the target cropping system and involved in this research are already using a lot of inputs and are willing to spend money on them, as the baseline survey data showed. If the research had been carried out in a rural area where farmers rely on shifting cultivation and do not spend money on external inputs, a lower rate would have been more appropriate

For the second application the compost application rate was reduced to 25 t/ha (2.5 kg/m$^2$). There were several reasons for this:

- The crop performance of tomatoes with 50 t/ha compost was much larger than with cow manure at 20 t/ha. It was clear that 50 t/ha has a marked effect and it was considered appropriate to ascertain how a reduced rate would compare.
- It was considered likely that the compost added in the first crop would still give some residual effects and thus a lower rate would be justified.
- The compost used in this second crop was richer in nutrients than the first compost used.

- Parallel work by other researchers with urban vegetable growers had indicated that juvenile vegetable plants of certain crops, for example lettuce, had a tendency to 'burn' when grown with compost at 50 t/ha. As such it seemed that this rate was too high.
- The smaller the amount a grower can apply with good results, the more likely he or she will be to use compost. Transportation is expensive and application hard work. Therefore, the lower the application rate that can be used with good results the better.

Since the second crop performed well with the lowered compost rate, and in order to avoid excess nutrient and heavy metal loading, it was decided to lower the rate further for the subsequent applications to the rate recommended for manures, namely 20t/ha. This rate was used for both the third and fourth application. (In fact, the fourth application was not intended and was only applied due to a misunderstanding between the researcher and the farmer).

The compost and the cow manure were spread evenly on the surface of the already prepared beds, and not incorporated into the soil surface. Farmers tend not to incorporate the manure and as such it was considered appropriate to follow this 'normal' farm practice also for the compost. The compost and manure were applied to the beds prior to transplanting or sowing.

The type of inorganic fertilizer used in the on-farm trial was a preparatory NPK (15:15:15) fertiliser which means that it contains 15% each of nitrogen (N), phosphorus ($P_2O_5$) and potassium ($K_2O$) (with the rest being a bulking agent). The fertiliser application rate and application method used was based on recommendations from the Ministry of Agriculture and its extension service. The method of application favoured by farmers, and recommended by the extension staff, is that of spot application to the plant. Therefore, this is what was done in the trial. The recommended rate for the crops grown is 15 g applied to each plant about 10-14 days after transplanting, or in the case when the crop is direct drilled, such as okra, when the crop is about one month old. How much fertilizer is applied per plot or hectare is therefore related to the planting density. In the case of the trial the peppers were planted at 40 plants per plot, the cabbage at 120 plants and the okra at 52 plants.

The results of the soil sampling and analysis of the composts and manures applied showed that the nitrogen, phosphorus and potassium supplied through the different materials and applications rates used over the trial period were as displayed in Table 5.3 below.

*Table 5.3 Supply of Nitrogen, Phosphorus and Potassium through compost and cow manure applications at each application, annually and in total over the full trial period, (kg/ha)*

| | **Compost** kg/ha | **Cow Manure** kg/ha | **NPK*** kg/ha |
|---|---|---|---|
| **Total N** (%) | | | |
| 1st application | 71 | 92 | |
| 2nd application | 194 | 370 | 45 |
| Year 1 | 265 | 462 | 45 |
| 3rd application | 170 | 407 | 135 |
| 4th application | 158 | 302 | 59 |
| Year 2 | 328 | 709 | 194 |
| **Total** | **593** | **1171** | **239** |
| **Total P** (%) | | | |
| 1st application | 103 | 26 | |
| 2nd application | 839 | 77 | 20 |
| Year 1 | 942 | 103 | 20 |
| 3rd application | 619 | 79 | 59 |
| 4th application | 664 | 67 | 26 |
| Year 2 | 1283 | 146 | 85 |
| **Total** | **2225** | **249** | **105** |
| **Total K** (%) | | | |
| 1st application | 273 | 314 | |
| 2nd application | 55 | 540 | 37 |
| Year 1 | 328 | 854 | 37 |
| 3rd application | 68 | 591 | 112 |
| 4th application | 36 | 631 | 49 |
| Year 2 | 104 | 1222 | 161 |
| **Total** | **432** | **2076** | **198** |

* Note that because the NPK was spot applied, the application rate on a per ha basis is comparatively low. Note also that the nutrient supplied through NPK are in an available form whilst those supplied through compost and manure are largely in an organic form unavailable for plant uptake.

*Source: This research*

As can be seen in the table above, nitrogen was supplied to the beds at a rate of 265 kg/ha in year one and 328 kg/ha in the second year. These amounts exceeded the maximum limits in, for example, Sweden (150 kg N/ha/yr) and the UK (250 kg N/ha/yr). However, it is important to bear in mind that this farming system was very different from a European system. Firstly, in Europe only one crop is grown in a year whereas in this farming system cropping is done all year round. Secondly, in this farming system mineralisation takes place all year round and rainfall, which may result in nutrient leaching, is relatively low. In northern Europe there is a dormant season without any crop growth and nitrogen uptake, coupled with a lot of precipitation and thus liability to nitrogen leaching. For cow manure, too, the amount of nitrogen supplied by the recommended rate exceeded the Swedish and UK benchmarks of 150 and 250 kg N/ha/yr respectively in both years.

The levels of total phosphorus that were supplied through the compost application rates used were very high. Because sewage sludge was used as a co-

composting agent in the municipal waste, phosphorus levels in the compost tended to be high. In fact, the high P concentration in the compost from James Town meant that it would not be possible to supply a sufficient amount of N without overloading P. With the application rates used, 942 kg P/ha was supplied in the first year and 1286 kg P/ha in the second year. This amount is considerably higher than the rates recommended on European soils. For example, in the UK recommendations for vegetable production range between 109 kg P/ha/yr for P deficient soils to 22-44 kg P/ha/yr for soils that fall within the target level (MAFF, 2000). In this context it is, however, important to bear in mind that these recommendations apply to available P. Phosphorus is immobile in the soil and much of the P supplied through compost and manure is unlikely to be available for plant uptake. In farm yard manure about 50% of the total P is typically available for plant uptake (*ibid.*). The amounts of P supplied through the compost applications led to a marked increase in both total and available P concentration in the topsoil. See Section 6.2.2 in Chapter 6 for more on this. The amount of P supplied through cow manure was 103 kg P/ha and 146 kg P/ha in year one and two respectively. This too was rather high, in spite of the fact that the application rates used were in line with the recommendations from the agricultural extension services.

Analysis of the manure and compost showed that potassium was generally higher in the cow manure than the compost. However, the K concentration in the compost produced at the Teshie/Nungua plant was very high, resulting in a high K supply from the first application when this compost was used. In year one the K supply through compost was 999 kg K/ha, compared with 74 kg K/ha in the second year. Potassium supply through cow manure applications was more stable with 854 kg K/ha supplied in the first year and 1222 kg K/ha in the second. Again, compared with the UK recommendations, the K supplied through cow manure and the first batch of compost from Teshie/Nungua was high. In the UK the recommended rate of mineral K for vegetable production is between 207 kg K/ha/yr on a K deficient soil through to 83-125kg K/ha/yr on a soil that is within the target in terms of K content (MAFF, 2000). In contrast to nitrogen and phosphorus, potassium in organic manures is more soluble and about 90% is typically in a form readily available for plant uptake (*ibid.*).

In Section 6.2.2 in Chapter 6 the effect that this had on the levels of total N, P and K in the soil will be reported.

## 5.3 The Research Process

This section sketches the process of interaction between the researcher and the growers, and the on-farm trial, and among various combinations of stakeholders.

### *5.3.1 Compost and Manure analysis*

In light of the information provided in Appendix B, it is important to know the chemical characteristics of the compost that is to be used as a soil improver. The compost used in this research was derived from organic household wastes collected by the municipal waste department and a local CBO. Much of the nutrient rich materials were removed at the household level and thus never ended in the waste stream at the composting or landfill site. Consequently, the nutritional quality of the raw materials of the compost was generally low (dry and with a high carbon, low nitrogen composition and mixed with inert materials such as sand). The household waste was co-composted with digested sewage sludge, which resulted in an increased nutrient level in the final compost. See Section 4.2.5 in Chapter 4 for more details on the composting process used (and the potential implications of this?.

The compost and manure used were sampled from each new batch prior to application. In order to ensure that the sample analysed was representative several sub-samples were taken and thoroughly homogenised. From this, a sample for analysis was taken. Because numerous sources and batches of chicken manure were used by the different growers throughout the year, sampling and analysis each time chicken manure was used was not feasible. Analysis was limited to three random samples to represent the 'typical' characteristics of the chicken manure used by growers. In addition, samples were taken of the sewage sludges used in the co-composting operations at both Teshie/Nungua and James Town. Below is a more detailed account of the number of samples of the different materials analysed:

<u>Composts:</u>

- The compost from the Teshie/Nungua plant was analysed twice. The first sample was taken at the time of the initiation of the experiments and the compost from this batch was used for the first application in both the on-farm trial and the vegetable growers' experiments.
- The second sample was taken to provide a comparison and to help validate the first sample. This was considered relevant as the analysis results of the first sample showed some surprising results (very low nitrogen content, high mercury and lead content)
- The compost from James Town was sampled for analysis three times. The first sample was from the batch used for the second application in both the on-farm trial and the vegetable growers' experiments.
- The second sample was taken from the compost used for the third application in the on-farm trial. Compost from this batch was also delivered to the vegetable growers and used by some of them (the ones that put a third application on their beds).

- The third sample of the James Town compost was taken from the batch used for the fourth and final application in the on-farm trial.

*Cow manure:*

- The cow manure samples were from each of the batches used in the on-farm trial.

*Chicken manure:*

- The chicken manure samples were taken from three different batches used by vegetable growers. They source their manure from different poultry growers, and store the manure for a varying length of time. Consequently, the properties of the manure are variable. Because of the number of vegetable growers involved in the experimentation, and the fact that they grow vegetable crops on a continuous basis and apply chicken manure to each and every crop, it was impossible to analyse the manure applied to each crop. The three samples taken and analysed serve as a guide to the typical nutrient characteristics of the chicken manure used by vegetable growers in Accra.

*Sewage sludge:*

- Two types of composted sewage sludge were analysed. The sewage sludge from the Dogo site was used for co-composting the waste at the James Town site, whilst the sludge from Teshie was used in the Teshie composting process. The origin of the sludge was domestic nightsoil from various types of latrines and septage (from septage tanks), which had been stabilised under anaerobic conditions in wastewater stabilisation ponds. The settled solids had been dredged from the sedimentation pond and co-composted with sawdust. The origin and processing of the sludges were similar but the age of the sludge differed; the sludge from Teshie was stored for longer and was more mature and weathered.

The chemical analysis of the compost and manure samples was carried out by Natural Resource Management Ltd. in Berkshire, U.K. using the BS4156, 1990, U.K. standard nutrient extraction method for growing media.

Microbiological analysis was also carried out on the compost. This was done by the Veterinary Laboratory of the Animal Health and Production Department of the AMA, where fresh samples of the composts and manures were screened for *Salmonella* and coliforms.

### *5.3.2 Soil sampling and analysis*

The soil of the on-farm trial field and selected experimental beds in the vegetable growing areas were sampled initially to ascertain their chemical nutrient status prior to compost amendments. In the on-farm trial the soil was subsequently sampled three more times at approximately six-monthly intervals in order to monitor changes in nutrient status and organic matter content.

Sampling points were determined through the systematic application of a grid. The soil was sampled initially and subsequently three more times at approximately six-monthly intervals to monitor changes in nutrient status and organic matter content. Sampling was done during the active growing phase of the crops when nutrient demand and uptake was high (Brookes, pers. comm., 2001). Using a Dutch auger, 10 sub-samples were taken from each plot and pooled as a composite plot soil sample. The samples were air dried and passed through a 2mm mesh in preparation for the laboratory analysis. For the first, baseline, sample two horizons were sampled, 0-15 cm and 15-30 cm. For subsequent samples only the upper horizon was sampled as the cost of analysis proved prohibitively expensive. Similarly, because of the cost of analysis, the samples from each plot were pooled further, in that the samples from each treatment from each block were combined to produce an overall treatment sample. Consequently, the analysis results were limited to treatment means only.

Chemical soil analysis was carried out by Natural Resource Management Ltd. in Berkshire, U.K. The procedures used are those outlined by MAFF/ADAS British Standard 3882). The analysis done is listed in A1.1 Appendix A.

In addition to soil chemical analysis soil texture and colour was assessed using the FAO system and Munsell's Soil Colour Chart (1990). The soil from the NPK beds was not analysed. Since the fertiliser was applied using a spot application method, it was felt that the results from a soil analysis would be too arbitrary to be meaningful.

### *5.3.3 Crop assessment*

In both the on-farm trial and the vegetable growers' experiments, crop performance was monitored during the growing period, as was any differences in weed occurrence, pest and disease infestation and water requirement. The on-farm trial farmer and his assistant had a logbook in which they recorded their operations and observations. The researcher was present during the setting up of the trial and at harvest times. In between regular visits were made to observe the trial and discuss the work with the farmer. In the vegetable growers' experiments the researcher and her assistant were not always present at planting and compost and manure applications, but regular visits were made during the growing period and, whenever possible, they were present at harvest to make assessments.

The assessments done varied somewhat according to the nature of the crop grown. They included:

*Vegetable growers' experiments*

- Plant count following transplanting and approximately two weeks following transplanting to assess the extent of die offs.
- Weight of 10 lettuces (or pieces of crops) per bed
- Diameter, height or circumference of 10 crops per bed
- Uniformity on an overall plot level using a scoring index from 1-5
- Extent of 'burning' / dying off on an overall bed level

- Differences in weediness

*On-farm trial*

- Emergence (only on okra since all other crops were transplanted)
- Count of dead and non-viable plants (on the first day of harvest)
- Uniformity on an overall plot level using a scoring index from 1 to 5
- Overall plot score for size/vigour & bushiness of plants on a scale of 1 to 5
- General description of plant colour differences between plots
- Height and width of 10 plants in each plot excluding the edge plants
- Fresh weight from each plot at each harvest date. (For cabbages, fresh weight of 10 heads per plot)
- Number of tomatoes, chillies and okras harvested in different size categories at each harvest occasion
- Differences in weediness.

As can be seen, some assessments were of a 'hard' 'objective' nature whereby the crops were counted, measured and weighed. Other assessments were more 'subjective', based on visual appearance and scoring on an overall plot basis, using indices on a scale from low to high. Visual scoring is a common method of assessment in horticultural research. It complements the measurement assessments to help gain a full picture of the performance of the crop and detect any differences between treatments.

### *5.3.4 Monitoring*

The researcher and/or her assistant visited each of the vegetable growing areas every week to see how the growers were getting on and to make sure not to miss out on too many assessments at harvest times. Experience elsewhere has shown that collection of quantitative data necessitates frequent contact between farmers and researchers, and that the quality of assessments increases where the researcher shows strong interest in the experimental activities (Hagman and Chuma, 2002). In addition to weekly visits to meet with the growers on an individual basis in order to discuss and record their observations and opinions, regular group meetings were held with growers in each of the three areas. These meetings were not just attended by the participating growers but also by surrounding growers who took an interest in the experimental activities and who were interested in learning about the outcomes. Each meeting was attended by approximately 20 people and lasted for about two hours. During these meetings information regarding the outcomes of the experiments was shared and ways to carry on discussed. Also general information about their farming and livelihood system were explored with the aid of a series of different PRA tools such as matrix ranking and Venn diagramming

The on-farm trial was also visited on a regular basis, sometimes to carry out crop or soil assessments, sometimes just to monitor how things were progressing. Some of these visits were lengthy during which the researcher would spend time chatting to the farmer and his assistant, frequently while helping with field activities such as weeding. On a few occasions the extension officer for the area came to the trial to have a look at what was going on. Neighbouring farmers would also visit the trial area occasionally to talk with the farmer about the work he was doing. Visits to the trial by other farmers and the local extension officers were encouraged and took place as organised activities and spontaneously. The farmer was always keen to explain his work to interested colleagues.

Towards the end of the experimental period a multi stakeholder workshop was held with the aim of bringing together and sharing experiences, to learn from the farmers about the outcomes of the research, and to explore the potential for using waste derived compost in the future. The workshop was held adjacent to the location of the on-farm trial which enabled the participants to observe the trial and the farmer to present his findings and experiences.

A mixture of farmers, agricultural extension staff, waste management professionals and researchers participated in the workshop. The multi stakeholder meeting allowed

- Farmers to meet each other to share experiences, and inform those who had not been actively involved in the experimentation;
- The waste management and agricultural extension sector to be informed by the farmers and researchers about the main findings of this research;
- Farmers to meet compost makers, and vice versa, and to explore market potential;
- A discussion on whether or not the use of composted city waste in agriculture has a future, to highlight where the constraints and opportunities are from the perspective of the different stakeholder groups present, and what, if anything, can be done by these groups to overcome the main constraints.

### *5.3.5 Data analysis*

Quantitative crop performance data was entered into a coded spreadsheet and analysed using both Excel and Genstat. The randomised block design of the on-farm trial enabled conventional statistical analysis to be carried out on the data generated. The quantitative data generated from this trial was analysed using ANOVA. In order to ascertain the overall differences between treatments and any cumulative benefits in crop growth resulting from repeated compost applications over time, the harvest data were normalised, allowing them to be added together in order to examine the overall treatment differences, as well as for the analysis of the underlying plot/plot variability (Mead, pers comm., 2002). By normalising the values, all crops can be combined, taking into account the differences between the crops (i.e. the fact that a cabbage head weighs much more than a tomato and that there are more tomatoes harvested from a plot than there are cabbage heads).

The analysis of the quantitative data generated from the vegetable growers experiments was less straightforward because of the unscientific experimental design and the multiple sources of variation between data sets. These data were grouped according to the various sources of variation, such as area, soil type, dry/rainy season, crop in relation to the latest compost application (i.e. first, second or third crop, following the first, second or third compost application). Hierarchical analysis of variance was then carried out for each variable. In order to enable all crops to be analysed together (i.e. to enable an overall crop analysis), the standardised difference between treatment means was calculated, which allowed the size of the difference between the treatments, regardless of crop, to be examined.

The socio-economic data gathered from surveys, SSIs, group discussions and PRA activities were analysed in Excel and where appropriate Chi-square analysis was used. Qualitative data and information gathered from individual conversations and interviews held with farmers, and from the farmer group meetings during the course of the experimentation were analysed using a thematic approach in which different sources of data and information were used together in varying combinations to address different sub-questions. The qualitative data and information proved invaluable in gaining an understanding of the growers' livelihood system and in identifying constrains and opportunities to linking waste to agriculture. Whilst valuable in its own right, the qualitative data and information were also useful in enriching the quantitative data. The way data and information gathered through participatory methods from different stakeholders at different times during the research was used is displayed in Figure 5.4.

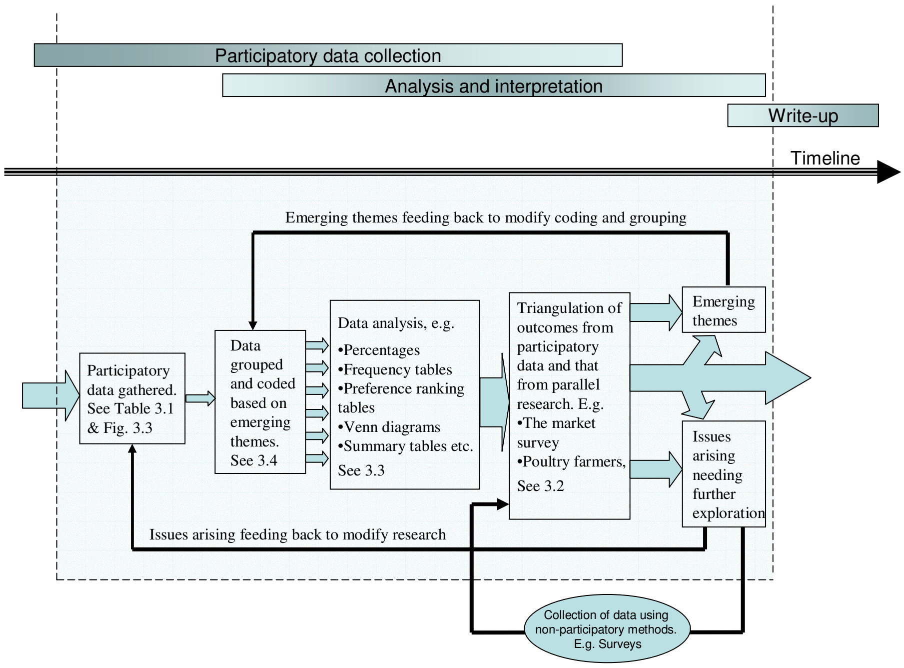



*Figure 5.4 Diagrammatic representation of the research process with regards to the use of participatory data collected*

*Source: This thesis*

## 5.4 Reflection on the researcher's role in process management

As I immersed myself in the experimentation with the growers I was aware that I was a participant in the research process, an instigator of change, and as such my involvement flavoured the process and affected the outcome of the research. By taking a pro-active role as a change agent rather than remaining solely a passive observer, the process merged research, development and intervention merged.

Being a white outsider I generated interest among many of the growers. Some wanted to be part of the experimentation because they were interested in finding out about the technology or were interested in experimentation. Others were more interested because of perceived benefits of being involved with a white outsider. As time progressed I became more aware of the different motivations for participating in the experimentation and I became aware that my presence generated both interest and jealousy. I came to realise that there were unintended relationships of power between me as an outsider and the growers, as well as among the seemingly homogenous group of growers. Because of this, the process of farmer selection, in which I played a major role, influenced the subsequent research and learning process.

Whilst a good open and honest relationship was developed with the growers, I remained an outsider and our worlds remained wide apart. I was aware that there are lots of relevant things that people will not say in 'public' or will not say to strangers they do not trust. It is difficult for an outsider to communicate effectively and to gain trust and openness. I made it a priority to always be honest in my communication with the growers and never promise anything I could not deliver. It was important for me, as an outsider, to contribute something to the process (i.e. knowledge of and information on the agroecosystem and practical experience of the technology being tested), and to build a relationship of credibility and accountability. Furthermore, in my role as a facilitator I strived to stimulate an atmosphere which was non-threatening and inclusive, where everyone got a chance to speak and be listened to. The focus was on group interaction and information sharing. Hagman and Chuma (2002:27) note that "*Facilitation is about asking the right questions at the right time in order to enhance peoples' critical self-reflection, discovery and self-awareness without pre-empting the responses. Facilitators lead the process but not the outcome and direction. The major difficulty is the 'steering' of the facilitation process which means to recognise and empathise situations, moods, group dynamics etc. and react with the right question and pattern to it*." These principles of facilitation underpinned my interaction with the growers.

The initial introduction, farmer selection, relationship building as well as design and implementation of the experimentation all was done by the researcher and her assistant. There were benefits and disadvantages in working this way. I found that researching in isolation from a larger project did have its benefits. It allowed me to develop a close working relationship with the growers, to be flexible, and to be responsive to emerging issues. I had the freedom to make my own choices and respond to the need for changes. The drawbacks of working in isolation from a larger group of colleagues are the limitations in term of time, staff capacity and resources. The limited impact and kudos that the project commanded had as a consequence, a limited ability to engage key actors such as the extension officers. Repeated and varied efforts were made to create links with the extension services and to create some form of involvement by them in the areas where the experimentation was carried out. However, success was unfortunately very limited. Chapter 8 and the end of Chapter 6 provide further reflective discussion on the research process and my experience of it.

# CHAPTER SIX – EXPERIMENTAL RESULTS

## Introduction

This Chapter reports the findings of (the) growers' experiments to test the effect of using MCW in vegetable production systems. The first part (Section 6.1) presents the results of compost and manure analysis and makes comparisons with results from other research. The second part reports the findings of the soil analysis, both in the vegetable growers' areas and the on-farm trial. In the on-farm trial changes in soil chemical properties as a result of repeated applications are given (Section 6.2). This is followed by the results of the cropping experiments with the vegetable growers', both in terms of crop harvest assessments and growers' assessments of the performance of compost in comparison with chicken manure application (Section 6.3). Section 6.4 reports the crop results of the on-farm trial. The chapter concludes with a reflection on the researcher's role in the research process (Section 6.5).

## 6.1 Compost and Manure Analysis Results

**Plant nutrient content**

Table 6.1 gives the total nutrient content, C:N (carbon:nitrogen) ratio and organic matter content of the composts, manures and sludges analysed. This analysis gives an indication of the potential nutrient value of the material. Although the proportion of the nutrients are in an organic form not available for plant uptake, it gives an indication of what might become available through mineralization and microbial digestion over a period of time.

Table 6.2 provides a comparison, giving the range and median for the analysis of composts from 68 different municipal waste composting sites in the UK. These waste composts were derived from source-segregated 'green waste' (vegetative waste from parks and private gardens), and are therefore of a different nature to the Accra composts which contains a wider range of waste materials and includes human waste. The chemical analysis displayed in Table 6.2 was carried out by the ADAS laboratory in the UK using the same methods of analysis employed by NRM in this research. Water extractable analysis was carried out to ascertain the available nutrient content of the composts and manures used in this research (Table 6.3). Again, the median and range of the results for analysis of 68 municipal greenwaste composts in the UK are given as a comparison (Table 6.4). Table 6.5 gives examples of total nitrogen (N), phosphorus (P) and potassium (K) contents of different organic wastes according to data from the Agricultural Development and Advisory Service (ADAS) in the UK (Cooke, 1975), whilst Table 6.6 provides examples of the nutrient content of different composts derived from municipal waste from different cities.

The analysis reveals that the N content of the composts was lower than that of the animal manures, particularly the chicken manure. Bearing in mind that a relatively large proportion of the N in fresh chicken manure is in the form of ammonia which is available to plants, the fertiliser value of chicken manure is clearly superior to that of compost. According to Cooke (1975:16) "about half of the total N in droppings and deep litter is equivalent to inorganic fertiliser" if added to moist soil. The N content of the compost from Teshie was particularly low. This is likely to be because:

(1) The compost had been stored at the composting site for a very long time (several years).

(2) The very low organic matter content of this compost indicates that much of the compost contained inert materials such as sand and soil. Much of the waste consists of street sweepings which, to a large extent are made up of sand and soil. Similar findings (i.e. a high proportion of soil in the compost from street sweepings) were reported from a research project on the potential for using urban waste in soil management in Hubli-Dharwad in India (DFID, 2000). The physical appearance of the compost from Teshie was reminiscent of black sandy soil. It was very heavy, with a finely textured, dusty appearance.

(3) Furthermore, it contained charcoal indicating that the windrows had caught fire, causing much of the organic material to burn, resulting in nutrient losses. Conversations held with staff at the composting site confirmed this to be the case. This also explains the low carbon content of the Teshie compost.

All the compost samples revealed potassium (K), carbon (C) and organic matter (OM) contents lower than those of the animal manure samples. Also, carbon was found to lie at the lower end of the range of values of the 68 samples of UK composts analysed by HDRA (Table 6.2). The compost produced at the James Town site was also made up of raw materials that contained a significant proportion of street sweepings. However, they did not suffer from the problem of the compost piles igniting causing loss of organic matter. Therefore, both the organic matter and the carbon contents were found to be higher in the James Town compost compared with the Teshie one, albeit lower than in the animal manures.

In terms of nitrogen availability, the C:N ratio is an important indicator. If the carbon content is too high in relation to nitrogen (N), the N in the compost and in the soil becomes locked up (i.e. immobilised) causing N starvation to plants (Edwards, 1995). Immature compost can have this effect. Iglesias-Jimenzes and Alvarez (1993:313) note than

> "*a wide range of results have been obtained in relation to the efficiency of compost as a source of N for plants because N availability is closely related to compost maturity. Immature composts induce a considerable increase in soil microbial activity to decompose the excess of labile C compounds, potentially causing a strong immobilisation of native and added available N, and consequently, N starvation and depressive effects on crop plants may occur.*"

In order to ensure a good composting process, a suitable C:N ratio for waste material is 25 to 35 (Inglesias-Jimenez and Garcia, 1992). Once the composing has finished, and the material has stabilised, the C:N ratio falls. The C:N ratio of the composted end product is an indicator of the compost's maturity. According to Inglesias-Jimenez and Garcia (1992), a C:N ratio of 20 is indicative of an acceptable maturity of the final product, a ratio of 15 or even less being preferable.

According to the HDRA composting association (HDRA Consultants Ltd, 1999) in order for composts to release 10% of the total N during the first growing season following application, the C:N ratio needs to be below 30. A C:N ratio above 30 is likely to cause problems of N immobilisation. As can be seen in Table 6.1 the C:N ratio of all the compost samples from both sites is low, indicating that the compost was well stabilised and mature. Thus N immobilisation following application to soil should not present a problem.

*Table 6.1 Total plant nutrients and carbon content and physical analysis of composts, manures and sludges, (%) The results are expressed on a dry weight basis*

| | Total N | Total P | Total K | Total C | C:N Ratio | OM content | Dry matter |
|---|---|---|---|---|---|---|---|
| Teshie Compost 1 | 0.17 | 0.25 | 0.65 | 4.83 | 23 | 8 | 83.9 |
| Teshie Compost 2 | 0.37 | 0.59 | 0.4 | 4.49 | 12.1 | 11.2 | |
| James Town Compost 1 | 1.11 | 4.8 | 0.31 | 7.94 | 7.1 | 20.2 | 69.9 |
| James Town Compost 2 | 1.15 | 4.2 | 0.46 | 6.42 | 5.6 | 24.5 | 73.7 |
| James Town Compost 3 | 0.97 | 4.1 | 0.22 | 8.39 | 8.6 | 20.8 | 81.4 |
| Chicken manure 1 | 2.43 | 1.63 | 1.44 | 36.29 | 14.9 | 69.4 | 87.7 |
| Chicken manure 2 | 2.56 | 1.35 | 1.47 | 43.66 | 17 | 83.7 | 84.4 |
| Chicken manure 3 | 2.79 | 2.19 | 2.23 | 24.4 | 8.7 | 49.4 | 85.5 |
| Cow manure 1 | 0.55 | 0.15 | 1.89 | 17.9 | 32.5 | 25.6 | 83.2 |
| Cow manure 2 | 2.09 | 0.43 | 3.05 | 35.75 | 17.1 | 68.5 | 88.6 |
| Cow manure 3 | 1.82 | 0.35 | 2.65 | 33.2 | 18.2 | 62.5 | 74.5 |
| Cow manure 4 | 1.24 | 0.28 | 2.59 | 27.6 | 22.3 | 55.7 | 81.2 |
| Sewage sludge Dogo site | 1.32 | 6.17 | 0.63 | 7.43 | 5.6 | 23.9 | 66.6 |
| Sewage sludge Teshie | 0.58 | 1.36 | 0.32 | 4.64 | 8 | 16.4 | 76.3 |

*Source: This research*

*Table 6.2 Median and range of total plant nutrients and organic matter content (%) of 68 different source segregated municipal 'green wastes' in the UK, composted in open-air windrows for a minimum of 12 weeks*

| | N | P | K | C | C:N | OM |
|---|---|---|---|---|---|---|
| Median | 1.1 | 0.2 | 0.69 | 13 | 12 | 19 |
| Range | 0.55-7.6 | 0.07-2.0 | 0.2-1.6 | 6-37 | 5.5-52 | 9.9-82 |

*Source: Values derived from the database of the Compost Analysis and Testing Service of HDRA Consultants, 1999*

*Table 6.3 Water-soluble analysis/water extractable elements of composts, manures and sludges, (mg/l)*

| | **pH** | **Electrical conductivity** µS/cm | **P** | **K** | **Mg** | **Ca** |
|---|---|---|---|---|---|---|
| Teshie Compost 1 | 7.3 | 1738 | | | | |
| Teshie Compost 2 | 7.5 | 2103 | 156.4 | 1801.3 | 287 | 204.9 |
| James Town Compost 1 | 7 | 2987 | 1029.1 | 971.5 | 1730.8 | 440.5 |
| James Town Compost 2 | 6.1 | 5145 | 1446.9 | 1540.3 | 3520.6 | 1404.3 |
| James Town Compost 3 | 6.7 | 2536 | | | | |
| Chicken manure 1 | 8.8 | 2232 | 509.5 | 1737.9 | 116.1 | 129.7 |
| Chicken manure 2 | 9 | 1009 | 221.9 | 1249.8 | 25 | 28.7 |
| Chicken manure 3 | 8.7 | 3420 | 379.4 | 5926.9 | 162.4 | 206.7 |
| Cow manure 1 | 9 | 4645 | | | | |
| Cow manure 2 | 9.3 | 3444 | 64.3 | 6576.3 | 103.3 | 89.1 |
| Cow manure 3 | 8.7 | 3753 | | | | |
| Cow manure 4 | 8.8 | 3667 | | | | |
| Sewage sludge Dogo site | 6.3 | 5091 | 1318.5 | 2137.5 | 3030.2 | 1054.8 |
| Sewage sludge Teshie | 6.5 | 3340 | 501.3 | 1348.8 | 1530.4 | 754.2 |

*Source: This research*

*Table 6.4 Median and range of water extractable analysis of 68 different source segregated municipal 'green wastes' in the UK, composted in open-air windrows for a minimum of 12 weeks, (mg/l)*

| | pH | EC, µS/cm | Phosphate | Potassium | Magnesium |
|---|---|---|---|---|---|
| Median | 8.7 | 773 | 15 | 1210 | 17 |
| Range | 6.2-9.4 | 80-2290 | 3-73 | 65-3230 | 5-54 |

*Source: Values derived from the database of the Compost Analysis and Testing Service of HDRA Consultants, 1999*

The Teshie compost was extremely low in N and C. The other surprising result of the composting analysis was the extremely high P content of the James Town compost. The P concentrations in the compost samples from James Town compared with those of analysis results from other research reveals that the P levels from the James Town samples were about 4 times as high. Composted municipal waste from Bangkok (Polprasert, 1996) contained 1.67% P, from Santa Cruz in Tenerife (Iglesias-Jimenzes and Alvarez, 1993) 1.25%, and from Perguia in Italy (Businelli, 1996) 0.9% (See Table 6.4). As can be seen in Table 6.2 P levels in composted municipal greenwaste in the UK lie in the range of 0.07-2%, (whilst the values given by Cooke (1997) in Table 6.3 show a lower range of 0.04-0.9% for municipal waste (type unspecified)). The source of the P in the James Town compost is the sewage sludge. The analysis results reveal that the mixing of sewage sludge with the municipal waste produced a compost with concentrations of soluble salts (particularly P and magnesium (Mg)), higher than those typical of compost.

The Dogo sewage sludge had a total P content of 6.17% and soluble P of 1319 mg/l. Sewage sludge is known to be rich in phosphorus, but the sludge from the Dogo site was exceptionally high in P. Johansson *et al.* (1997:10), for example note that: "*Sewage sludge often contains considerable quantities of P and may thus replace fertilisation with artificial fertilizers*." During the course of the study reported in this thesis, the suspicion grew that the staff at the James Town composting site were mixing sewage sludge with the municipal waste at a higher rate than initially designed and officially admitted. The analysis seems to support this suspicion.

*Table 6.5 Mean and range of the major plant nutrients in different organic wastes, based on data from the Agricultural Development and Advisory Service (ADAS), UK, (%)*

| | **Nitrogen** | | **Phosphorus** | | **Potassium** | |
|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range |
| Poultry manures | | | | | | |
| - *Deep litter* | 1.7 | 0.3-3.5 | 0.9 | 0.04-2.3 | 1.1 | 0.17-2.1 |
| - *Broiler litters* | 2.3 | 0.4-3.6 | 0.9 | 0.09-1.7 | 1.1 | 0.25-2.0 |
| - *Battery* | 1.5 | 0.5-4.5 | 0.5 | 0.13-2.1 | 0.6 | 0.17-3.3 |
| Cattle FYM | 0.6 | 0.3-2.2 | 0.1 | 0.04-0.9 | 0.5 | 0.4-1.2 |
| Sewage sludge | 1.0 | 0.1-2.7 | 0.3 | 0.04-2.1 | 0.2 | 0.01-0.7 |
| Municipal town refuse | 0.5 | 0.3-1.0 | 0.2 | 0.04-0.9 | 0.3 | 0.17-1.3 |

*Source: Cooke, 1975*

*Table 6.6 Examples of the nutrient content of different composts derived from mixed municipal waste of different cities.*

| | **Composted municipal refuse from:** | | | **Municipal solid waste (MSW) compost from Hubli-Dharwad, India [4]** | | |
|---|---|---|---|---|---|---|
| | **Bangkok [1]** | **Santa Cruz de Tenerife [2]** | **Perugia, Italy [3]** | **MSW only** | **MSW + Distilled sludge** | **MSW + Nightsoil** |
| N % | 2.58 | 3.1 | 1.9 | 0.42 | 0.7 | 0.6 |
| P % | 1.67 | 1.25 | 0.9 | 0.34 | 0.35 | 0.56 |
| K % | 0.58 | 3.83 | 1.1 | 0.95 | 0.97 | 1.07 |
| Mg % | 0.49 | 0.87 | | 0.8 | 0.8 | 1.3 |
| Ca % | 6.2 | 9.29 | | 3 | 4.4 | 3.2 |
| Fe % | 4.4 | 1.82 | | | | |
| Copper % | 0.09 | 0.046 | | | | |
| Zn % | 0.3 | 0.1 | | | | |
| pH | 7.2 | | 7.6 | 8 | 7.3 | 7.6 |
| Cu mg/kg | | 463 | 240 | 2.6 ppm | 2.5 ppm | 2.9 |
| Zn mg/kg | | 1043 | 674 | 5.5 ppm | 5.1 | 5.2 ppm |
| Pb mg/kg | | 224 | 750 | | | |
| Cr mg/kg | | 73 | 81 | | | |
| Ni mg/kg | | 58 | 52 | | | |
| Cd mg/kg | | 2 | 5 | | | |
| Hg mg/kg | | 2 | | | | |

*Sources:*

1. *Polprasert, 1996*
2. *Iglesias-Jimenzes and Alvarez, 1993*
3. *Businelli et al., 1996*
4. *School of Public Policy et al., 2000*

Apart from P being extremely high and C being slightly low, the total content of OM and other nutrients in the compost from James Town falls within the range typical of that of composted waste (Tables 6.2 and 6.5).

The electrical conductivity (EC) gives an indication of the overall amount of dissolved salts. In composted material it usually falls between 400 and 2000 uS/cm (HDRA, 1998). Both the Teshie and the James Town composts had high EC values, similar to those of the animal manures. This was mainly caused by the high soluble K in the Teshie compost and high concentrations of soluble P and Mg in the James Town compost. The source of these high concentrations of soluble nutrients appears to be the sewage sludge. High EC values can have toxic effects on germinating plants and juvenile seedlings if compost is applied at high rates and/or the compost or manure is in close contact with the roots. The problems associated with high conductivity (i.e. stunting and die-off) are usually only an issue in container growing, and usually not found in field production where the concentrations tend to be lower (HDRA, 1998). Analysis was done also to determine soluble N (i.e. Ammonia N and Nitrate N). However, because of the volatile nature of nitrogen and the fact that the samples had to be stored before analysis could be carried out, the results are not meaningful.

The cow manure used in the first application had a lower nutrient content than subsequent batches. The nutrient content of animal manures varies greatly depending on feeding regimes and the manure management employed (Lekasi *et al.*, 1998). Open air and sun dried kraal manure is typically low in nutrients (Tanner and Murwira, 1984; Tenywa, *et al.,* 1999), so the nutrient properties of the manure in the first application sample might not be untypical. The manure used in the first application had been stored longer than that for subsequent applications, which explains the low N content. In fact, the N content was so low, and thus the C:N ratio so high (32.5) that there was a risk of immobilisation of soil N through applications of this manure. All the samples of cow manure were rich in potassium, as may be expected in cattle manure. The majority of K (90%) in farm yard manure is in a soluble form available for plant uptake (MAFF, 2000).

The chicken manure was considerably richer in N than the cow manure and the composts, and, in accordance with properties typical for chicken manure (e.g. Cooke, 1975), P concentrations were in excess of those of the cow manure. Whilst the K content in the chicken manure samples was substantially higher than in the compost ones, it was slightly lower than in the cow manure. These results are in line with Cooke's (1975:16) who states that "*fresh poultry droppings contain twice as much N as FYM, they are much richer in P and contain about as much K as FYM*". Edwards et al. (1995) note that poultry manure litter can be a source of P contamination to soil and water when applied at excessive rates. They report that the P in poultry litter collected from 147 poultry houses in Alabama ranged between 0.61 and 3.9% on a dry weight basis with an average P content of 1.6%. In view of this, compost of the kind produced in Accra would fall into the category of composts which may carry the risk of P contamination when applied to land. Both Zn and Cu concentrations were higher in the chicken manure samples than in the other materials. The pH was higher in the animal manures than in the composts and sludges.

**Heavy Metal Contents**

This section presents the results of the heavy metal analysis carried out on the composts and manures and compares these with other composts (Tables 6.6 and 6.8). Table 6.7 show the heavy metal concentrations of the composts, manures and sludges analysed in this research. Table 6.8 shows the medium and range of the results of an analysis of 68 composted green wastes in the UK (HDRA Consultants Ltd., 1999) and analysis carried out on a compost sample taken from the Teshie/Nungua site in 1997, as part of a UK funded research project.

*Table 6.7 Potentially toxic elements of composts, manures and sludges, (mg/kg)*

| | Cadmium Cd | Copper Cu | Lead Pb | Chromium Cr | Nickel Ni | Zinc Zn | Mercury Hg |
|---|---|---|---|---|---|---|---|
| Teshie Compost 1 | 1.15 | 52.6 | 158 | 38.9 | 19.5 | 285 | 0.2 |
| Teshie Compost 2 | 0.47 | 60.1 | 56.4 | 66.2 | 16.7 | 245 | 1.5 |
| | | | | | | | |
| James Town Compost 1 | 0.76 | 40.7 | 34.2 | 12.9 | 10.4 | 241 | 0.28 |
| James Town Compost 2 | 0.33 | 35.8 | 26.5 | 14.4 | 11.6 | 254 | 0.5 |
| James Town Compost 3 | | 29.4 | | | | 233 | |
| | | | | | | | |
| Chicken manure 1 | | 21.1 | | | | 286.5 | |
| Chicken manure 2 | 0.27 | 16.7 | 2.31 | 2.07 | 2.79 | 117.2 | 0.1 |
| Chicken manure 3 | 0.56 | 39.5 | 5.58 | 10.1 | 6.92 | 358 | 0.11 |
| | | | | | | | |
| Cow manure 1 | 0.36 | 14.5 | 4.5 | 14.1 | 6.25 | 62.6 | 0.06 |
| Cow manure 2 | | 18 | | | | 99.9 | |
| Cow manure 3 | | 11.2 | | | | 53.7 | |
| Cow manure 4 | | 13.4 | | | | 61.3 | |
| | | | | | | | |
| Sewage sludge Dogo site | 0.28 | 32.7 | 32.2 | 16.5 | 9.3 | 227 | 0.32 |
| Sewage sludge Teshie | 0.77 | 52.9 | 189 | 24.5 | 11.9 | 333 | 0.27 |
| Baseline soil sample from on-farm trial field (Aug, 1999) *0-15 cm* | 0.23 | 19 | <0.01 | 75 | 25 | 22 | 0.05 |
| *15-30 cm* | 0.2 | 22 | <0.01 | 79 | 28 | 31 | 0.06 |

*Source: This research*

*Table 6.8 Heavy metal analysis results of Teshie/Nungua compost in 1997 and median and range of total PTE content of 68 different source segregated composted 'greenwastes' that have been composted in open-air windrows for a minimum of 12 weeks, (mg/kg)*

| | Teshie Compost 1997 | UK municipal greenwaste composts | |
|---|---|---|---|
| | | Median | Range |
| Cd | 0.79 | 0.49 | 0.1-2.9 |
| Cu | 123 | 44 | 12-288 |
| Pb | 64 | 107 | 12-216 |
| Cr | 25.5 | 19 | 5.9-157 |
| Ni | 15.7 | 18 | 7-67 |
| Zn | 570 | 185 | 75-656 |
| Hg | 0.78 | 0.17 | 0.01-1.6 |

*Sources: 1. Harris and Smith, 1997; 2. Values derived from the database of the Compost Analysis and Testing Service of HDRA Consultants, 1999*

Appendix B provides information on the potential risks involved in using soil amendments containing heavy metals. Various European standards for permissible concentrations in composts and other organic amendments are also provided along with a discussion of the considerable differences of opinion about what constitutes safe concentrations and application levels. Whilst European conditions are different from those of the tropics and a direct transfer of recommended guidelines from one context to another may not be particularly appropriate, guidelines for the permissible heavy metal concentrations in soil amendments are lacking for Ghana. The European standards thus are useful as a benchmark against which to judge the quality and potential usefulness of the composted waste produced in Accra

In comparing the results of the analysis of the study samples with the European guidelines given in Appendix B, it can be seen that all the composts and manures were below the critical limits for copper, chromium and nickel. The cadmium level in the first sample from the Teshie compost was above the maximum permissible level for some of the more stringent standards (Austria, Netherlands, Denmark and EU ecolabel) and the lead concentration in this sample was too high to pass as acceptable. So too was the lead, and less so also the chromium concentration in the (composted) sewage sludge from Teshie that was used to co-compost the municipal waste (although the batch of sewage sludge sampled was not the same one that went into the compost sampled).

Graphs B2.1 a-g in Appendix B show the concentrations of each of the heavy metals analysed in the different materials and the maximum permissible limits according to the criteria for the German RAL and the EU Ecolabel standards.

The compost samples from the James Town compost and the sewage sludge from the Dogo site (which was used in the co-composting process for this compost) were all within the acceptable limits except for zinc and cadmium (first sample only) according to the most stringent standards (i.e. EU 'eco-agric', UK UKROF and Austria class A, see Appendix B). Two out of the three chicken manure samples were also above the maximum permissible rates for zinc, according to these standards. Zinc is one of the most ubiquitous and abundant elements in the human environment and is regarded as one of the more difficult elements to manage in the general environment (Baird *et al*., 2005). It is difficult to keep concentrations within the permitted levels and much of the composted wastes and animal manures fail to fall within the limits (Lennartsson, pers comm., 2000). The higher zinc levels in the chicken manures are thought likely to originate from the poultry feed.

The cow manure samples fell well within the acceptable limits for the elements analysed according to all the European regulations used as examples. The cows from where the manure came are extensively reared without external feed concentrates, so zinc and other heavy metal concentrations were expected to be low. With the notable exception for zinc in chicken manure, the municipal composts, and in particular the compost from Teshie, had generally higher concentrations of lead, nickel, mercury, copper and chromium (Teshie compost only), than the animal manures. The reason why the compost produced at the Teshie plant tended to have higher rates of heavy metals than the one produced in

James Town was likely to be because the waste was not source separated at Teshie. The waste was simply put into windrows straight from the waste collection trucks and capped with composted sewage sludge. Because of operational constraints the windrows were left for long periods of time before the material was sieved and the organic fraction separated out. When the composting production was resumed, material was produced by simply sieving out the organic, decomposed fraction of the old windrows. At the time of taking the first sample of this compost the plant had been shut down for almost two years. During this time heavy metals from ferrous materials, batteries, plastics, various dyes etc. had plenty of time to contaminate the organic fraction of the waste. The analysis results of the two sewage sludge samples taken indicate that the sludge from the Teshie plant was higher in heavy metals than the one from Dogo. The reason for this is unclear.

Although all amendments, except the ones from the Teshie operation, did not contain heavy metals exceeding the maximum permissible limits, both the compost from James Town and the chicken manure could supply substantial amounts of heavy metals if applied at high rates over a period of time. The heavy metals supplied to the soil through the application rates used in the on-farm trial and the potential build-up over an extended time period has been calculated and discussed in Appendix C.

**Non-Chemical analysis**

Microbial analysis was done on two samples each of composts from both the Teshie/Nungua and James Town plants and on three chicken manure samples. The samples were screened for *Salmonella spp*. and *E. coli spp*.; both pathogens commonly used as indicator species in assessing levels of faecal contamination (Shields, 1999; USEPA, 2003b). No *Salmonella spp.* were detected in any of the samples. In one of the samples from James Town *E. coli* was isolated, but the level was below the EU Ecolabel permitted limit of 1000 CFU/g (HDRA, 1998).

The compost from Teshie consistently had higher levels of inert contaminants than the James Town compost. These were mainly fragments of glass and plastic, but also the occasional metal fragment.

## 6.1 Soil Properties

What follows is a general presentation of the soil properties of the experimental sites and of changes in nutrient content in the on-farm trial soil following compost and manure application. The presentation of the soil analysis is followed by a discussion on heavy metal loading and a projection of possible outcomes with repeated compost applications over time.

### *6.2.1 Vegetable growers' experimental sites*

There were differences in soil types both between and within each of the three vegetable growing sites. The sites could be split into three main categories in terms of soil texture as illustrated in Figure 6.1 where the soil types of the experimental beds analysed are indicated in accordance with texture.

1. In Marine Drive, because of the history of the land as a park with trees, paths and terraced borders, the soil varied substantially within short distances. Marine Drive had the lightest soils with the highest sand content. The soil colour was brown (HUE7.5YR/4/4, HUE7.5YR4/3) to dark reddish brown (HUE5YR/3/3), and a texture of sandy clay loam, sandy loam or loamy sand, with localised gravel where paths used to be.
2. In Dzorwulu the soils were more of a silty type with the experimental beds falling into the silty clay loam and silty clay categories. The soils became more clayey closer to the river. The colour of these soils ranged from dark brown (HUE7.5YR/3/4) to brownish black (HUE10YR/3/2) as the clay content in relation to silt increased. The more clayey areas were prone to water logging during very wet conditions and heavy rainfall.
3. Korle Bu had the most uniform soils across the experimental beds. Here the soils were brownish black (HUE5YR/3/1, HUE5YR/2/1, HUE10YR/3/2, HUE10YR/2/2), heavy and clayey. The majority of the experimental beds were classified as clay soils whilst others were silty clays and clay loams. The water table was high and the clayey soils of the area are prone to water logging during the wet season and compaction and cementation during dry conditions.

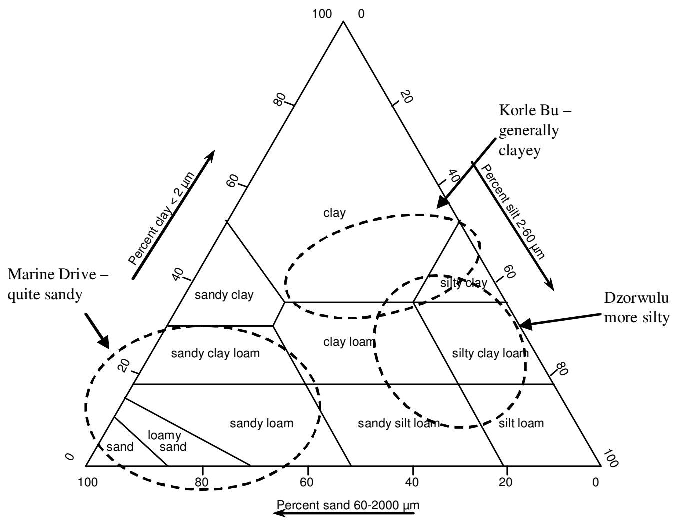



*Figure 6.1 The soils of the experimental sites in relation to the Soil Pyramid*

*Source: Adapted from Hodgson, 1974 in White, 1987*

Judging from the selected soil samples analysed across the three sites, the chemical fertility of these soils was generally good[40]. Bearing in mind the high and frequent inputs of chicken manure used by the growers, the high nutrient levels in the soil are perhaps not surprising, particularly as only the top 15 cm of the soil was sampled. Both organic matter (OM) and total nitrogen (N) content of all the soils were average whilst total phosphorus (P), potassium (K) and magnesium (Mg) concentrations were high. In fact the content of both total and available P was extremely high in all soil samples. Whilst pH was lowest in the Marine Drive soils, all three sites had soils that were mildly alkaline. At the bottom of Tables 6.9 and 6.10 the results of the baseline soil sample taken across the on-farm experimental field are given as a comparison. This land had not been intensively cultivated and irrigated in contrast to the vegetable growing sites and the soil chemical properties were very different. The on-farm trial soil had a lower chemical fertility; organic matter, N, available P and exchangeable sodium (Na) were all low.

The soils in Dzorwulu were most fertile. Not only did they have a better texture than the sandy Marine Drive soils and the heavy clay soils of Korle Bu, they also had a higher cation exchange capacity and high concentrations of exchangeable calcium, potassium and magnesium. The exchangeable magnesium and potassium in the Korle Bu soils were also high, but the CEC (cation exchange capacity) and exchangeable calcium were average. The sandy Marine Drive soils had a CEC which was low to medium and a low exchangeable calcium content. However, exchangeable potassium and magnesium were high here too.

All the soils at all three sites had a high sodium content. Growers recognised soil salinity as being an important constraint to production with some beds (not the experimental ones) being more or less unproductive because of salinity problems. The problem was considered by the growers to be more serious in Marine Drive and Korle Bu than in Dzorwulu. The results of the soil analysis seem to confirm this. The exchangeable sodium in the few soil samples taken reveal higher concentrations in the Marine Drive and Korle Bu soils than in the Dzorwulu soils. The exchangeable Na in both the soil samples from Korle Bu were very high. This coupled with the high clay content and pH of these soils indeed indicate a possible salinity problem. Exchangeable Sodium Percentage (ESP) is one way of ascertaining the salinity of a soil. This is the proportion of exchangeable Na of the overall cation exchange capacity (CEC). Thus:

$$ESP = \frac{ExchangeableNa(meq/100gsoil)x100}{CEC(meq/100gsoil)}$$

"*Either ESP or the milliequivalents of exchangeable sodium are usually good indicators of the structural stability of a soil….. Most soils containing expanding type clay minerals exhibit unfavourable physical properties at levels of ESP greater than 15% or of exchangeable sodium greater than 3 meq/100 g of soil*" (Euroconsult, 1989). According to these guidelines the Korle Bu soils, with

[40] The rating system used by Euroconsult for fertility classification was used to gauge the soils.

exchangeable Na of 3.23 and 2.29 and an ESP of 17 and 12.5 % respectively, have the potential to incur salinity problems. Likewise, the second soil sample from Marine Drive had an ESP of 15.2% and an exchangeable Na content of 2 meq/100 g soil. However, this soil was more sandy and free draining.

*Table 6.9 Available and exchangeable cations (P, K, Mg, Ca and Na)*

| Area | Sample | Available P | Exchangeable K | | Exchangeable Mg | | Exchangeable Ca | | Exchangeable Na | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mg/l | Mg/kg | Meq/100g | Mg/kg | Meq/100g | Mg/kg | Meq/100g | Mg/kg | Meq/100g |
| Marine Drive | 1 | 105.4 | 335.4 | 0.86 | 379.2 | 3.16 | 894 | 4.47 | 276 | 1.2 |
| | 2 | 122 | 292.5 | 0.75 | 549.6 | 4.58 | 902 | 4.51 | 476.1 | 2.07 |
| | 3 | 147 | 518.7 | 1.33 | 510 | 4.25 | 900 | 4.5 | 370.3 | 1.61 |
| Dzorwulu | 1 | 59.4 | 425.1 | 1.09 | 1780.8 | 14.84 | 2644 | 13.22 | 236.9 | 1.03 |
| | 2 | 141 | 300.3 | 0.77 | 1197.6 | 9.98 | 2288 | 11.44 | 253 | 1.1 |
| | 3 | 126 | 230.1 | 0.59 | 1532.4 | 12.77 | 3440 | 17.2 | 416.3 | 1.81 |
| Korle Bu | 1 | 155 | 475.8 | 1.22 | 652.8 | 5.44 | 1626 | 8.13 | 742.9 | 3.23 |
| | 2 | 172 | 413.4 | 1.06 | 765.6 | 6.38 | 1600 | 8 | 526.7 | 2.29 |
| On-farm trial, baseline sample | 0-15 cm | 8.4 | 121 | 0.31 | 391 | 3.26 | 1762 | 8.81 | 59.8 | 0.26 |
| | 15-30 cm | 8.6 | 146 | 0.37 | 412 | 3.43 | 2069 | 10.35 | 75.9 | 0.33 |

*Source: This research*

*Table 6.10 Total nutrient content of selected soil samples from the three vegetable growing areas*

| Area | Sample | pH | OM | CEC | Total N | Total P | Total K | Total Mg |
|---|---|---|---|---|---|---|---|---|
| | | | % | meq/100g | % ww | Mg/kg | Mg/kg | Mg/kg |
| Marine Drive | 1 | 7.5 | 2.2 | 10.7 | 0.14 | 755 | 1474 | 1031 |
| | 2 | 7.2 | 2 | 13.6 | 0.127 | 830 | 2734 | 1876 |
| | 3 | 7.6 | 3 | 12.8 | 0.2 | 1756 | 2337 | 1612 |
| Dzorwulu | 1 | 8.1 | 2.7 | 31.2 | 0.176 | 904 | 1365 | 5471 |
| | 2 | 8 | 2.1 | 24.3 | 0.147 | 1453 | 1431 | 3594 |
| | 3 | 7.7 | 2.3 | 35.5 | 0.173 | 1078 | 1453 | 5008 |
| Korle Bu | 1 | 8 | 2.5 | 18.8 | 0.177 | 1264 | 2098 | 1887 |
| | 2 | 8.1 | 2.7 | 18.3 | 0.207 | 2498 | 2235 | 2168 |
| On-farm trial, baseline sample | 0-15 cm | 7.4 | 1.0 | 13.2 | 0.087 | 110 | 1146 | 1685 |
| | 15-30 cm | 7.6 | 0.8 | 15.2 | 0.06 | 119 | 1225 | 1710 |

*Source: This research*

*Table 6.11 Ratings according to Euroconsult (1989)*

| | Available P (Ohlsens extraction) | Exchangeable cations (meq/100g) | | | | OM | CEC | Total N |
|---|---|---|---|---|---|---|---|---|
| | ml/l | K | Mg | Ca | Na | % | meq/100g | % |
| Extremely high | >20 | | | | | | | |
| Very high | 15-20 | >1.2 | >8 | >20 | >2 | >6% | >40 | >0.3 |
| High | 10-15 | 0.6-1.2 | 3-8 | 10-20 | 0.7-2 | 4.3-6% | 26-40 | 0.226-0.3 |
| Medium | 5-10 | 0.3-0.6 | 1.5-3 | 5-10 | 0.3-0.7 | 2.1-4.2% | 13-25 | 0.126-0.225 |
| Low | 0-5 | 0.1-0.3 | 0.5-1.5 | 2-5 | 0.1-0.3 | 1-2% | 6-12 | 0.05-0.125 |
| Very low | | <0.1 | <0.5 | <2 | <0.1 | <1% | <6 | <0.05 |

### Heavy metal content

The results of analysis of the heavy metal content were compared against European standards provided in Appendix C. The heavy metal concentrations of the soils at the urban vegetable growing sites were relatively higher than that typical of rural agricultural soils. Chromium, nickel and cadmium levels were all quite high viewed against the various limits laid down by the European Union and individual European countries for agricultural soils. In fact according to the more stringent standards (such as those adopted in Sweden), the levels for cadmium, chromium and nickel concentrations exceeded the limits. Compared to the EU standard, however, all soil samples complied with the limits for all metals analysed. Lead, zinc and mercury were all higher in the vegetable growers' soils compared with the soils of the less urbanised and intensively farmed on-farm trial location. However, with the possible exception for chromium at the Marine Drive site, none of the soils sampled revealed heavy metal concentrations of hazardous proportions.

*Table 6.12 Total heavy metal content in selected soil samples taken from the top 15 cm across the three vegetable growing areas and the on-farm trial field, (mg/kg dry soil/matter)*

| Area | Sample | Cadmium Cd | Copper Cu | Lead Pb | Chromium Cr | Nickel Ni | Zinc Zn | Mercury Hg |
|---|---|---|---|---|---|---|---|---|
| **Marine Drive** | 1 | 0.63 | 11.8 | 13.8 | 91.5 | 15.1 | 40.1 | 0.12 |
| | 2 | 0.18 | 20.3 | 7.6 | 99.4 | 27.8 | 90.7 | 0.12 |
| **Dzorwulu** | 1 | 0.15 | 27.3 | 6.62 | 84.6 | 28.1 | 59.7 | 0.13 |
| | 2 | 0.2 | 24.2 | 7.89 | 76.5 | 21.1 | 67.4 | 0.15 |
| **Korle Bu** | 1 | 0.02 | 14 | 5.2 | 62.2 | 16.9 | 64.5 | 0.18 |
| **On-farm trial field** | | 0.23 | 19 | <0.01 | 75 | 25 | 22 | 0.05 |

*Source: This research*

Comparisons were also made against the average heavy metal content of a number of soils from different parts of northern Europe (Table C3.2, in Appendix C). This revealed that the heavy metal content of the soils at the three vegetable growing sites in Accra were generally higher, particularly so for chromium, nickel and mercury. Only lead concentrations were lower than in the European soils. Considering that the European soils samples were taken from rural agricultural soils and not within urban conurbations the slightly higher heavy metal concentrations is the Accra soils are not surprising.

In this context the widespread use of wastewater for crop irrigation is relevant. The rivers and drains flowing through Accra receive both industrial and domestic effluents. Apart from containing nutrients (N, P and K) and trace elements (e.g. Na) valuable for crop growth, this water contains pollutants of various types and concentrations depending on location and season. Whilst the main health concerns relate to heavy metals, pathogens, toxic organic compounds, excess concentrations of salts, and suspended solids are also of concern. Unregulated and continuous irrigation with wastewater also may lead to problems such as salinisation, phytotoxicity and soil structure deterioration (soil clogging) (Polpraset, 1996).

In Accra the waters running through the rivers and drains contain substantial amounts of faecal matter and associated pathogenic viruses, bacteria, protozoa and helminiths. Use of such water for irrigation of vegetables poses health risk for both growers and consumers, particularly when used on vegetables that are eaten raw. Beernaerts (2000) points out that the AMA Health Department periodically express concern for the rise of incidence of intestinal diseases, particularly in children, because of the consumption of contaminated food. She notes that the main source of vegetable contamination identified by Accra laboratories is the wastewater used for irrigation. Studies on wastewater quality in Accra and Kumasi (Owusu and Mensah, 1998; Cornish *et. al*., 1999) have identified high concentrations of *E coli* and general coliforms as well as intestinal nematodes. Industries such as breweries, tanneries and the many informal textile industries in Accra also discharge effluents into the surface water bodies, leaving trace elements and heavy metals. For example, Owusu and Mensah (1998) found that effluent discharged from a textile factory in Accra contained high concentrations of potassium and sodium, which are elements present in the dyes used. Effluent from tanneries contain substantial quantities of chromium salts (JICA, 1996 in Birley and Lock, 1998). There thus is growing concern about the practice of wastewater irrigation in urban agriculture in Accra, particularly in relation to the potential threat to health of consumers, but also to the tourism industry. However, there is little or no routine monitoring of water quality by government agencies such as the EPA and, in spite of proposals for byelaws to regulate the practice (Keraita and Drechsel, 2004), the use of waste water for irrigation remains unregulated.

In this research, the quality of the irrigation water used by the experimenting growers was not analysed. The issue of water quality emerged in the course of the research and the possible value of including such analysis into the study was considered. However, the decision not to do so was taken for several reasons. The water quality is highly variable in time and place depending on proximity to pollution source and degree of dilution. For reliable data to be collected samples would have had to be taken on a regular basis over an extended period of time. The task would have been large and there were budgetary and labour constraints.

The soils at the vegetable growing sites had higher concentrations of Na, P, Pb and Hg than the on-farm trial soil. Bearing in mind the fact that wastewater is known to contain varying degrees of pollutants, be it in the form of excess nutrients, heavy metals or pathogens, and that irrigation with such water has been carried out extensively over a long period of time, it may be speculated that the higher concentrations of these elements could be the result of the use of wastewater. The land used for the on-farm trial had previously been used for rainfed cropping, thus had not received water from the stream. The samples of chicken manure analysed, with the exception of Zn, did not contain high concentrations of heavy metals, so assuming these samples were representative, the chicken manure is not likely to be the source of the higher levels of Pb and Hg. In Appendix B and C, further discussion of the implications of heavy metal contamination is provided.

**Growers' perceptions of their soils**

Because of the variability of soils in Marine Drive, the growers' opinions at this site about the quality of their soils differed considerably. Many of the growers were generally quite happy with their soils in terms of structure, water holding capacity, workability and ability to produce a good crop. They said that their soils perform well in the rainy season compared with many other areas. Some growers complained of salinity problems and those growers on the more sandy soils (loamy sand) had soil structure and water retention problems. During the dry season the area tended to dry out and many growers were unable to carry on cultivating. In Dzorwulu many of the growers also were happy with their soils. They felt that the structure and fertility was generally good, although during periods of heavy rainfall many would suffer from water logging. Some growers complained of the soils being salty. Growers in Korle Bu perceived soil salinity and water logging as their main problems. Their soils also had a tendency to get very hard and difficult to work when dry. The growers here did not feel that the soil quality had deteriorated, but was similar to 5-10 years' ago.

The growers at all three sites used soil colour and vegetative growth as main indicators of soil fertility. There was a general perception that a darker soil is more fertile than the lighter coloured ones. Prolific growth of crops and weeds, and the size, greenness and 'freshness' of leaves, were seen as important indicators of soil fertility. Some growers also mentioned that if, when digging the soil, it contained worms and other insects it was a sign the soil is fertile. Growers also talked about the soils' crumbly structure, and ability to form lumps, as important indicators of soil quality.

### *6.2.2 On-Farm Trial site*

The soil at the on-farm trial site was a sandy clay loam of a very dark greyish brown colour (HUE10YR/3/2). The initial soil sample taken across the whole trial plot and analysed chemically for nutrients and heavy metals revealed that the soil had low chemical fertility. Organic matter (OM) content, total nitrogen (N), available phosphorus (P) and exchangeable sodium (Na) were all low. The cation exchange capacity (CEC), exchangeable calcium (Ca) and exchangeable potassium (K) were medium, while magnesium (Mg) levels were high (Tables 6.14 and 6.15).

When the heavy metal concentrations in the baseline soil sample from the on-farm trial field were compared to the eco-toxicological (soil) quality criteria laid down by the European Union and individual European countries, the heavy metal concentrations fell comfortably below the EU limits for agricultural soils and those of most European countries (see Appendix C). However, of the elements analysed, chromium (Cr) and nickel (Ni) levels were relatively high. Whilst the concentration of these elements was below the limits of most European standards, they were above the acceptable limits according to the most stringent standards such as those adopted by Sweden and Denmark. In addition to gauging the heavy metal concentration against European standards, a comparison was made with a number of agricultural soils from various parts of northern Europe (Johansson *et. al.*, 1997). In relation to these soils both Ni and Cr concentrations were slightly high, whilst the concentration of all other elements analysed were comparable or low. (See Tables C3.1, C3.2 and C3.3 in Appendix C).

**Changes in soil chemical properties in the on-farm trial**

The changes in soil properties and nutrient status through the period of the study are given in Tables 6.13 and 6.14 and presented in Graphs 6.1 a-k. The results of the soil analysis shown in the tables are from the following samples:

- First sample - 20 June 2000, 10 months after the start of the trial, after two compost and manure applications had been added (10 months after the first compost application and 3 months after the second), and while the second crop (chilli pepper) was actively growing
- Second sample - 23 Oct 2000, 4 months after the previous sample, and 2 months after another compost and manure application had been added. So this sample was taken after the third compost application during the active growth of the third crop (cabbage).
- Third sample - 1 March 2001, 4.5 months after the previous sample, and 1.5 months after the fourth and final compost and manure application. The sample was taken during the active growth of the final crop (okra).

Several changes in soil chemical properties as a result of compost and manure amendments were recorded, of which the most striking was a marked increase in P from compost applications. There was a six, six and sevenfold increase in total P over the un-amended soil following the second, third and fourth compost applications respectively. For available P the increase was correspondingly 5 fold, 8.7 fold and 9.6 fold, resulting in P accumulation in the topsoil in excess of crop requirements. According to the rating used by Euroconsult (1989), available soil P changed from medium to extremely high. For soils in the UK an index for available P ranging from 0 (deficient) to 9 (very large) is used, with most UK agricultural soils having indices of between 1 and 4 (MAFF, 2000). Gauged against this rating system, the available P index increased from index 0, indicating P deficiency, to index 5, which is within the target level.

Considering the high P concentration in the compost and the resulting increases in soil P following the high application used in the trial, it would be appropriate to set the application rate according to P levels rather than the more commonly use of N concentration to determine application rates. In fact, at the third application of compost soil P had reached a level at which further P application should be set to match crop uptake (MAFF, 2000). Given the immobility of P, at low soil concentrations crop roots may not be able to access the P. As such P additions to a P deficient soil may not have any appreciative effect on crop growth unless a sufficient amount is added. In view of the low P concentration of the soil (as is known to be the case in many tropical soils (Sanchez, 1976)) the fact that the compost contained high concentrations of P is agronomically valuable. However, care should be taken to avoid excess build-up in the soil. Research has shown that soil P build-up can occur with resulting leaching (Edwards *et al*., 1995; Heckrath, 1998; MAFF, 2000). The UK recommendations are that for soils at a P index of 3 or above, total inputs of P should not exceed the total amount removed by crops, as there is an increased risk of P loss from soils which are at soil P index 4 or over (MAFF, 2000). The accumulated P in the topsoil following the fourth application therefore could pose an environmental problem.

There was a gradual increase in both total and available P as a result of cow manure applications too, but nowhere near as dramatic as that resulting from compost applications. After the fourth application of cow manure the available P index was 3 compared to index 0 in the unamended soil. Total soil N remained unchanged with both compost and cow manure applications. Although the cow manure treatment had the highest N concentration, followed by compost and lastly the control treatment, the differences were very small and soil N in all three treatments was rated as low, according to the Euroconsult classification.

*Table 6.13 Available and exchangeable cations (P, K, Mg, Ca and Na) in the on-farm trial soil. Samples were taken during the active growth stage of the crop following two, three and four applications of compost and cow manure.*

| **Sample taken** | **Appli-cation** | **Available P** | **Exchangeable K** | | **Exchangeable Mg** | | **Exchangeable Ca** | | **Exchangeable Na** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mg/l | Mg/kg | Meq/100g | Mg/kg | Meq/100g | Mg/kg | Meq/100g | Mg/kg | Meq/100g |
| Baseline sample | 0–15 cm | 8.4 | 121 | 0.31 | 391 | 3.26 | 1762 | 8.81 | 59.8 | 0.26 |
| | 15–30 cm | 8.6 | 146 | 0.37 | 412 | 3.43 | 2069 | 10.35 | 75.9 | 0.33 |
| First sample 20/6/00 | Compost | 50 | 179.4 | 0.46 | 456 | 3.8 | 1200 | 6 | 75.9 | 0.33 |
| | Cow manure | 9 | 284.7 | 0.73 | 417.6 | 3.48 | 1880 | 9.4 | 117.3 | 0.51 |
| | None | 10 | 124.8 | 0.32 | 361.2 | 3.01 | 1904 | 9.52 | 37.3 | 0.16 |
| Second sample 23/10/00 | Compost | 85.7 | 241.4 | 0.62 | 652.04 | 5.43 | 624 | 3.12 | 129.44 | 0.56 |
| | Cow manure | 27.4 | 565.5 | 1.45 | 429.60 | 3.58 | 1392 | 6.96 | 246.1 | 1.07 |
| | None | 9.8 | 187.2 | 0.48 | 422.40 | 3.52 | 1514 | 7.57 | 195.5 | 0.85 |
| Third sample 1/3/01 | Compost | 79.1 | 342.5 | 0.88 | 1001.03 | 8.34 | 1310 | 6.55 | 232.19 | 1.01 |
| | Cow manure | 34.8 | 883.97 | 2.27 | 444.59 | 3.7 | 1614.8 | 8.07 | 335.6 | 1.46 |
| | None | 8.2 | 203.05 | 0.52 | 400.6 | 3.34 | 1042.4 | 5.21 | 332.54 | 1.45 |

*Source: This research*

*Table 6.14 Total nutrient content of the on-farm trial soil*

| **Sample taken** | **Appli-cation** | **pH** | **OM** % | **CEC** meq/100g | **Total N** % ww | **Total P** Mg/kg | **Total K** Mg/kg | **Total Mg** Mg/kg |
|---|---|---|---|---|---|---|---|---|
| Baseline sample | 0 – 15 cm | 7.4 | 1.0 | 13.2 | 0.087 | 110 | 1146 | 1685 |
| | 15 – 30 cm | 7.6 | 0.8 | 15.2 | 0.06 | 119 | 1225 | 1710 |
| First sample 20/6/00 | Compost | 7.5 | 1.1 | 11.7 | 0.108 | 640 | 1230 | 1664 |
| | Cow manure | 7.9 | 1.2 | 14.9 | 0.106 | 150 | 1399 | 2039 |
| | None | 7.8 | 0.9 | 14.2 | 0.095 | 106 | 1106 | 1739 |
| Second sample 23/10/00 | Compost | 7.4 | 2.1 | 14.3 | 0.091 | 903 | 1623 | 2232 |
| | Cow manure | 8.1 | 2.4 | 13.6 | 0.102 | 234 | 1968 | 2188 |
| | None | 7.4 | 1.4 | 13.9 | 0.07 | 149 | 1466 | 2082 |
| Third sample 1/3/01 | Compost | 7.9 | 2.9 | 16.2 | 0.097 | 1601 | 1752 | 2705 |
| | Cow manure | 8.4 | 2.3 | 16.6 | 0.123 | 436 | 2210 | 2310 |
| | None | 8.4 | 1.4 | 13.1 | 0.08 | 320 | 1385 | 1989 |

*Source: This research*

Compost amendments also resulted in increased soil Mg, Na and OM contents. The originally high exchangeable Mg concentration increased further with compost amendments so that after the fourth application the soil Mg content had become very high. Such high Mg concentration could potentially induce potassium deficiency (MAFF, 2000). However, potassium levels of the soil also increased as a result of compost amendments, indicating that the increased Mg concentration did not pose a problem in relation to K availability.

OM increases were recorded in both the compost and cow manure amended soils. Both increased from a low to a medium rating. In spite of the compost having lower OM content (8-24.5%) than the cow manure (25.6-68.5%), the soil OM increases were slightly higher in the compost treatment. A reason for this result may be that more of the OM in the compost is more humified (i.e. has been converted to humus) and thus is more stable than that in the cow manure which is prone to faster breakdown leaving little OM left in the soil after growing periods.

The results indicate that exchangeable Na increased over time, but not as a result of compost or cow manure applications. There was a gradual increase in exchangeable soil Na in the compost and manure amended soil and in the unamended soil alike, such that the concentration changed from low to high over the trial period. In fact, at the last soil sampling occasion th Na concentration in the on-farm trial soil had become similar to several of the soils at the vegetable growing sites. Whether or not watering with water containing high concentrations of wastewater had an effect on soil Na is unknown, but it is the most likely explanation for this increase considering the recorded increases in the unamended soil. The fact that the soils at the three vegetable producing sites had higher Na concentrations further supports my hypothesis. These soils have received irrigation from wastewater for a long time whilst the on-farm trial land had previously been under rainfed cropping. The results of the analysis of the soil samples taken from the vegetable growing sites showed these soils to have a much higher Na concentration, particularly so in the Korle Bu area where the irrigation water used was most polluted.

Apart from the marked increase in soil P, the increase in Na, and the more moderate yet clearly detectable increase in Mg (mainly exchangeable) and OM, there were no changes in soil chemicals properties as a result of compost amendments. pH, CEC, total N, total and exchangeable K and exchangeable Ca all remained unchanged or insignificantly altered. Cow manure amendments resulted in an increase in soil K. Exchangeable K increased from low to very high after the third application.

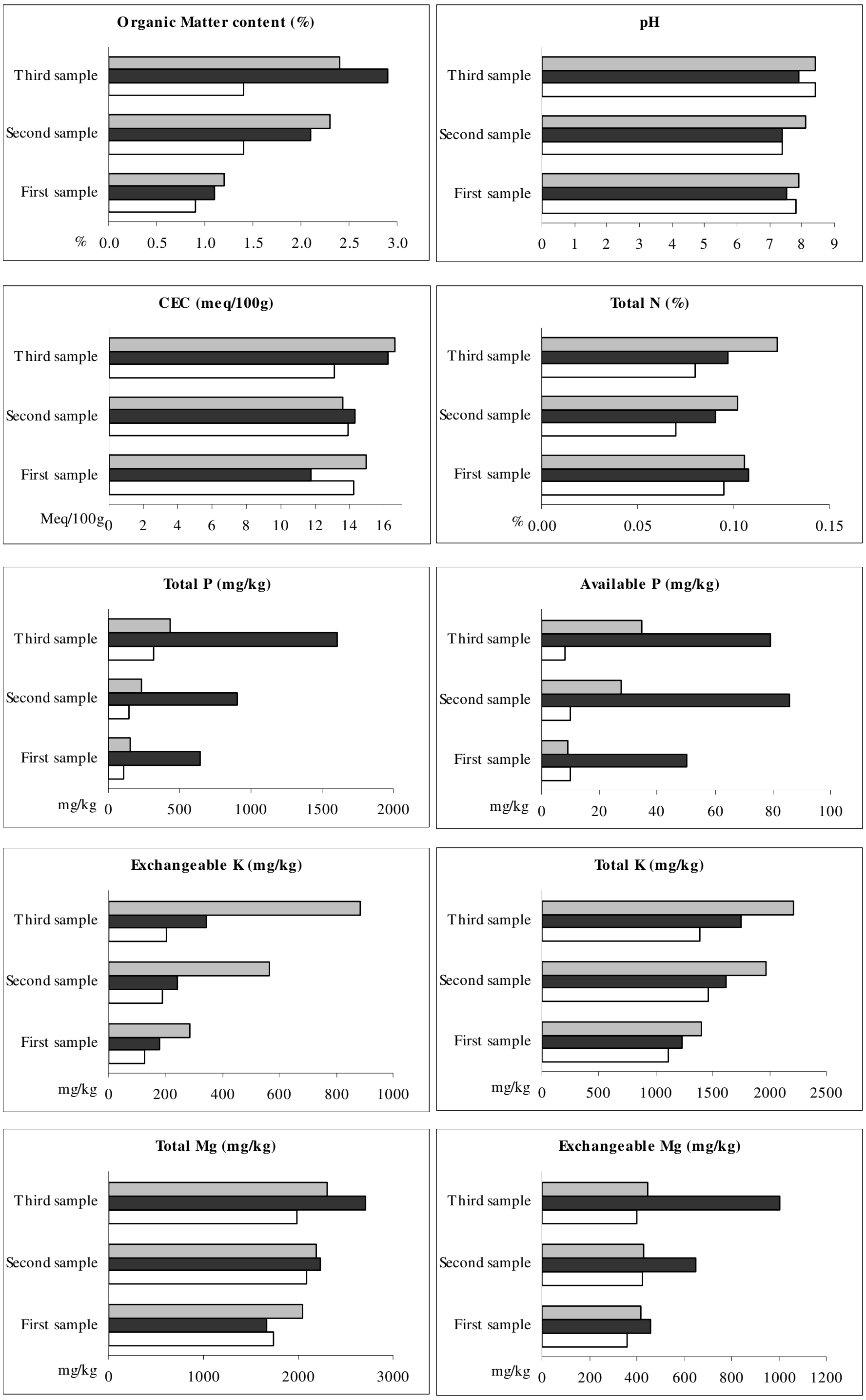
*Table 6.15 Ratings according to Euroconsult (1989)*

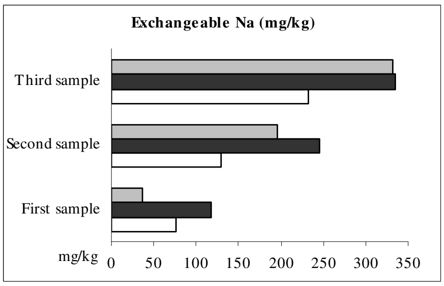
| | OM % | CEC meq/100g | Available P (Ohlsens extraction) ml/l | Total N % | Exchangeable cations (meq/100g) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | K | Mg | Ca | Na |
| Extremely high | | | >20 | | | | | |
| Very high | >6% | >40 | 15-20 | >0.3 | >1.2 | >8 | >20 | >2 |
| High | 4.3-6% | 26-40 | 10-15 | 0.226-0.3 | 0.6-1.2 | 3-8 | 10-20 | 0.7-2 |
| Medium | 2.1-4.2% | 13-25 | 5-10 | 0.126-0.225 | 0.3-0.6 | 1.5-3 | 5-10 | 0.3-0.7 |
| Low | 1-2% | 6-12 | 0-5 | 0.05-0.125 | 0.1-0.3 | 0.5-1.5 | 2-5 | 0.1-0.3 |
| Very low | <1% | <6 | | <0.05 | <0.1 | <0.5 | <2 | <0.1 |

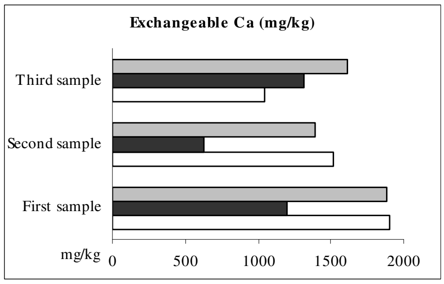
*Table 6.16 Classification of soil available P analysis results into an index used in the UK*

| Index | Available P (Ohlsens extraction) ml/l |
|---|---|
| 0 | 0-9 |
| 1 | 10-15 |
| 2 | 16-25 |
| 3 | 26-45 |
| 4 | 46-70 |
| 5 | 71-100 |
| 6 | 101-140 |
| 7 | 141-200 |
| 8 | 201-280 |
| 9 | >280 |

*Source: MAFF, 2000*


Organic Matter content (%)
Third sample
Second sample
First sample
% 0.0 0.5 1.0 1.5 2.0 2.5 3.0
pH
Third sample
Second sample
First sample
0 1 2 3 4 5 6 7 8 9
CEC (meq/100g)
Third sample
Second sample
First sample
Meq/100g 0 2 4 6 8 10 12 14 16
Total N (%)
Third sample
Second sample
First sample
% 0.00 0.05 0.10 0.15
Total P (mg/kg)
Third sample
Second sample
First sample
mg/kg 0 500 1000 1500 2000
Available P (mg/kg)
Third sample
Second sample
First sample
mg/kg 0 20 40 60 80 100
Exchangeable K (mg/kg)
Third sample
Second sample
First sample
mg/kg 0 200 400 600 800 1000
Total K (mg/kg)
Third sample
Second sample
First sample
mg/kg 0 500 1000 1500 2000 2500
Total Mg (mg/kg)
Third sample
Second sample
First sample
mg/kg 0 1000 2000 3000
Exchangeable Mg (mg/kg)
Third sample
Second sample
First sample
mg/kg 0 200 400 600 800 1000 1200





*Graphs 6.1 a-l Some chemical properties of the topsoil after the second, third and fourth compost and manure applications*

*Source: This thesis*

**Heavy metal loading**

Even though the heavy metal concentrations in an organic soil amendment are below the permissible limits, they can accumulate in the soil to reach hazardous levels if applications are heavy and/or repeated over time. Since heavy metals are generally stable and remain in the soil once added, the loading to the soil over time is a more important consideration than the actual concentration in any one sample of compost or manure (HDRA, 1998). No regulation in relation to heavy metal loading in soils exists in Ghana. As such comparisons with regulation within Europe were used as a guideline to ascertain the levels which may be considered hazardous. As can be seen in Appendix C, the European standards are highly variable, with the most stringent standards only permitting very low annual loading rates of heavy metals. Therefore a projection of increases in heavy metal concentrations in the soil following different application regimes over time was made. The findings of this are presented in Appendix C. What follows here is a summary of the main points of this projection.

With the high compost application rates used in the on-farm trial (i.e. 50 + 25 t/ha in year 1 and 20 + 20 t/ha in year 2) the heavy metal delivered through compost applications failed to meet the limits of many of the European regulations. This was particularly so for lead and zinc. For the first and highest application rate the more contaminated Teshie compost was used. This resulted in a high delivery of heavy metals, in particular lead. Overall, the trend for heavy metal delivery during the two-year trial period:

1. Complied with the less stringent regulations (such as the UK sludge regs. and the EU Ecolabel)
2. Were within acceptable limits for about half of the elements according to the intermediate standards (such as those adopted by Spain, France and Ireland)

3. Failed to comply with the standards of the most stringent regulations (such as those laid down by Sweden, Norway, Finland, Denmark, Netherlands and Germany).

If the Swedish sludge standards are used as the benchmark, all the heavy metals supplied through the compost applications in both years failed to meet the acceptable limits. In fact, even the cow manure failed to comply with these standards for all heavy metals with the exception of copper and mercury in the first (but not second) year. The fact that the manure came from cows that were free ranging and the application rate used was in line with the recommended rates from the agricultural extension service, question is raised of what organic amendment practice may ever comply with the Swedish standard.

With the exception of zinc and lead in the first year, heavy metal delivery even at the high rates used in the on-farm trial did not exceed the maximum permissible annual average dosage, according to the EU Ecolabel and UK sludge regulation criteria. However, the results clearly indicate that repeated applications over time may lead to build-op of heavy metals in the soil to levels which could be hazardous. Judging by the chemical analysis results of the two samples taken, this is clearly the case for compost from the Teshie plant in relation to Lead, Cadmium, Chromium and Mercury.

The first result to emerge from this analysis is that according to the most stringent standards, compost can either be applied to supply sufficient nutrients, but risk overloading with heavy metals, or it can be applied to stay within the safe limits for heavy metals, but as such not supply anywhere near enough nutrients and organic matter. Therefore, unless heavy metal concentrations can be kept low in WDC, it does not represent a particularly valuable soil fertility input. However, using the less stringent European standards as a guideline, the analysis reveals that even the relatively contaminated compost produced in Accra can be applied at sufficiently high rates to supply crop nutrients without risking soil contamination from heavy metals.

In order to ascertain the possible build-up in soil through repeat applications over time, a projection of loading rates was calculated, at different application rates, for both the two composts. This projection is presented in Appendix C. The results indicate that over a 10 year period the Teshie compost would supply twice the amount of copper (Cu), nickel (Ni) and mercury (Hg) and four times as much lead (Pb) and chromium (Cr) as the compost produced at James Town. Cadmium (Cd) and zinc (Zn) also would be delivered at a higher rate, but the difference would be less dramatic. Considering the lower nutrient and organic matter content of the Teshie compost, the superior quality of the James Town compost is evident.

However, even though the heavy meatal concentrations in these composts are higher than in compost produced and used in Europe, the scenario used as an example in Appendix C suggests that, apart from zinc, even if used at moderately high rates over an extended period of time, it would still be safe in terms of heavy metal build-up in the soil. That said, there are potential risks associated with heavy metal delivery through repeated use. Thus, for MCW to act as a valuable input for agriculture it is important to ensure that heavy metal concentrations are minimised. The difference in quality between the James Town and Teshie composts clearly illustrates how investment in waste separation pays off in terms of compost quality.

## 6.3 Vegetable Growers' experimental results

### *6.3.1 Crops grown*

All growers grew lettuce as their first crop. Subsequently, many growers chose to grow other crops in order to find out how they would perform in the compost-amended beds. There was some variation in crops grown between the three sites. In Marine Drive lettuce was by far the most common crop, followed by sweet pepper, spring onion and cabbage. Here the vast majority of growers carried on growing lettuce throughout the year, and this is the only crop many of them ever grow. By contrast, in Dzorwulu and Korle Bu growers wanted to experiment with other crops including cabbage, sweet peppers, carrots, spring onions, jute and solanum. (See cropping calendar for fuller information, Figure 5.2 in Chapter 5). In Dzorwulu, onion production was widespread during the 'onion season'. In Korle Bu the production was less market oriented. Growers sometimes experienced difficulties in marketing their produce and many liked to grow crops that they would eat themselves. The production of traditional soup greens was more common here than in the other two areas. Also, the soil in Korle Bu was clayey and prone to water logging, and according to the growers, some crops did not perform well here. Intercrops of lettuce/cabbage, lettuce/spring onion and lettuce/cauliflower were also grown. In both Korle Bu and Dzorwulu many growers practised intercropping, but this was less common in Marine Drive. Figure 6.2 illustrates the proportion of lettuce crops grown in the three areas in relation to other sole crops and lettuce intercrops.

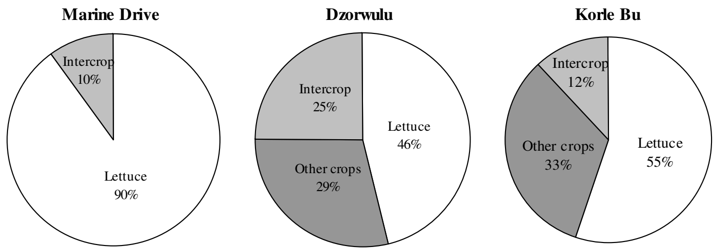



*Figure 6.2 Proportion of lettuce crops grown in relation to intercrops and other sole crops in the three experimental areas during the time of the research*

*Source: This research*

### *6.3.2 Number of crops assessed*

In spite of regular visits and careful coordination with the growers to ensure that the crops could be assessed at harvest, the researchers were not always present at harvest and therefore the crops could not be assessed by them. Growers would sell the crops on a whole bed basis to the market women, who would come and harvest the crops at their convenience at the rate at which they were able to sell. Sometimes the pre-arranged date and time for harvesting changed and when the researchers turned up for assessment the beds had already been cleared. (This had implications for the assessment data, as discussed later in Section 6.3.3)

Over time we saw that the better the growers' experimental capacities became and the more that their understanding of the principles of comparative observation and the value of quantitative data collection increased, the more likely they were to negotiate with the market women to ensure that the researchers gained access to the crop before harvesting.

There was a clear difference between the three sites in this respect, however. The growers in Dzorwulu developed a fuller appreciation of the importance of assessment in order to draw scientifically meaningful conclusions from the experiments. They had been exposed to Farmer Field School (FFS) activities in the past and had more contact with the extension services, and were more accustomed to the more theoretical aspects of agriculture than their colleagues in Marine Drive and Korle Bu.

The importance of quantitative assessments to ensure the credibility of experimental research is usually not appreciated by farmers (Gubbels, 1997; Stolzenbach, 1997). If there are differences in crop performance between treatments, these are easy to notice by the growers who attend their crops on a day-to-day basis and as such they do not see the relevance of recording the differences precisely. During the experimentation the growers made qualitative assessments of the general appearance of the crop and noted colour and lushness differences. They did not have previous experience of measuring and weighing plants and did not have access to equipment to carry out such comparisons. For them the visual comparisons were enough and they did not see any point in measuring the yield. Because of these factors and because many of the crops were sold on a whole bed basis, the price received for the bed emerged as a relevant criteria for assessment.

It was not unusual for crops to fail, notably because of drought or flooding. Growers were sometimes unable to keep up with the watering during the very driest and hottest periods when evapotranspiration was at its highest, particularly if they were not farming full time but had other jobs or were studying. Sometimes growers had to abandon their crops for reasons of ill health or commitments elsewhere that made it impossible for them to attend the crops on a regular basis. During periods of very dry weather water sources would also tend to dry up leaving growers with no option but to let the crops go to waste. The growers in Marine Drive were particularly constrained by lack of water. They suffered water shortages for extended periods during the year, when crops dried up and growers suspended their activities. Conversely, in the wet season crop failure was mainly a result of the crops being washed away or rotting in waterlogged beds. During heavy rainfalls it was not uncommon for all the crops, along with much of the soil on a bed, to be washed away. Korle Bu in particular, but also Dzorwulu, suffered crop failures as a result of water logging in the wet seasons. Pest attack was another, albeit less common reason, for crop failure.

Dzorwulu was the area with the highest success rate, both in terms of crops growing on to be harvested, and in terms of the number of crops the researchers were able to assess. The growers here were aware of and appreciated the importance of quantitatively assessing the outcome of the experiments and made an effort to accommodate the needs of the researchers. In Korle Bu there was a high rate of failure. There are several likely reasons for this. The growers here farm land that suffers problems of water logging, compaction and salinity. Also, the majority of the growers had full time night jobs and as such the time that they could devote to the farming was limited. These growers were less commercialised than the growers in the other two areas, in part because of the difficulties in selling their produce, as a result of the poor quality of the water they use for irrigation. The Korle Bu growers appeared to have a more relaxed attitude to their farming, not necessarily counting on selling or getting a good price for their produce and as such were not overly worried if the crops failed. This relaxed attitude could also be the result of the frequent crop failures – the growers had become used to the loss. Certainly, during the year of the experimentation, a high proportion of the crops failed. In addition, a number of crops were not assessed as they were harvested before the researchers had a chance to do so. This was usually down to misunderstandings between the growers and the researchers or the growers' inability to fully grasp the purpose and principles of experimentation and hence the importance of the assessments. The growers just grew the crops with the compost and 'knew how it worked for them'. The fact that, through collecting data from all the participating growers and collating the information gathered it would be possible to draw richer conclusions and share the findings with others, was never fully realised by the growers in Korle Bu. The same judgement, to a lesser degree, also could be made about the growers in Marine Drive. Here too a higher proportion of crops grown to completion were not assessed compared with in Dzorwulu. Figure 6.3 illustrates the proportion of the crops planted at the three sites that failed, were assessed, or grew to completion but were not assessed. The Cropping Calendar in Figure 5.2 in Chapter 5 illustrates the number and type of crops grown by each individual grower, as well as the crops that failed.

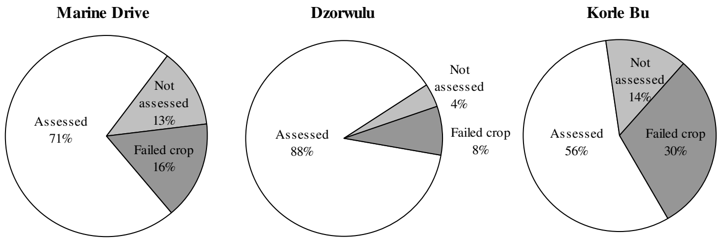



*Figure 6.3 Proportion of crops that were assessed in the three areas*

*Source: This research*

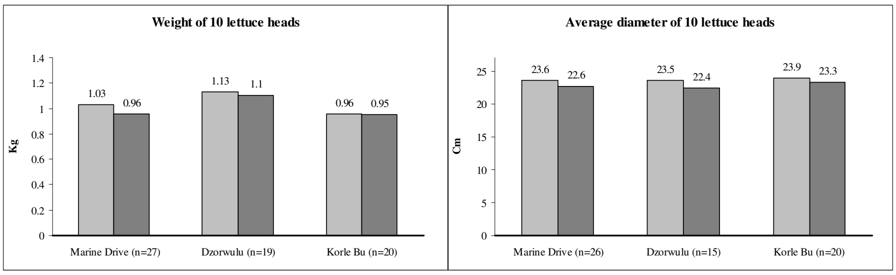
### *6.3.3 Crop performance*

The 93 crops grown by 23 growers during a period of one year resulted in many interesting findings (and enriched everyone's understanding).

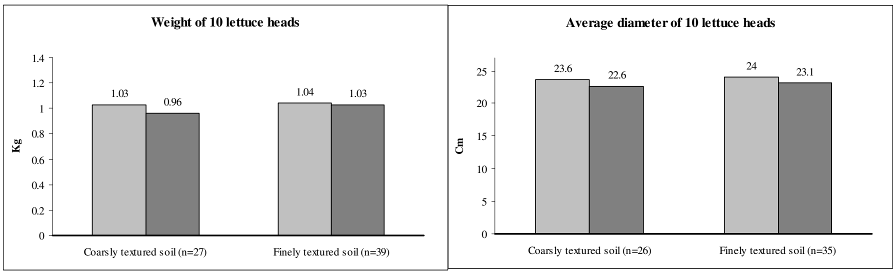
*Harvest data*

In terms of the quantitative crop assessment of plant size and weight at harvest, the data did not show any significant differences between the crops grown in compost and chicken manure amended beds. Analysis of variance was carried out on all the lettuce crops alone and on the standardised difference of the treatment means of all crops. Neither revealed any statistically significant treatment differences. The harvest data was grouped in a number of ways to detect whether or not variables such as area, soil type, seasonality, continuous compost applications over time and cropping sequence following compost applications, had any effect on the size of harvested crops. No treatment differences were detected in any of the combinations of analysis. Graphs 6.2-6.4 display the harvest data for the lettuce crops, according to these criteria. Whilst lettuces grown during the very driest periods were smaller (significant at $P>0.05$) than those grown during the wettest period, the differences between treatments were negligible. The proportion of failed crops was also somewhat higher during the driest periods (29%), compared with the wettest (18%) and overall (19%), but the difference was not significant.

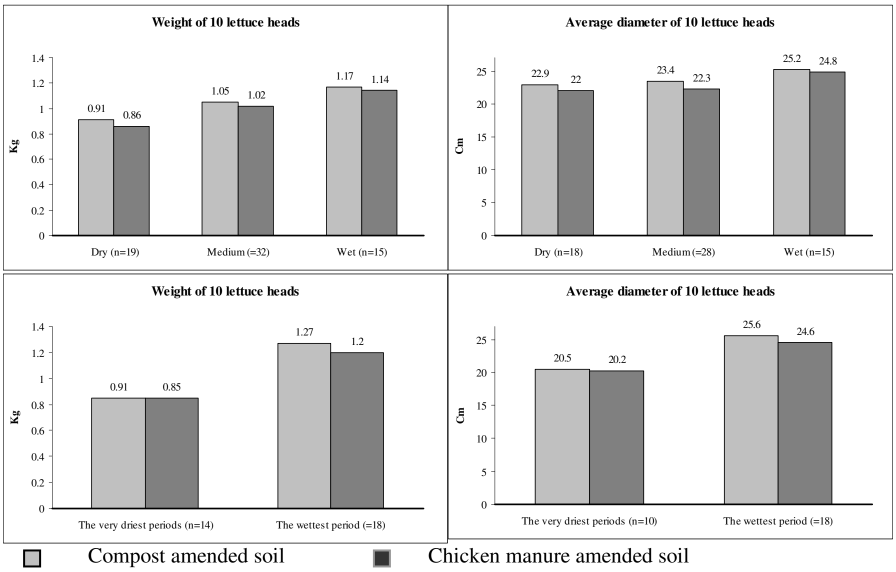
Although the harvest data show very promising results, these results alone do not show the full picture and, viewed in isolation, the harvest assessment would be misleading. There was a clear tendency for juvenile, newly transplanted plants to burn and die off more in the beds amended with compost, over and above that which occurred in the chicken manure amended beds. The harvest assessment results do not show this since assessment was only done on a random sample of 10 heads/or plants. Therefore, viewed in isolation the harvest assessment would be misleading and overly optimistic.




*Graphs 6.2 a & b   Average weight and diameter of lettuces harvested in the three areas*




*Graphs 6.3 a & b   Average weight and diameter of lettuces harvested in different soil types*

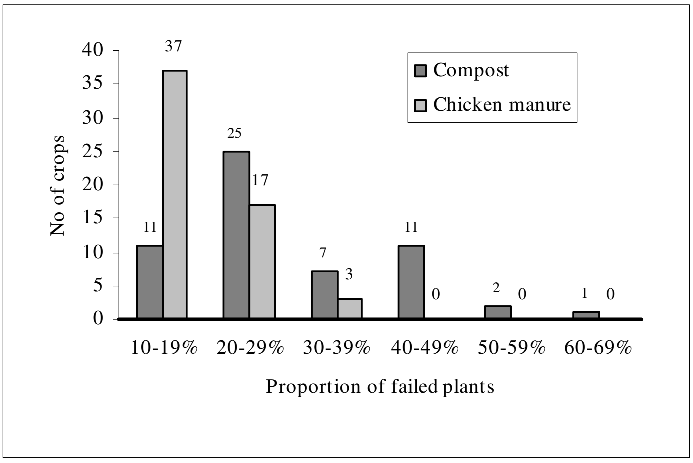



*Graphs 6.4 a – d   Average weight and diameter of lettuces harvested in different seasons*

*Source: This research*

*Survival rate*

The overall survival rate in lettuce plants grown throughout the research period was 71% in the compost beds and 81% in the chicken manure beds. Sometimes there would be no burning, whilst other times it could be quite severe with a negative effect on the overall yield. In more than one third (37%) of crops the extent of burn out was 30% or more, whilst in one quarter (25%) of crops grown, 40% or more of plants died. Burning occurred in beds amended with chicken manure, too. It is common practice for growers to replace transplants that fail one or two weeks into the growing period, and they expect to do this. However, in the compost amended beds more plants died out than in those amended with chicken manure. In the chicken manure beds none of the lettuce crops grown had die-off of 40% or more. In the vast majority of crops (95%) the extent of die-off was below 30%. The difference in die-off between the two treatments was statistically significant (P>0.05). Growers remarked that the nature of burning in compost amended soil was different to that with chicken manure, and that it was directly related to watering. When burning occurs with chicken manure, because the manure is immature, or too much is applied, it will burn regardless of watering. However, with compost they noticed that the plants only burnt if the plants became dry and that if the growers kept the soil wet then the plants did not burn. They theorised that the reason for the burning was likely to be related to the drying effect of the compost. As one grower remarked, "if you are lazy (like me) and do not work hard to water and fork the soil than the results from compost will not be good." (Adama, pers. comm., March 2000)




*Graph 6.5 Categorisation of proportion of plants that died off in the lettuce crops grown with compost and chicken manure respectively, (n=57)*

*Source: This research*

In the early stages of experimentation it was believed that the tendency to burn could result from the initial high application level, and that by reducing the amount of compost added the problem would reduce. This did seem to have some effect. Although burning was a problem throughout, the most serious problems did occur in the first crop following the first application.

*Yield*

The plants in the compost beds that did survive, generally grew very well and frequently outgrew the ones in the lettuce beds, presumably partly because they had more space. Although not statistically significant, the slightly larger size of the compost plants is illustrated in Figure 6.4, which shows the proportion of harvested crops where the diameter and weight of plants produced in the compost amended beds exceeded that of plants grown with chicken manure.

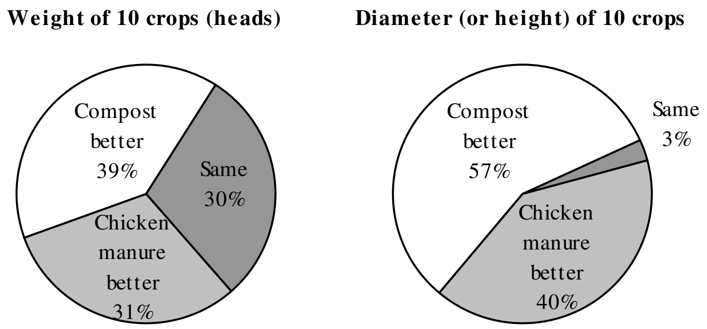



*Figure 6.4 The relative performance of the two treatments for all the crops grown to completion and assessed*

*Source: This research*

Estimated yield figures derived from plant count data and the weight of 10 lettuce heads/bed, show that on average the chicken manure treatment produced a 5 % higher yield than the compost treatment (Table 6.17). According to this calculation, the compost treatment produced an average yield of 16.5 t/ha and the chicken manure treatment 17.4 t/ha. Given that the extent of die-off was 10% higher in compost amended beds, yet the yield difference was 5%, illustrate that, in accordance with visual observations, the plants grown in the compost beds that did survive grew well.

So, in spite of problems with crop establishment and burning, crops grown in compost amended soil tended to catch up and produce a yield only slightly smaller than when chicken manure was used.

*Table 6.17 Yield figures for lettuce crops, (n=57)*

| | Average (t/ha) | Range (t/ha) | Proportion of harvests with the highest yield (%) |
|---|---|---|---|
| Compost | 16.5 | 2.7 – 35.8 | 31 |
| Chicken manure | 17.4 | 7.4 – 36.5 | 69 |

*Source: This research*

Another point can be made in relation to the fact that the plants grown with compost had a tendency to catch up with the chicken manure ones and fill out the bed in spite of the fact that more juvenile plants died off. It has been noted already that the market women may buy crops on a whole bed basis from the growers. By the time the crop reached maturity the appearance of the two beds was similar, (unless the burning off in the compost bed had been particularly severe). The plants grown with compost had a lush green colour and the plants generally looked very healthy. Growers thus did not get paid less for the compost beds compared with the chicken manure ones. It transpired that the precise number of plants on a bed was relatively unimportant, and that the appearance of the bed was a more important factor in the eyes of the market women. Nevertheless, the problem with burning clearly represents a serious constraint and there is a need to experiment further to find appropriate application rates and possible mixes with other fertility amendments (e.g. chicken manure) to maximise the fertiliser effect whilst minimising the problem with burning. However, this research illustrates that, under the marketing system used in the vegetable production systems in Accra, there is room for a high degree of flexibility with regard to applications .

*Overall bed appearance*

Crop uniformity was partly assessed visually using a scoring system (1-5) on an overall bed appearance basis, partly through calculating the standard deviation between the quantitative measurements (be it head diameter, plant height of circumference depending on the crop in question), taken on the 10 crops assessed at harvest from each bed. The standard deviation analysis did not show any significant differences between the treatments. Crops were selected at random and included both large and small specimens in both treatments. The scoring of uniformity produced a similar result at harvest, but there were differences in the earlier stages of growth. The growth of plants in the compost amended beds tended to be slower to take-off after transplanting, and as the crop started to grow the difference between individual plants tended to be more diverse than in the chicken manure treatment. Later, however, the compost treatment typically 'caught up' producing plants with similar uniformity to those grown with chicken manure. So, although the compost beds would frequently have gaps in them as a result of the higher degree of die-off compared with the chicken manure treatment, any difference in size between surviving plants had disappeared by the time the crop reached maturity.

### 6.3.4 Growers' assessments

Growers' observations and reports on the performance of compost compared with chicken manure revealed many interesting findings. Although there were some variations in experience and opinions of growers at the three sites, as well as between seasons and among growers at any one site, two main findings stood out as the experimentation progressed. One was the tendency for juvenile crops to burn in compost amended beds, as discussed above. (Interestingly this was not a problem encountered in the on-farm trial in any of the crops). The other thing that was noted by all growers, as well as by the on-farm trial grower, was the tendency for the compost amended soil to dry out faster.

This observation was a surprising outcome. In fact, it was completely opposite to that which had been anticipated as a possible outcome at the onset of the experimentation. A commonly cited benefit to compost and one that the research set out to monitor and expected to observe through continuous compost applications, was improved water retention in the soil (through the addition of OM).

Polprasert (1996:110) for example, writes that

> "*composts improve the physical properties of soils as evidenced by increased water content and water retention; enhanced aggregation; increased soil aeration, soil permeability and water infiltration; and decreased surface crusting. The greatest improvements in soil physical properties occurs in sandy and clay soils*."

This research found the opposite to be the case. It did not take long for before the growers noticed that the watering requirement was larger on the compost-amended beds that the ones with chicken manure. The compost beds dried out quicker and the water did not percolate into the soils as easily as when the soil has been treated with chicken manure. The same was found in the on–farm trial where the compost amended beds not only dried out quicker than the ones with cow manure but, according to the farmer, even the soil in the un-amended beds held the water better than the compost amended soil. The growers noted that the compost needed approximately double the watering effort compared to the chicken manure, i.e. it took twice as long and required twice as much water. Clearly this is an important constraint since water is often in short supply and watering is the most labour demanding of their activities.

There appeared to be a clear link between watering and the extent of burn-off. With chicken manure growers could get away with not watering for two to three days, but with compost this was not the case. During dry weather juvenile plants grown on the compost beds would burn and die off unless growers paid attention to keeping the beds well watered. This led growers to speculate that compost would be a good soil input to use during the rainy season when it is not so hot and the evapotranspiration is lower. During this time many growers, particularly those on clay soils in Dzorwulu and Korle Bu, do not like to use chicken manure as it makes the soil too sticky and wet.

The problem of higher water requirement in the compost treatment compared with the chicken manure one, remained when a second crop was grown without further compost amendment. This is perhaps not surprising, since chicken manure was added to each crop and the manure with its high water retentive quality acted like a mulch when spread on the soil surface. The Teshie compost, by contrast, was not compost as normally understood and described in the literature when water holding properties are discussed. This material had a high sand (from street/yard sweepings) and low organic matter content, and as such did not have the capacity to hold/retain water in the same way as compost rich in humus would. Although huge variations exist, compost typically is considered to have an organic matter content of 20 %; this material had an organic matter content of roughly half that.

Several other characteristics of the compost were identified by the growers, using criteria set by themselves, either at the onset of the experiments or as they emerged as relevant during the experimentation. Their assessments using these criteria are summarised below.

Plant size: In terms of plant size the growers agreed that there were no great differences between the two treatments. This is confirmed by the weight figures provided in Graphs 6.2-6.4.

Speed of growth: Here there was no clear agreement amongst the growers, as they had had rather varying experiences. The majority of the growers were of the opinion that the plants grown with chicken manure would grow fastest in the initial period following transplanting, but that compost plants would catch up. However, several growers had had the experience of the compost plants growing faster than the chicken manure plants.

Greenness & Lushness: Whilst both treatments produced fresh and lush looking plants and some growers said that they looked the same when matured, many commented that the lettuce plants grown with compost had a darker green colour than the ones grown with chicken manure. Growers consider greenness and lushness to be important criteria for judging the quality of the crop. In fact, many growers rate these qualities as important, some even more important, than speed of growth.

Uniformity: The growers in Dzorwulu generally felt that the plants grown with chicken manure were more uniform in size and shape than the ones grown in compost. The growers in the other two areas did not think this was the case and explained that any large variations between plants within the same bed was likely to stem from size differences already apparent at transplanting. However, the growers who had had problems with the juvenile plants burning in the compost treated beds and subsequently replanted in the empty spaces, ended up with large plant size variations in the bed. In fact, any differences from the beginning tended to be perpetuated, as the larger plants out-compete the smaller ones.

Weeds: There were differing opinions amongst the growers with regard to weed growth. Some had noticed that weed growth was more prolific in the compost amended beds whilst others felt that the beds with chicken manure had more weeds. Others said that they had not noticed any differences. Some growers were quick to weed their beds and so did not observe any differences for that reason.

Pests and diseases: No differences were observed in relation to pest and disease attacks between the two treatments.

Nursery production: A few growers in both Korle Bu and Marine Drive had tried using their experimental compost beds as nursery beds, with very good results. Chicken manure was considered not very good to use in a seed bed as it burns the seedlings.

Soil Quality Effect of soil salinity: No difference in soil structure and workability was noted by the growers. However, some commented on the fact that there was a need to fork the soil surface of the compost amended beds more frequently to aid water percolation. Some of the growers perceived that compost helped reduce the problem of soil salinity. They commented that whilst chicken manure helps a little, the effect of adding compost seemed far better. It is difficult to see any reason for this. The chemical analysis does not show any characteristics of the compost which may validate the growers' claim. With regards to the extractable sodium content of the compost and chicken manure samples analysed, the concentrations are variable and there are not enough samples to draw any conclusions. However, from the few samples analysed the compost does not appear to have a lower concentration of this element than the chicken manure; thus, if anything, the analytic results indicate the opposite of the growers' perception.

Flexibility: Several growers commented that crop growth was less predictable with compost than chicken manure. The nitrogen content is higher and more readily available in chicken manure and as such it is easier to manipulate crop growth. (i.e. to match application with crop demand). If a crop needs a nutrient boost the addition of chicken manure will have a near immediate effect. With compost this is not the case. Growers felt that using compost as a fertility input was more of a 'hit and miss' affair.

Labour demand: Beds amended with compost required more work in terms of watering and forking of the soil surface to allow the water to percolate. As this is done manually it represents a potentially prohibitive constraint to use. However, the growers noted the fact that compost does not have to be added as often as chicken manure as a positive factor in terms of labour input.

*Box 6.1 Summary of Growers' assessment of compost performance*

| | Positive | Negative |
|---|---|---|
| **Compost** | • Lasts longer in the soil so do not need to apply to every crop - labour and money saving.<br>• Plants grow greener and lusher in compost<br>• Provided appropriate management is given, crops grow bigger and sometimes faster<br>• Good for using on nursery beds. Cannot use chicken manure for this<br>• Helps improve crop performance of salty land. | • Plants burn and sometimes grow stunted under dry weather conditions<br>• Water requirement is higher<br>• Needs more management to perform well – both watering and forking of the soil surface - higher labour demand<br>• Less control and predictability than with chicken manure – because a more delayed effect with compost, cannot rectify the situation once it goes badly<br>• Less plant uniformity |
| **Chicken Manure** | • Predictable - know how to use it and get consistently good results<br>• Plants grow faster and frequently bigger<br>• Can manipulate the growth, i.e. add a little extra if the crop needs a boost during growth<br>• Better crop uniformity<br>• Serves as a mulch which preserves water<br>• Can get away with skipping the watering for a day or two | • Does not last in the soil, need to apply to every crop - labour and money costs<br>• Can be too hot (fresh) and burn the crop. If so, the burning is worse than with compost because watering does not help<br>• Not good during the rainy season<br>• Too much use can make the soil salty<br>• Can be difficult to get hold of |

*Source: This research*

## 6.4 On-farm trial results

### *6.4.1 Crop performance*

What follows is an account of the crop performance in the on-farm trial. Some of the more detailed results are given in Appendix D. Crop yields showed positive effects to compost amendment in all crops. Although the crop response varied between crops and the differences between treatments was not always statistically significant, the compost treatment consistently produced the best results. The harvestable yields of the four crops are summarised in Table 6.18, with the extent of statistical significance indicated by letters adjacent to the yield figures

*Table 6.18 The yield of the different crops grown in the on-farm trial*

| | Compost | | | Cow manure | | | NPK | | | Control | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kg/plot | t/ha | | kg/plot | t/ha | | kg/plot | t/ha | | kg/plot | t/ha | |
| Tomato | 11.6 | 5.8 | (a) | 10.23 | 5.1 | (a) | N/A | N/A | | 6.08 | 3.1 | (b) |
| Chilli Pepper | 3.16 | 1.6 | (a) | 2.41 | 1.2 | (a) | 3.01 | 1.5 | (a) | 2.27 | 1.1 | (a) |
| Cabbage | 34.9 | 17.5 | (a) | 32.8 | 16.4 | (a) | 18.7 | 9.4 | (b) | 4.5 | 2.3 | (b) |
| Okra | 2.77 | 1.4 | (a) | 2.45 | 1.2 | (a) | 2.69 | 1.3 | (a) | 2.17 | 1.1 | (a) |

The letters denote where there are significant differences between treatment means.
Values with the same letter means that the difference is not statistically significant at P>0.05

*Source: This research*

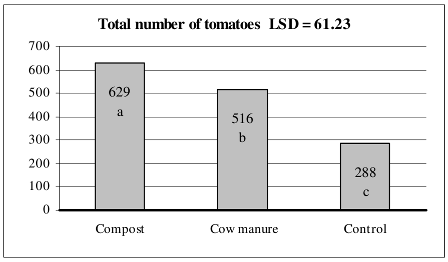
In general, the yields in all crops were poor. Watering was carried out manually by carrying watering cans from the adjacent stream. The predominately dry growing conditions coupled with the free draining characteristics of the soil on which the trial was located resulted in less than optimum growing conditions in terms of crop water requirements. The cabbage crop suffered a serious aphid attack towards the latter part of the growing period, which adversely affected the yield.

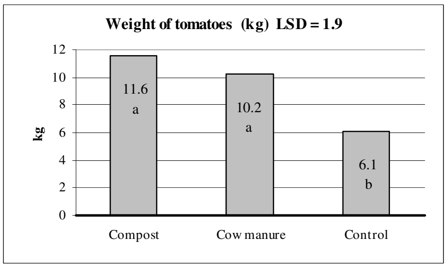
Low yields, like the ones experienced in the trial for tomato and okra, according to the farmer are not unusual within the local farming systems, wherever these crops are grown. Chilli pepper, cabbage and lettuce are less commonly grown within the La stool land area and the farmer had had limited experience with these crops, thus he was unsure of how to interpret the yield results in relation to 'normal' outcomes. Notwithstanding the overall low yields, differences between treatments were nevertheless evident.

**Tomato crop**

The tomato crop response to compost amendment in the first crop following the first application was above expectation. The compost application rate was set high (50t/ha) because of the materials' low nutrient (particularly N) and organic matter content, thus the effect from a single application was not expected to be marked. Similar work on waste derived compost applications to arable land in the UK (HDRA, 1999) after several growing seasons failed to produce any significant yield responses, even at high application rates (up to 75t/ha/yr). With this in mind, the large crop response experienced after the first application was unexpected, particularly in view of the low nitrogen content (0.1%) of the material. The compost treatment produced better results than the cow manure treatment, although the difference was not significant. Both treatments did, however, produce statistically significant ($P<0.05$) better results than the control treatment (Graphs 6.6a&b). Fresh weight yields in plots amended with compost almost doubled over the control, in the first tomato crop.

The farmer was very pleased with the outcome and eager to proceed with the experimentation. He sowed okra towards the end of the tomato crop without applying any further compost or manure to the beds. Unfortunately his goats got into the trial and destroyed the crop at six weeks and no assessments were done on this crop. The decision was made to fence the trial area to prevent a repeat of this event in the future. As a result of this happening there was a gap in the production of approximately two months.



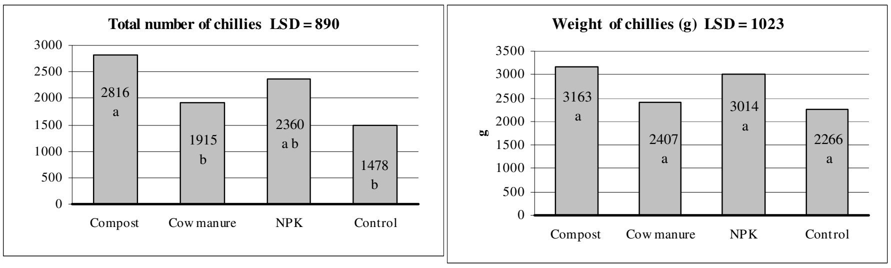

*Graphs 6.6 a&b Total number and weight of tomatoes harvested over 5 weeks, (treatment mean)*

*Source: This research*

## Chilli Pepper

A second application of compost and cow manure was added to the beds and then chilli pepper was transplanted into the beds. The rate of compost was lowered to 25 t/ha whilst the cow manure rate remained the same at 20 t/ha. At the request of the farmer an NPK treatment was introduced to the trial. (The implications of this adjustment for the statistical design of the experiments are discussed in Section 6.4.2). Initially the weather conditions were very dry. The crop had difficulty establishing and the labour demand for watering was substantial. However, the crop took off and produced peppers over a harvest period of 13 weeks. The difference in yield was less clear-cut compared with the preceding tomato crop. The compost and NPK treatments produced statistically ($P<0.05$) higher yield than both the cow manure and control treatments in terms of the number of chillies harvested, but in terms of fresh weight there were no significant differences between the four treatments (Graphs 6.7a&b).

The farmer was, however, of the opinion that the compost treatment had produced the best looking plants, followed by the NPK treatment, cow manure treatment and control treatment, in that order. He also noticed that the compost amended soil dried out faster than the other beds. This observation was surprising considering that, as mentioned in Section 6.3, one of the main perceived benefits to compost amendment is the improved water holding capacity of the soil. However, given the low OM content of the compost used, particularly that from the Teshie/Nungua site, and the water retention improvements gained from compost is derived from the supply of organic matter through compost, it is perhaps not surprising that no benefits to water holding capacity was noticeable.




*Graphs 6.7 a&b Total number and weight of chillies harvested over 13 weeks, (treatment mean).*

*Source: This research*

**Cabbage**

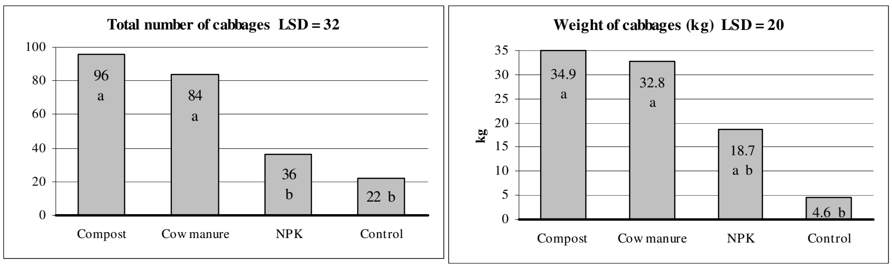
Following the chilli crop a third compost and cow manure application was made. This time the application rate was reduced further to 20 t/ha. The cow manure application rate on the other hand, was increased to from 20 to 30 t/ha. The farmer felt that the cow manure treatment did not perform very well and wanted to increase the rate, particularly since cabbage is a nutrient demanding crop.

Approximately one month after the final harvest of chilli the cabbage was transplanted. The crop suffered some aphid and caterpillar attacks and was sprayed with both neem and *Bacillus thurengensis*. At six weeks after transplanting the crop looked very healthy and clear differences could be seen between the treatments (Appendix D, Photo 6.1). The farmer invited local colleagues to see the trial and to discuss the findings to date. Several farmers came to have a look, many of which were participating in the local FFS initiative funded by the FAO and run by the extension service. At one occasion 10 farmers from the FFS came to discuss the trial and help with weeding (Photo 6.2). Unfortunately the FFS facilitator never attended. The local extension officer, however, visited the trial on several occasions.

Towards the end of the cropping period the crop became re-infested with aphids that badly damaged the crop and resulted in a poor harvest. In spite of the dramatically reduced plant size following the aphid attack, the crop was still harvested. The differences between treatments that had been observed and recorded prior to the attack were reflected in the harvest data. The NPK treatment failed to produce good results. Many plants in this treatment had died early on in the growing period and those that survived were variable in size, in spite of following the spot application method as well as the rate and timing of application recommended by the extension service. The failure of the NPK treatment to produce a good crop of cabbage was likely to be caused by the spot application method used which resulted in a too high a nutrient concentration near the root of the juvenile plants. The farmer was of the opinion that the crop would have performed better if the fertiliser application had been added at one month instead of two weeks after transplanting.

Both the compost and manure treatments produced yields which were seven-fold that of the control and nearly double that of the NPK treatment. Although the compost treatment performed slightly better than the cow manure treatment, the difference was insignificant. Both the compost and manure treatments produced significantly more cabbage heads than the NPK treatment, but the difference in weight was not statistically significant (P>0.05). Cabbages grown to a harvestable size in the NPK treatment were, however, bigger than those in the compost and cow manure treatments. Consequently, the difference in weight between the three treatments was not statistically significant (at 5%).

The farmer was very disappointed and disheartened with the outcome of the trial. Having started out extremely promising, the late stage aphid attack virtually rendered the crop unmarketable. The labour investment in watering, spraying and weeding had been substantial in this crop. Cabbage is one of the most lucrative vegetable crops and the farmer had hoped to gain a substantial return to his investment. In spite of the disappointing outcome of this crop, he was pleased with the crop response in the compost amended beds and was of the opinion that compost was the best treatment. However, once again the farmer noted that the compost treated beds dried out more quickly than the other beds. He also noted that there was more weed growth in the compost beds.




*Graphs 6.8 a&b Total number and weight of cabbages harvested, (treatment mean)*

*Source: This research*

*Photo 6.1 The cabbage trial at 6 weeks after transplanting, prior to the aphid infestation*

*Photo 6.2 The on-farm trial farmer discussing the cabbage crop with fellow farmers*

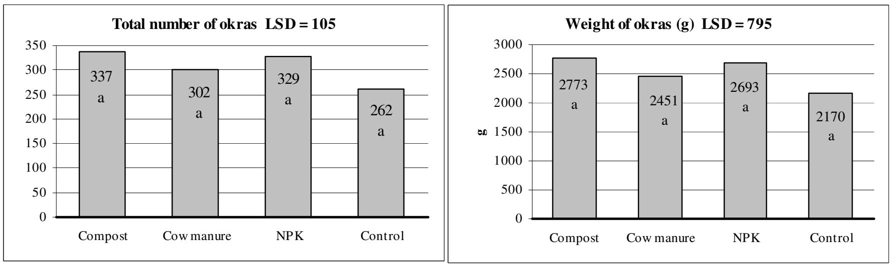
**Lettuce**

Immediately following the cabbage harvest a crop of lettuce was transplanted without any further compost or manure amendment. This crop was in the ground for five weeks and was never quantatively assessed, as the researcher was not in the country at the time of harvest. However, visual inspection by the farmer indicated that there were no clear differences between the plants grown in the compost, manure and NPK amended beds, whilst the plants grown in the unamended control beds were smaller and paler in colour. Generally the crop performed well and produced a good crop.

**Okra**

A fourth and final compost and manure application was made before a crop of okra was sown. This time the rates remained unchanged at 20t/ha of compost and 30t/ha of cow manure. The fact that a fourth application of compost was added was due to a misunderstanding between the researcher and the farmer. This was a mistake which resulted in nutrient and heavy metal supply in excess of what had been intended.

This time the compost treatment did not perform as well as in earlier crops. It is possible that this was due to the fact that too much had been supplied. The results indicated that emergence and initial plant growth was slower in the compost amended beds. During the early stages of crop growth, plant uniformity, size and bushiness were scored on an overall plot basis, and showed that crop growth was inferior in the compost treatment compared with the plants grown in the cow manure amended and the control beds. (see Appendix D). The plants grown with NPK also scored lower than those in the cow manure and control treatments. However, by harvest, the initial differences between treatments had evened out and both the compost and NPK treatments produced a slightly higher yield than either the cow manure and control treatments did, although the yield differences were not statistically significant.




*Graphs 6.9 a&b Total number and weight of okras harvested over 11 weeks, (treatment mean)*

*Source: This research*

### *6.4.2 Analysis of Normalised Values*

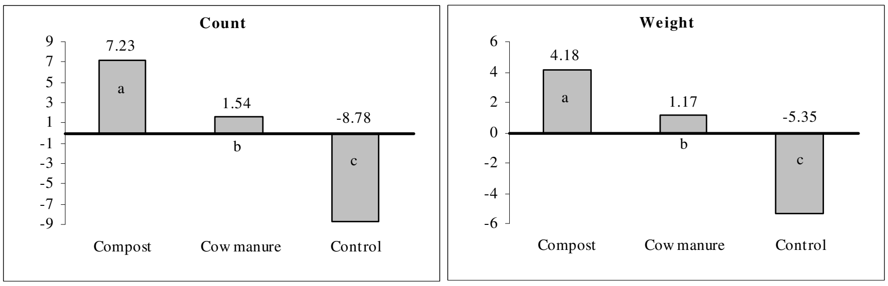
In order to ascertain the overall differences between treatments and any cumulative benefits in crop growth resulting from repeated compost applications over time, the harvest data were normalised and the overall treatment differences were analysed. One possible approach to combining all crops together is analysis of normalised values which allows for the analysis of the underlying plot variability (Mead, pers. comm., 2002). By normalising the values all crops can be combined together taking into account the differences between the crops (i.e. the fact that a cabbage head weighs much more than a tomato and that there are more tomatoes harvested from a plot than there are cabbage heads).

Because an NPK treatment was added to the trial in the second crop, the data was grouped in two different ways for the analysis.

- First, one set of analyses was done on all crops, including only the three treatments that were used from the beginning (i.e. excluding the NPK treatment). This analysis was done on: Tomatoes, Chilli Pepper, Cabbage and Okra, grown in Compost, Cow manure and non-amended beds.
- Secondly, another cumulative analysis was done whereby the first tomato crop was excluded, thus allowing for the NPK treatment to be included. This analysis was done on: Chilli pepper, Cabbage and Okra, grown in Compost, cow manure NPK and non-amended beds.

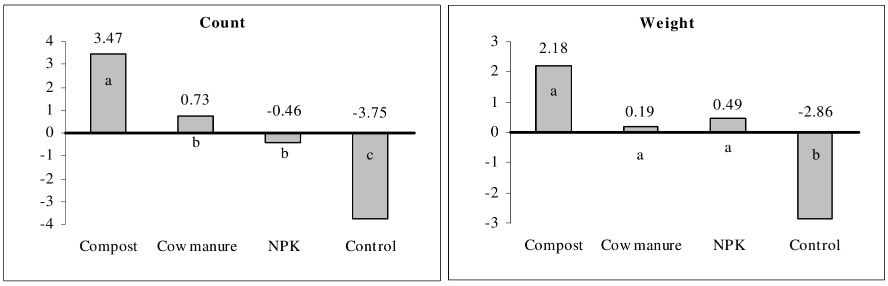
The combining together of the crops further highlighted the differences between the treatments (Graphs 6.10 ans 6.11). There were significant treatment effects in both sets of analysis for both weight and count. For the analysis which included all crops, but excluded the NPK treatment, the difference was statistically significant between each treatment. Compost performed best, followed by cow manure and lastly the control treatment. For the analysis which included the NPK treatment and therefore excluded the tomato crop, the picture was slightly different. Again, the compost treatment performed best; by count it was significantly better than the other treatments but by weight the difference between compost, cow manure and NPK was not statistically significant (at $P>0.05$). There were no significant differences between the cow manure and the NPK treatments by either count or weight. The control treatment consistently produced significantly poorer results than the other treatments.

The overall poor performance of the NPK treatment could be ascribed to the dry weather conditions, causing the crop to suffer from burning and possibly also to the fact that the farmer was unaccustomed to using the spot application method of NPK. Although he followed the recommendations given by the extension services it is possible that he did not get the application procedure quite right, for example in terms of application distance from the crop roots, and the need for watering following application.




*Graphs 6.10 a&b  Differences between treatments based on normalised data, including all four crops and three treatments*

*Source: This thesis*




*Graphs 6.11 a&b  Differences between treatments based on normalised data, including three crops and all four treatments*

*Source: This thesis*

### *6.4.3 Farmer's assessment*

The farmer was happy with the outcome of the trial and impressed with the crop performance in the compost amended beds. His assessments repeatedly showed the compost treatment to be better than the other treatments. With the exception of the final okra crop, following a fourth application of compost, there were no problems of die-off and burning with the newly germinated or transplanted seedlings, (as was experienced by some of the vegetable growers). The farmer, like the vegetable growers, however did notice an increased water demand in the compost beds.

He felt that he had learnt a lot about vegetable production and about the principles of comparing different options through experimentation. One reason why the farmer had been interested from the start in carrying out the trial was so that he would learn about growing vegetables. Apart from the traditional tomato and okra crops, he had no prior experience in vegetable production and was interested in learning about commercially lucrative exotics such as lettuce and cabbage. When the trial period came to an end the farmer wanted to carry on using the site for experimental purposes. He was keen to try out crops and soil fertility inputs that were new to him. At the time that I was leaving, he planted some mango trees along the edges of the field and was getting started on trying both poultry and pig manure. With regards to the continuing use of MCW, he said that although he was very impressed with the material, it would not be cost-effective for him to use it as he had plenty of manure from his own livestock.

He was bitterly disappointed about the failure of the cabbage crop and was convinced that witchcraft by jealous fellow farmers was the cause of it. He had invested a lot of time, inputs and effort in this crop. Investment in watering, weeding and spraying during earlier aphid attacks had resulted in a very healthy crop. The cabbage heads were fully formed by the time the detrimental attack occurred, which was one reason why the farmer convinced that there was witchcraft behind the attack. Many of the neighbouring farmers had visited the trial and the farmer had been happy to discuss his work with them. He subsequently felt that some people were jealous and wanted to punish him for his 'luck'. The farmer subsequently became concerned that if it was witchcraft fuelled by jealousy that was the cause of the poor outcome he would have second thoughts about inviting other farmers to share his experiences.

## 6.5 Summary of the main findings

This chapter has presented the results of testing waste derived compost (WDC) as a soil amendment in existing farming systems. In this section the main findings from the experimental work with vegetable growers, the on-farm trial, and the compost, manure, sludge and soil analyses are summarised. The focus here is on the relative usefulness of WDC in local crop production systems in terms of the agronomic aspects. In Chapter 7 a broader view of the potential for using WDC in agriculture is taken, examining the system as a whole from the perspective of key stakeholders.

### *6.5.1 Soil, compost, manure and sludge analysis*

The results of the analysis of the Teshie compost in terms of its high heavy metal content and low nitrogen (N) and organic matter (OM) content, suggest that this compost is of an unacceptable standard. In order to supply enough nitrogen and organic matter to be of agronomic value, application rates supplying hazardous levels of heavy metals would need to be used. As such it would not be appropriate to recommend the use of this compost to farmers and growers. The results of the analysis of the James Town compost showed this to be the better alternative. Nutrients and organic matter contents were higher whilst the heavy metal concentrations were generally lower. This compost contained exceptionally high concentrations of phosphorus (P). In fact, so much so that the P supply through compost amendments is likely to be the limiting factor in terms of loading rates (rather than N and heavy metals, as is more common). Considering that many tropical soils are deficient in P, compost of this kind could represent a valuable soil input, particularly if mixed with chicken manure to ensure adequate N supply for crop growth.

There is a risk of heavy metal build-up in the soil through continuous application. The projection of build-up (Appendix C) showed that long term applications could result in the most stringent European guidelines for maximum permissible levels being exceeded. According to more lenient standards, such as the EU Ecolabel and the UK Sludge Regulations, long term applications would still be within the safe limits.

The soils at the vegetable experimentation sites generally contained higher concentrations of nutrients, organic matter and heavy metals than the less intensively farmed on-farm trial soil. The elements that were notably lower in the on-farm soil were N, P, OM, Na, Zn, Hg and Pb. The soils in the vegetable growing areas receive frequent chicken manure application whilst the on-farm trial soil had been under a low intensity rainfed cropping system. The wastewater used for irrigation in the vegetable producing areas contains both nutrients and heavy metals and its continuous use over time is likely to contribute to salinisation and build-up of heavy metals in the soil. In fact, it could be argued on the basis of my research that heavy metal pollution from air and irrigation with waste water pose a greater risk than that from compost. Thus judging the compost quality against the most stringent standards used in Europe may be overly cautious. Nevertheless, the presence of one practice that is environmentally questionable, should not condone the practice or introduction of another. For compost to be an attractive long term soil input to farmers and growers the quality of the material needs to be improved. The method of composting used at the Teshie/Nungua plant is not suitable for producing material that has agricultural value.

### *6.5.2 Crop performance*

From the onset of this research, it became clear that the main soil fertility input used by growers is chicken manure. My initial reaction was that this would not compare favourably with compost. Chicken manure is rich in soluble nutrients and produces crop growth responses not dissimilar to those of chemical fertiliser. Compost is more of a soil improver, releasing nutrients slowly over a longer period of time. Having said that, the P concentration in the James Town compost was exceptionally high and not typical of compost. In practice, the compost treatment performed above expectation producing crop responses that were comparable to the chicken manure treatment. In the on-farm trial the crop response to compost amendments was striking with the compost treatment consistently producing better results than the other treatments. However, the application rates used were high. With the exception of commercial small-scale vegetable producers who apply high rates of chicken manure to each crop at each planting, the high application rates used in the on-farm trial would most probably not be feasible for most farmers and growers.

Although the compost treatment performed surprisingly well, there were some problems. The tendency for juvenile plants to burn and die-off in the compost amended soil and for the compost treatment to need more watering than the other treatments emerged as common problems. The two were related; by ensuring adequate watering the problem of die-off appeared to be controlled. Providing the crop survived the initial growth stage, the performance in the compost amended soil was good with crops growing as large and lush as in the chicken manure amended soil. Compared with cow manure, and even in some cases NPK, crops grown with compost (at the high rates used) did better.

The growers were happy with the crop performance from compost, but saw the watering issue as a potential problem. They were of the opinion that compost would be an attractive alternative to chicken manure during the rainy season. They also liked the fact that they did not need to apply compost to each crop, as they do with chicken manure. However, there was a general consensus that compost was less reliable and predictable than chicken manure. When applying chicken manure they would know the crop response and be able to time the application and the rate to match crop nutrient demand. With compost this was not possible. In the words of one farmer: "*it is applied prior to transplanting and then you hope for the best*" (Ruby, pers. comm., 2001). Overall the growers were generally of the opinion that the compost was good and that they would like to use it providing they could access it at an affordable price. The considerations of access and price are covered in Chapter 7.

## 6.5 Reflections on the research process

The remainder of this Chapter cover my reflections on the experimental process and my role as a researcher. Many aspects of the research were pre-determined before the fieldwork commenced. The aim was to explore the effects of using MCW in local cropping systems and to that end the research project was technology driven. Whilst the technology was pre-determined and the approach did not leave growers with the possibility to engage in a process of identifying their priorities and driving the research agenda, the methodology was flexible and the experimentation process collaborative. The experimentation phase was entered into with the aim to maximise growers' participation in the research process within the boundaries of the pre-determined research project and its chosen technology (i.e. MCW). It was a flexible and iterative process with growers having a major say in how to run the experiments and the researcher taking a 'back seat role', acting as a facilitator and observer. The way the implementation phase was conducted was in line with much of the thinking in action research. The experimentation was collaborative in that the researcher, her assistant, and the growers worked together with shared, negotiated roles and responsibilities for different aspects of the research.

The literature on participation (e.g. Biggs 1989, Cornwall *et al*., 1995; Pretty, 1995) has identified different modes of participation, each with different degrees of outsider vs. insider control and contribution in the research and development process (See Figure 6.5 for an example). According to this schema of the modes of participative research and development, this research fits best into the category of collaborative work.

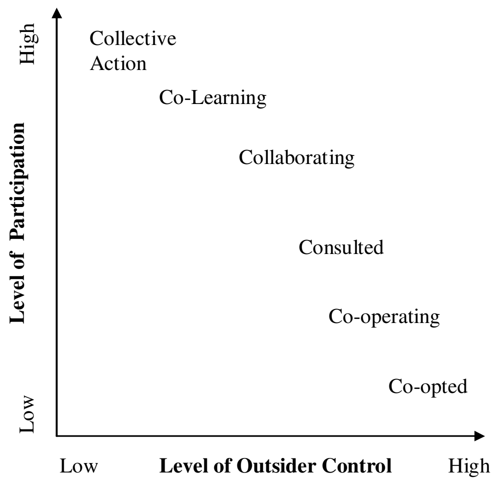



*Figure 6.5 Different types of on-farm research in relation to the level of participation and outsider control*

*Source: Adapted from Biggs, 1989; Pretty, 1995 and Cornwall et al., 1995*

For the majority of growers, whether directly or indirectly involved, participating in research was a new experience for them. As mentioned previously, the main approach to agricultural research, development and extension in Ghana has been based on the ToT model (transfer of technology) and apart from a farmer field school (FFS) pilot project, the extension support given to farmers and growers within Accra is based on this model. The growers in Dzorwulu had previously been exposed to the FFS initiative as their area was selected as one of the sites for the FFS pilot project. Other than that the growers had never been involved in any research or extension development before and were not used to participating, or even being consulted, in any such activities.

Working with the growers the way I did was very rewarding, although it would be misleading to imply that the experimentation was smoothly implemented without frustrations and doubts. At various stages during the process problems arose, some of which were resolvable, others of which led to the research being modified. The iterative process chosen for the research allowed for modifications to be made. The group meetings represented good opportunities to take stock of the work and to make changes on the basis of the feedback emerging. From the point of view of the Ph.D. research, problems or challenges encountered along the way related essentially to the tension between the technical and the methodological aspects of the research which invariably presented itself in terms of the choice at accept an interdisciplinary approach and methodological pluralism; and balancing grower and researcher control in attempting to satisfy the criteria of both parties.

***Methodological pluralism***

There was a tension between the technical and the methodological development throughout the research which extended beyond the experimental work and will be discussed further in Chapter 8. This may be a 'normal' facet of Ph.D. research, but nevertheless represents a challenge when faced in the field. In terms of the work with growers the questions that arose related to whether (1) I was researching the potential for compost use, or conducting research on the research process itself; and (2), the work was research or, in fact, development. Whilst emerged in the day-to-day practicalities of the praxis, it was easy to lose sight of the fact that what was taking place was a mix of all these aspects.

The experimental part of the research was an area where the academic and applied met. Working with farmers on experimentation invariably sets up an interface of complementary action and a platform for dialogue. However, throughout the experimental period I was often left with the feeling that what I was doing was not actually research but rather development work, although I had entered into it with the aim of 'doing research'. This calls into question the boundary categories, i.e. the classification of research, development research, development and so on. On the technical side, the data generated were not overly 'scientific'. With regards to the methodological aspects of the research, I found that the potential for the research process to bring about an environment conducive to stimulate (and encourage) dynamism, enthusiasm and social learning was constrained by the very fact that the experimentation was entered into with a pre-determined technology. For example, it emerged early on that testing compost was not the most pressing of needs for growers. Had it been a project with the primary aim to assist the development of the growers, the focus of the project could have changed to include issues such as water supply and marketing, as topics identified by the growers of being of primary importance to them. My work would then have been a more participative endeavour with greater potential for stimulating enthusiasm and for researching the processes of co-learning, communication, and reflections on experiences and outcomes, as we worked together towards objectives that the growers themselves identified as important. As it was, I was limited to stay within the boundaries of examining the appropriateness of MCW. Nevertheless, I kept 'balancing the tight rope', attempting to hold together the technical and methodological aspects of the research with one foot in natural science and the other in social science. I had to keep reminding myself not to focus too much on one aspect at the expense of the other and, as such, compromising the underlying principle of the interdisciplinary of the study.

***Researcher' vs. Growers' criteria***

Another challenge of the experimentation with the vegetable growers was that of differentiating between the overall Ph.D. project and the experimentation, and of ensuring that the work satisfied the aims and objectives of both the growers and the researcher. From my point of view, I needed to ultimately produce a Thesis and, as such, data and information that were in a scientifically useable form. The growers did not have any interest or understanding of this. Their way of assessing the performance of a technology is very different from that employed in science (Gubbels, 1997; Stolzenbach, 1997; Ishag *et al.,* 1997). The underlying principle of letting the growers control much of the research process and to be the managers of the experiments meant that they frequently made decisions which meant that data collection plans had to be modified. Some changes (e.g. different crops grown, different frequencies of compost application) could easily be accommodated within the overall design of the data collection and analysis. Others were more problematic; for instance, several growers frequently changed the plots on which they applied compost in order to maximise the land on which compost was applied.

As discussed in Chapter 5, the variation in experimental management was considerable, which meant that the data were rather inconclusive, and from a scientific point of view did not have high discriminatory value. However, the research never set out to provide a detailed study of compost quality and performance but rather to provide an insight into its performance under real cropping conditions and its potential for use by local farmers and growers. As such, the growers' perceptions and judgements were of fundamental importance and could not be gained unless the growers got to test the material for themselves. The growers had to be able to use the compost the way they wanted to. This meant that the research had to tolerate highly ambiguous situations producing very variable data - but anything else would not have provided a collaborative environment and learning would have been impeded. Having been through the 'ups and downs' experience of experimentation with the growers, I maintain that data generated from on-station research would also have been inconclusive, because of the variability of the composted material (See Chapter 2, Section 2.2.3).

In Chapter 2 the rationale for carrying out trials to test compost and for choosing to work with farmers was discussed. In brief, the main points made were:

- It provided quantitative data on the performance of crops grown with compost in relation to existing farmer practices.
- The underlying rationale was to explore the issue under real-life conditions using existing compost derived from urban waste (regardless of its quality) in existing farming systems.
- It had emerged from the initial stakeholder interviews and farmer baseline survey that farmers and growers had limited knowledge of municipal waste derived compost and felt unable to speculate on its potential for use unless they tried it for themselves. Interviews with growers would not have been enough to gain an insight into the actual potential for using MCW in local farming systems.

In addition to these was an implicit reason which had not been apparent to me before starting the fieldwork, but which gradually dawned on me once I started working with the growers. I came to realise that by carrying out the experiments I had an excuse to spend time with the growers. In other words, the experimentation served as a mechanism for building and sustaining an ongoing interaction with the growers and thus for getting to know them and their views in a way that interviews could never provide. We had a common project and as such I had a reason to keep visiting them and gain an in-depth understanding of their farming system, in a way that I would not have done had I only visited them to do interviews and PRA activities. The compost trials were a vehicle for having an ongoing interaction which led to the development of mutual trust and learning. This research provided something for both the growers and I, and no one felt used. We were involved in it for different reasons, but both parties gained something from the experience. I was conscious that I did not want to purely extract information from them. So, whilst the value of the quantitative data was only moderately useful from a scientific point of view, the work provided a lot of other valuable information and, above all, mutual learning experiences that have helped me to interpret the data and the 'meaning of compost' in a real world context..

Regular visits were made to the on-farm trial and frequently extended periods of time was spent there talking to the farmer and his assistant, often while helping with field activities such as weeding. By visiting regularly and sharing some of the work tasks, a moderately informal relationship was built which enabled free chatting and informal feedback. Also, as time went by and trust was built, time was also spent with the farmer in social contexts removed from the farm activities. Such interactions helped to foster a degree of informality in the relationship between the researcher and the farmers. This, in turn helped create an environment in which the farmer felt able to be relaxed and able to be honest in his evaluation of the researcher and for related yet unforeseen issues to emerge.

***Outcomes, Impacts and Learning Experiences***

I started the research with a general interest in collaborative experimentation. I was convinced of the benefits of farmers' experimentation for testing the appropriateness of new and modified technology and for aiding adoption. I expected insights to be gained along the way through a process of data collection, analysis and reflection. I hoped that the flexible and informal approach used would encourage growers to adapt and adopt the technology and that it would generate an interest amongst other growers who were not directly involved in the experimentation. I ultimately hoped that a certain amount of farmer-to-farmer information exchange and learning would evolve as growers engaged in the experimentation. In fact, one of the objectives of the research as set out initially was to monitor any such interaction and any co-learning that resulted from the process. However, whilst there was much interest in participating in the experiments and the attendance of non-experimenting growers at the regular group meetings was high, in between the meetings there appeared to be limited curiosity among non-participating growers and limited farmer-to-farmer exchange of information about the work. My research diary is full of entries relating to my concerns about the apparent lack of enthusiasm and curiosity amongst the growers to adapt the technology, explore options, and learn from each other's experiences.

Both participating and non-participating growers were invited to use the compost that had been delivered to the sites and to try it out and feel free to experiment with it, on its own or combination with other fertility inputs, e.g. chicken manure. Few-non-participating growers used the compost and of those involved in the experimentation very few modified and experimented with its use (but see further below). They tended to wait for us to tell them how to do it. It transpired that other growers did not feel they could use the compost, even when invited to do so. Growers appeared to think that the experimenting group was an exclusive club, which they had to join, even though they were repeatedly (at the group meetings or at other times) invited to participate in the experimentation or simply to use some compost. The vegetable growers, (less so the on-farm trial farmer), had weak sense of ownership of the experiments. Whenever they were asked what they thought of the compost they were positive, in some cases even when it was obvious that the crop was doing worse with the compost amendment. They referred to the experiments as the 'school work' and on occasion I sensed that they were keen to manage the experiments well in order to please me. Naturally, as an outsider people related to me in a special way. I was aware that what they were saying and what they actually thought were not always the same. It became increasingly clear that farmer participation is a process which develops somewhat more slowly than I had anticipated.

Whilst the relationship and interaction between the researcher, her assistant and the growers was good, I felt by the end that we had only just started; that the short period of one year in the case of the vegetable growers and 1.3 year in the case of the on-farm trial farmer, was not enough to build up the trust, capacities and learning to (1) experience any real change in the growers' attitudes to and capacities for experimentation and (2) to bring about developments for positive change.

***Signs of innovation***

Notwithstanding the fact that the experimentation did not animate growers to adapt and adopt the technology to the extent that had been anticipated, several positive outcomes emerged during the course of the work. Some of the growers experimented with using the compost on other beds, trying it out on several types of crops. Some tried mixing it with chicken manure to see if the longevity of the compost and the nitrogen concentration of chicken manure could be harnessed to maximum effect. Mid-way through the research period experimentation with making compost on site with crop and household wastes were set up at two of the sites, at the request of the growers. Following this experience, a couple of growers started making their own compost and some began to utilise the decomposed material from the communal crop waste piles that were scattered around the cropping areas. Growers previously had never utilised this material and the crop waste was frequently burnt to clear the sites.

Although the growers were largely unable to articulate their learning experiences, I think these developments point to the fact that some learning had taken place and that innovation processes (as distinct from mere technology transfer) were beginning to develop. A difficulty with experience-based learning is the long time frame needed to see the effects of many actions (Holland and Silva, 2001). The fact that growers in Dzorwulu seemed able to move forward innovations is a case in point. Here they had been involved with FFS and had learnt from that.

With the limited time at my disposal, I felt unable to open up the experiments too much to growers' expectations, in fear of fear of ending up in a situation whereby I had no analysable results. However, looking back, it would probably have been useful to have changed or expanded the treatments examine mixing compost with chicken manure. The very high phosphorus content of the compost and the high concentration of soluble nitrogen in the chicken manure meant that a combination of the two was likely to be beneficial. The fact the experimental design was not changed to accommodate this finding meant that the experience may not have been as useful to the growers as it could have been. The importance of ensuring that the activities are challenging in terms of new knowledge and opportunities, so that the interest of all members is be held, has been stressed in the literature (Sheath and Webby, 2000). This means that the focus may need to evolve. The experiments at the vegetable growing sites did not evolve enough to retain the enthusiasm of all growers involved. However, had the monitoring of crop response to compost been abandoned in favour of making the work more in line with the growers' interests, then the validity of results would have been compromised. A fine balance had to be struck between what was achievable and what was desirable. This was a challenge and a key learning experience for me. By balancing research and development and in striving for interdisciplinarity and appropriateness, the question which this experience posed is: Do we end up doing bad science and bad development and as a result, doing noting well? I will return to this question in Chapter 8.

As I reflected on my experience I have come to realise that more time and consideration ideally should have been given to the starting process. I had limited time and entered into the implementation of the experimentation rather too quickly and as such may not have built the foundations for effective and inclusive participation and learning processes sufficiently well. I came to conclude that so much emphasis had been placed on the practicalities of the 'getting started' that the initial period had not been as inclusive as it could have been. The experiments had been set up too fast without giving enough emphasis to the importance of the initiating phase in the whole research process. Although an open initial meeting was held at each site to ascertain the level of interest in both the technology and experimentation, some growers who might have had an interest were unable to attend or were simply unaware of the meeting. The initial meeting was followed by a planning meeting to negotiate roles and design the experiments. The invitation to participate remained open to all growers in the areas. Communication was open and honest and the growers who volunteered to participate did so knowing that they would be part of a process that neither they nor I could guarantee would benefit them, and that they would not be given any payments or hand-outs. It was important to me not to force or entice people into anything unless they were interested. The invitation to participate was continuously extended throughout the period and several growers joined at various stages.

As time progressed, however, issues of conflict, exclusion, and jealousy began to emerge. In some cases it took the form of mistrust and jealousy, of not wanting to share information freely. Clearly this was not a conducive atmosphere for joint experimentation and co-learning. This was mainly evident in the Marine Drive area. Here there was a divide between the growers which proved to be an enduring problem for the research. Whilst we had believed that everyone had been invited to the initial meetings, the social dynamics at this site were such that the growers would not share meeting venues. Unaware of this, we went ahead with the setting up the experiments with those who showed interest, leaving another group of growers feeling excluded and offended. Half-way through the research period another set of experiments, with compost delivered separately, had to be set up at this site. In retrospect it seems that the time constraints of the project meant that the experiments were executed without sufficient attention being given to discovering such conflicts and divides, and to designing the research in such a way as to minimise tension. This proved an important learning experience for me.

Although the growers were largely unable to articulate their experiences in terms of learning, I think the innovations that did begin to occur point to the fact that some learning had taken place. Furthermore, apart from first order learning (Argyris and Schön, 1996; King, 2000, SLIM Policy Briefing No.6, 2004) about the compost and its performance in crop production, there were indications to suggest that the growers had gained an increased understanding of experimentation and became more familiar with and able to interact with researchers than they had previously been (second order learning). Indirectly, the fact that the growers in Dzorwulu were more able to understand the objectives and principles of experimentation, whereby they appreciated the importance of monitoring and data collection and recording indicated that the previous FFS activities they had been involved with had resulted in them gaining this knowledge. However, a difficulty in assessing the impact of experience-based learning is the long time frame needed to see the effects of many actions (Holland and Silva, 2001). It was not possible to categorically conclude that capacity strengthening had taken place as a result of the experimentation, but there were indications from the growers that they had found the experience rewarding, over and above leaning about compost. For instance, when assessing the experience the growers mentioned that the equal partnership that had underpinned the experimentation was the most positive point. During the research a relationship based on mutual trust developed which aided the gradual process of participation, and the sense that the partnership was equal in practice not only in word. The growers liked the fact that we worked with them to test something rather than telling them what to do. They liked the fact that their views mattered, that they were able to have their say and were listened to. They thought that the meetings we held were inclusive and non-threatening. These points came out particularly strongly at a workshop attended by waste managers and technicians, extension officers and researcher (Accra, 2001). The growers said that they had never before been in a situation where they were able to speak and where their views carried equal weight to everyone else's. They had done the experimentation and as such knew more about the performance of the compost than the extension officers did. They were in the role of informing the extension officers, waste managers and composting technicians about the performance of the compost in their cropping systems, and they found this empowering.

## Concluding remarks

It is clear that there were both strengths and limitations to the experimental work. The experience provided me with valuable lessons which have informed my thinking about my work. Based on my experience, I suggest that the following aspects are of importance in fostering co-learning in experimentation with growers. That:

- People are involved because they want to be; that they have an interest in the experimentation and/or the technologies tested
- The objectives, working practice, experimental design and roles are agreed and accepted
- Communication is open and honest
- An atmosphere of openness, trust and mutual respect is fostered
- The experiments are kept relevant to retain the interest and appropriateness. This may require changes to be made and as such the experimental design should be:
- The experimental design is able to accommodate modifications and additions – i.e. flexible and iterative
- The experimentation is open for new people to join in
- Group meetings/activities are held for exchange/share experiences and ideas
- Activities such as meetings and exchange visits are made to foster links with peers, other groups and resource people
- There are good links with extension support services. This is something which I continuously attempted to establish, but without much success

I am convinced that the natural relationships built up in the interaction with the growers were important in fostering co-learning. However, there were several aspects of the experimentation with impeded such development, including: (1) the existence of conflicts and general divisions between growers; (2) a weak sense of ownership in the experiments which hampered the potential for co-learning; (3) the technology was not their primary choice and as such the potential for stimulating enthusiasm was limited; (4) the fact that the researcher was, in all respects, an outsider to the growers. It is possible that the effects of the first two points could have been minimised if more time had been devoted to the initial, pre-implementation phase, as discussed above.

The impact of the research was limited but it was a small project run over a short space of time, so to have expected otherwise would have been naive. My experience and study of past development projects have led me to conclude that people will carry on doing what they are doing and want to do, unless they want to change either because what they are doing is not working any more or because the alternative(s) that they are introduced to are, in their view, substantially better. Looking back, I would not have changed the general approach to the experimentation, i.e. that of letting the growers try the compost for themselves to see if it made sense to them. This meant for them to try it without me forcing or persuading anyone based on pledges of success, or of setting about changing their cropping system. Balancing the fine line between this principle and the desire to stimulate a sense of enthusiasm for the experimentation was challenging and rewarding and I certainly learnt a great deal from this experience.

# CHAPTER SEVEN – DISCUSSION: MULTI STAKEHOLDER PERSPECTIVES ON THE POTENTIAL FOR USING MUNICIPAL WASTE COMPOST IN AGRICULTURE

## 7.1 Introduction

At this point it is time to return to the basic research question: What is the potential for utilising composted urban waste in agriculture as a soil improver? The matrix table below (7.1) displays the research sub-questions and describes how the different research activities have contributed to answering each one.

On the basis of (1) exploring the farming systems in and around Accra, and the support structures in place for them, (2) past and present waste management strategies and the challenges faced in relation to waste management, and (3) experimental work with growers to test the agronomic effects of using the types of waste derived compost produced in Accra in vegetable production, it is time to attempt to tie the findings together, in order to seek to answer the research question in a systemic way. It is important here to re-iterate the issues of comprehensiveness and boundaries raised in Chapter 2. Whilst systemic research and intervention embodies the notion of comprehensiveness, it is impossible to achieve this in practice. Following the thinking of Midgley and other systems thinkers, the view adopted here is that "*methodology for systemic intervention must facilitate considerations of issues of inclusion, exclusion and marginalisation by promoting reflection on boundaries*" (Midgley, 2000:103). The boundaries of the research presented in this thesis, i.e. the cut-off points for analysis, were drawn in relation to space, time, disciplines, stakeholders, and waste types. The considerations made in relation to boundary choices were discussed in Chapter 2. This chapter looks at the potential for utilising city waste as compost in agriculture, as viewed from the perspective of several stakeholders. They have more or less divergent objectives and motivations, and differing scales of operation and thus draw different boundaries to those of the researcher. The different stakeholders' perspectives on the potential for linking composted city waste to agriculture is followed by a discussion on the institutional aspects of governance in relation to urban waste management.

*Table 7.1 The extent to which different research activities contributed towards answering the research questions*

| Research question \ Research activity | Baseline survey of FS in and around Accra | Experimentation with growers | Compost, manure and soil analysis | Interviews with market traders | Interviews with poultry farming professionals | Interviews with agricultural, waste management and health professionals and urban planners | Workshop | Individual and groups meetings and PRA exercises with growers |
|---|---|---|---|---|---|---|---|---|
| Does the use of composted urban waste in agriculture have any benefits for farmers, consumers and waste sector professionals | * | *** | *** | * | | ** | *** | *** |
| Does the use of composted urban waste in agriculture have a positive contribution towards sustainable management of the urban environment? | | | *** | | | *** | *** | (*) |
| How can changes be implemented that lead to a shift towards increased composting and subsequent agricultural utilisation of urban waste? | * | | | | | *** | *** | * |
| What are the short and long-term effects of using urban waste derived compost as a soil amendment? | | *** | *** | | | | * | * |
| How willing are farmers to use it? | * | | | | | * | *** | *** |
| How appropriate is it to farmers, in relation to other options for soil improvement? | * | ** | ** | * | * | | ** | ** |

* some relevance ** moderately relevant/ of medium relevance *** very relevant

*Source: This thesis*

Closely related to the issue of systems boundary setting is the concept of *externalities*; an *externality* being something which has an either positive or negative external effect outside the system considered. The perspectives of the different stakeholders, and the constraints and opportunities that concern them, mean that different externalities are brought into view, as will be seen in Section 7.4 of this chapter. Perhaps as a general statement, it can be said that an externality at the smaller scale becomes an integral part of the system when the systems boundary is expanded to include a higher scale of interaction. This point can be illustrated briefly by the following examples:

- The production of compost may significantly reduce the landfill-space required. This is likely to be an external issue to a farmer. However, for the municipality official concerned with waste management, it would be a major consideration.

- Composting is labour demanding, unpleasant, and potentially health hazardous work, with low returns. A waste management professional such as a hauler may not see composting as an attractive waste treatment and disposal option. The environmental and public health benefits of composting may be seen as externalities to a waste management professional involved in the day-to-day business of handling waste but not to policy makers. They may view composting of waste as an intrinsic component of sustainable waste management.

**The Stakeholders**

It was stressed in Chapter 2 that the study topic represents a systemic problem area, with a series of interconnected and interdependent issues. It involves a wide range of stakeholders including: urban planners; waste technicians and engineers, agricultural development organisations, policy makers, farmers and growers, formal, semi-formal and informal waste traders, consumers and donors.

These each have a varying stake in the issue, a varying degree of interaction with each other and the issue at stake, and they are operating at different hierarchical levels, with different degrees of influence.

Figure 7.1 illustrates key stakeholder institutions and groups in Accra in relation to organic urban wastes and agriculture. They, are located in relation to their degree of formality, sector category (agricultural, waste management or neither of these), and systems scale at which they primarily operate.[41]

[41] i.e. the organisational or hierarchical level at which they participate.

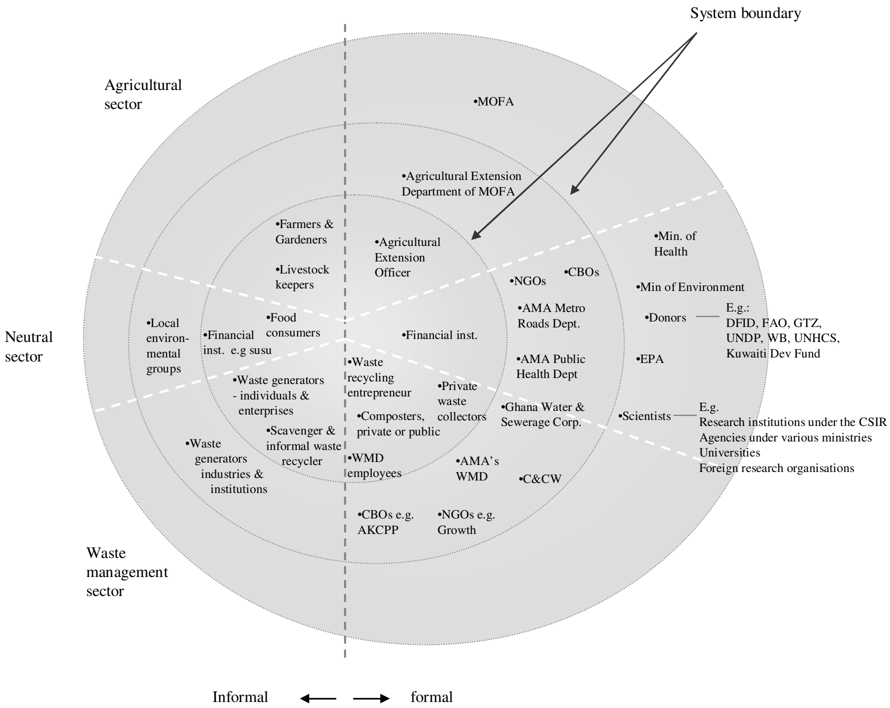


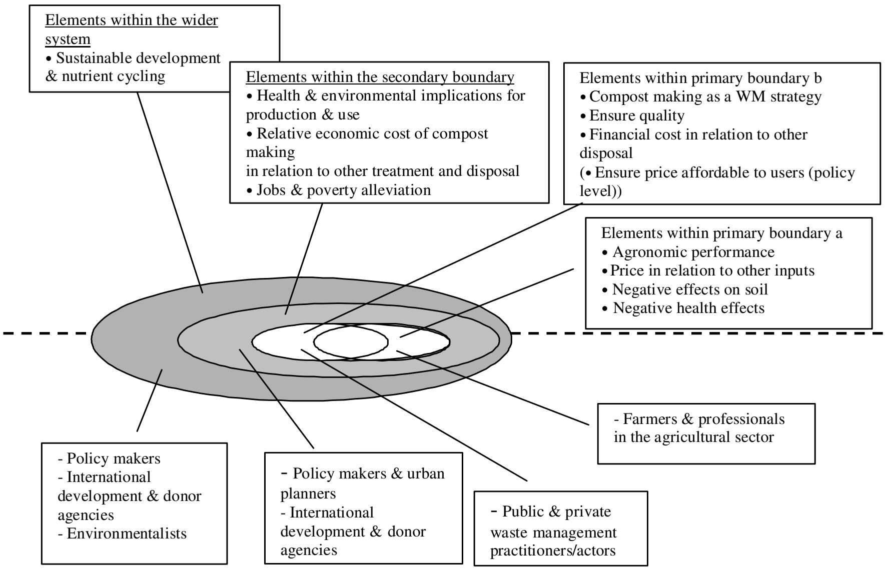

*Figure 7.1 Key stakeholders linking organic urban wastes to agriculture in Accra in the agricultural, waste management or other sectors, their degree of formality and the hierarchical systems level at which they operate*

*Source: This thesis*

For the purpose of structuring the discussion that follows, the stakeholders have been grouped into three broad categories according to the main perspective and concerns they have. They are: (1) potential users of MWC such as farmers and others in the agricultural sector, (2) potential producers of MWC, and (3) policy makers.

Figure 7.2 below illustrates the key considerations, and perhaps the motivations, in assessing the potential for using urban wastes in agriculture for the stakeholders in each group. The policy group has been split into two different levels of operation.

**Elements within each system**




**Level of operation of different Stakeholders**

*Figure 7.2 Key elements of consideration(s) at different systems levels and levels of operation of different stakeholders*

*Source: This thesis*

## 7.2 Compost users' perspectives

### Willingness to use

From the urban and peri-urban farmers' and growers' perspective their willingness to use MWC is determined by a number of factors including: their knowledge of compost and its effects; type of farming system; socio-cultural issues; land access/tenure; availability of compost; quality of the compost; cost. Many of these have been discussed before. They are summarised in below:

Knowledge and awareness

One factor in farmers' willingness to use MWC is their knowledge and awareness of the material and of the potential benefits of using it to enrich the soil (Sanio *et al.*, 1998). The baseline survey showed that although composting of municipal waste has taken place in Accra since 1980, very few farmers and growers were aware of this. Furthermore, knowledge of compost and composting, and of the agronomic effects (in general and municipal waste compost in particular), was found to be limited. Farmers felt unable to comment on their willingness to use it, as they did not know what it was and how it would perform when used in their cropping system.

Similar findings have been reported elsewhere. Harris *et al.* (1997) ascribe the limited use of urban waste amongst peri-urban farmers in Nairobi to a lack of knowledge and awareness of how to use such wastes, this in spite of the fact that there was general appreciation of the benefits of organic materials in relation to artificial fertilisers, and in spite of high and rising costs of both artificial fertilisers and animal manures. Maxwell and Zziwa (1992) in a study of urban agriculture in Kampala, Uganda, also note a lack of knowledge as a major reason why farmers do not use urban wastes.

Type of farmer

The baseline survey indicated that the type of agricultural practitioners most likely to be willing and able to use MWC are commercial vegetable growers and backyard gardeners. Interviews with agricultural and composting professionals supported these findings. The more intensive the production system and the higher the degree of commercialisation, the more likely the farmers are to be willing to spend money on soil fertility inputs. The situation for backyard gardeners is somewhat different. Many people in this group are typically middle class professionals or expatriates who do not farm to make an income, but do farming as a hobby and/or to supplement their diet. They can afford to spend money on soil improvement. Seasonal farmers of rainfed crops such as maize and cassava, and/or who farm mainly for subsistence would not be able and willing to spend any money on soil fertility inputs. Instead they rely on the traditional method of shifting cultivation[42].

Socio-cultural issues

Attitudes towards use of waste derived compost in agriculture, and consumption of foodstuffs produced with it, may play an important role in the potential for linking waste to agriculture. There may be cultural taboo or social stigma associated with handling and use of waste derived materials. For example, in Muslim cultures there are often restrictions on waste handling and use. According to Koranic law, household waste should be removed from the house at the end of each day and contact with human waste is prohibited (Furedy *et al.,* 1997). The use of composted waste containing sewerage is therefore not condoned in Islamic society. However, Islamic law is not always followed to the letter. Resource constraints and religious, cultural and ideological variations lead to a variety of practices, not all in keeping with Koranic law (Allison *et al*., 1998). Allison *et al.* (1998) suggest that the willingness to handle and use waste is related to class and that the cultural reluctance to contact waste is generally more common among middle and upper classes than among the peasantry.

---

[42] Fallow periods are being reduced, particularly in the peri-urban areas where land is scarce and tenure arrangements insecure.

During the course of this research no cultural or social objection regarding the use of municipal waste derived compost, or indeed digested sewage sludge, was encountered amongst the farmers or vegetable growers, be they Christians or Muslims. All the growers participating in the research were aware of the origin of the different constituents of the compost. As an addition to the experiments with municipal compost, the predominately Muslim growers in the Dzorwulu area were given some sewage sludge from the Teshie/Nungua plant to try. They were fully aware of the origin of the material and expressed no objection to using it. When asked whether or not they would have any cultural problems with using it, they said that what mattered to them was whether or not it worked well and whether or not it was accessible and affordable.

Although farmers do not have any problems with using waste derived compost, it is, however, possible that consumers may. At the time of the research the use of wastewater for irrigation of urban vegetables produce, (particularly those eaten raw), was a topic of concern, amongst consumers, market traders and policy makers. It was not uncommon for market traders to avoid disclosing the origin of the produce when they sourced it from within Accra, since many consumers are reluctant to buy such produce. It is conceivable that similar objections to those expressed with regards to wastewater irrigation could be expressed for the use of waste derived compost as a soil improver, particularly as it contains human waste.

<u>Land Tenure</u>

It is often argued that farmers are unwilling to invest in soil improving and fertility building measures if their land rights are not moderately secure (Allison *et al*., 1996; Reijntjes *et al*., 1992). Although the urban vegetable growers were cropping under informal land use arrangements, they did, with the exception of the growers within the Korle Bu hospital area, not tend to feel insecure about their land rights. They considered their land access secure enough to be willing to spend money on soil inputs that would have long term benefits. Having said that, had the compost amendments failed to show any short term benefits it is doubtful whether the growers would have been willing to carry on.

The vegetable growers are used to spend money on fertility inputs and are willing to do so even when land access is insecure and certainly when informal. This coupled with the fact that the use of artificial fertilisers are not very popular meant that they were keen to explore the possible benefits of compost. The potential for long term soil improving effects was attractive to them, indicating a willingness to invest in longer term measures. What emerged was that what concerned the growers was quality and price. In other words: Is it any good? If so, is it affordable and/or cost-effective?

<u>Availability/Access</u>

For farmers to be able and willing to use compost it needs to be readily available and accessible. Closely related to availability and accessibility is transportation, and this is a cost matter. Compost is bulky and as such transportation is a major issue. This is the reason why urban vegetable growers who are close to the source and are able and willing to pay for soil inputs were identified as having the greatest potential to use the material. Other groups include backyard gardeners as well as commercial peri-urban vegetable and fruit producers who buy in bulk.

Findings from other studies suggest that urban waste are most readily utilised in agriculture where alternatives are not available or too expensive (Allison *et al*., 1996). Whilst MCW is available in Accra, so are other sources of soil inputs, notably chicken manure, and as such the potential for use is largely dictated by quality and price in relation to alternatives.

Quality

The concerns in relation to quality can roughly be divided into three areas:

1. Short and medium term agronomic performance, i.e. nutrient content and structural properties,
2. Long term soil fertility effects and associated agronomic performance, i.e. heavy metal content,
3. Human health concerns, i.e. pathogenic and inert contaminants.

The growers' main criteria for assessing the quality of the compost related firstly to the effect on immediate crop growth followed by the long-term effects on soil fertility. Farmers were interested in how the crops perform in compost amended soil and, in time, if the soil becomes polluted. High levels of heavy metal, to the point where application could affect plant growth, would also be a consideration. Concerns about any possible health effects were generally not expressed by the growers, although the high concentration of glass fragments in the compost from the Teshie/Nungua plant was seen as a possible constraint to use. Many urban vegetable growers do not appear to be overly concerned about their own health, and they did not think that the possibility of pathogens in the compost constituted a major constraint to use. The careless use of agrochemicals and polluted wastewater testify to, what can only be describes as a disregard for their own health.

The issue of health and safety in relation to compost quality is, nevertheless, critically important and, although it does not appear to be at the top of farmers criteria when assessing the potential, WDC cannot be considered viable in agriculture if it contains hazardous levels of potentially toxic elements (PTEs), (be it heavy metals, pathogens, viruses, parasites or inert contaminants). The issue of quality will be dealt with further in this Chapter.

As noted in Chapter 6, farmers were generally pleased with the compost performance. The main drawbacks were related to increased water requirement, the extent of burning of juvenile plants and the unpredictability of crop performance in relation to chicken manure and chemical fertilisers. They perceived the areas for greatest potential for use as a substitute for chicken manure during the rainy season, or when chicken manure was in short supply, in use in nursery production and for mixing with chicken manure.

<u>Price</u>

Having established that: (1) some farmers, notably the commercial vegetable producers, are able and willing to pay for soil fertility inputs and (2) that they would use WDC providing the agronomic effects are satisfactory, the question whether they are willing to pay for WDC remains to be explored. Of critical importance to farmers is whether they can afford to use it and, importantly, how the price compares with other fertility inputs. The growers who participated in the experimentation consistently said that they would use compost if the price was right, particularly during the rainy season, in nursery production or when chicken manure was in short supply. A view expressed by one grower, and echoed by many others was that "*It doesn't matter what we use, it is all the same to us. The price is what matters",* and: *"it is good to have access to a range of soil inputs*" (Fuseini, pers. comm., 2000). They said that they would be willing to pay the same as for chicken manure, some would even consider paying a bit more. The reason given for this, in spite of the fact that crops tended to perform better when grown with chicken manure, was that it lasts longer in the soil.

So, the critical question that emerges from the analysis presented above is how the compost compares financially with chicken manure and artificial fertilisers. What follows is a financial comparison between composts and these inputs, based on the prices in Accra at the time of the research. Two types of comparisons have been made: (1) the cost of using the application rates generally used by farmers or recommended by the agricultural advisory service, in relation to two of the compost application rates used in the research (50t/ha and 25t/ha); (2) the relative cost of the different fertility inputs in relation to the amounts of primary nutrients (N, P, K) they deliver. The cost of both compost and artificial fertilisers depend on the quantity purchased. Therefore several price scenarios have been worked out. See Appendix D for further detail on the calculation procedure.

*<u>Poultry manure</u>*

Poultry manure is by far the most commonly used manure. The increased availability of poultry waste particularly in urban and peri-urban areas, has encouraged its use in vegetable cultivation (Nurah, 1999).) The manure is generally obtained free of charge from the poultry farms, although occasionally growers would purchase bagged poultry manure from middlemen who bring the manure to the farms.

Transportation costs vary depending on the distance to the poultry farm, and the amount needed. Means of transport used ranged from walking and carrying sacks on their heads, handcarts, tro-tros (minibuses used as local buses), hired taxies or pick-ups, through to large tipper trucks. If they get the manure from a local source they may carry a sack on their head or using a handcart. Alternatively, if they need a lot of manure and have to go some distance to get it, they may hire a truck. It is common for growers to co-ordinate their purchase and hire a truck. Prices are very variable depending on the driver and the distance to the poultry house. Growers commonly reported to pay between 20 000- 30 000 cedis (£2-3) for the transport of about 10-30 bags and between 70 000 – 80 000 cedis (£7.4-8.4) for the hire of tipper truck. If growers go for the more expensive option of buying manure ready bagged form a middleman who delivers the manure to the farm, the price tends to be about 3000-5000 cedis (£0.3-0.5) for a 50 litre (20 kg) bag. Assuming a cost of transport of 30 000 cedis for 30 20 kg sacks, the cost of poultry manure to the farmers is 50 cedis per kg (£0.005), or 50 000 cedis/ tonne (£5.3).

*Artificial fertilisers*

Inorganic fertilisers are the second most commonly used nutrient input amongst urban vegetable growers. The use varies considerably amongst farmers and in general there is a clear preference for chicken manure. There is a widespread perception amongst farmers, traders and many consumers, that crops grown with artificial fertilisers are of inferior quality, both in terms of taste and storage properties (This research, Harris *et al*., 1997). This notion, coupled with the fact that following the implementation of structural adjustment policies, fertiliser prices have become prohibitively expensive, has resulted in limited use of inorganic fertilisers amongst growers. Nevertheless, many growers still use artificial fertilisers occasionally, particularly during the rainy season when the use of chicken manure is not popular. The fertiliser most commonly used in vegetable cultivation are compound fertilisers, particularly NPK 15:15:15, but ammonium sulphate and foliar fertilisers (Phostrogen) are also used (Nurah, 1999). At the time of the research (March 2001) the cost of NPK (15:15:15) fertiliser was 3500 cedis (£0.37) for a 1 kg bag, 50000 cedis (£5.3) for a 25 kg sack and 90000 cedis (£9.5) for a 50 kg sack[43].

*Municipal waste derived compost*

Compost from both the Teshie/Nungua and the James Town sites can be purchased either in 40 kg sacks or in bulk. Both places charged 5000 cedis (£0.53) for a 40 kg sack, undelivered. Assuming a transportation cost of 30 000 cedis and that 30 sacks are purchased at each occasion, as done in the poultry manure example, the cost of compost would be 150 cedis/kg (£0.016) or 150 000 cedis (£15.8) per tonne. This is three times more expensive than chicken manure. Alternatively compost can be bought in bulk. Compost from Teshie/Nungua was charged at 20 000 cedis/tonne, undelivered, or delivered at 200 000 cedis for a truckload containing 5-6 tonnes. Such a quantity is generally too much for the small-scale urban vegetable growers, even if they get together with their colleagues for a joint purchase. Adding a transportation cost of 30 000 cedis to the 20 000 cedis for a tonne of compost bring the cost to 50 000 cedis a tonne. The same price as for bagged poultry manure. The James Town site sold compost by the container load as an alternative to bagged sacks. A container contained 3 tonnes and was sold for 200 000 cedis, i.e. at 67 000 cedis/tonne (£7). For this price the compost was delivered to the farm. At this site they did not have the measuring and weighing equipment to provide the buyer with a tonne at a time. It was either sold by the container load or bagged in sacks.

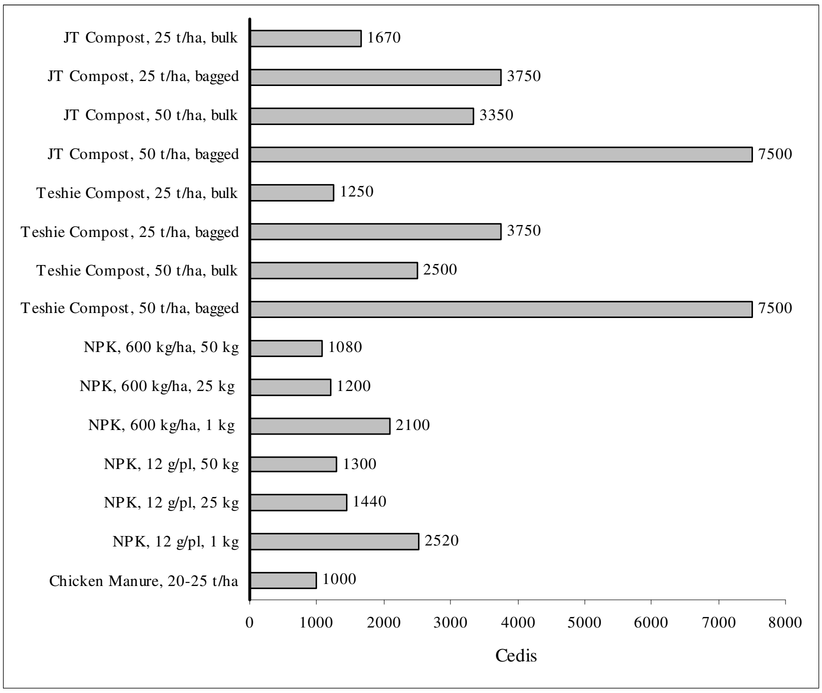
[43] Based on prices at the farm shop used by the majority of vegetable growers in Accra (AGLOW).

Table 7.2 and Graph 7.1 show a cost comparison between using compost at the application rates used in the research with the manure and fertiliser applications typically used by farmers or recommended by the agricultural services (See Appendix E for how this was calculated). At first glance, this reveals that compost is considerably more expensive than chicken manure and, unless bought in bulk, more expensive than using NPK fertiliser. However, the prices in Table 7.2 and Graph 7.1 do not reflect the true cost of using compost since both chicken manure and inorganic fertilisers have to be applied to each and every crop, whereas compost does not. The findings from the experimental work with the vegetable growers indicate that with the rather high application rates used in the research, an application to every third crop would be sufficient. When comparing the cost of compost as a soil amendment and fertility input in the light of this, the picture looks somewhat different. For every application of compost, three poultry manure applications would have to be made. So, based on the assumptions above, at an application rate of 25 t/ha compost expenditure on a 10 $m^2$ bed would cost anything between 1250 and 3750 cedis depending on whether it was bought in bulk or bagged, expenditure chicken manure 3000 cedis and anything between 3240 and 7560 cedis for NPK depending on application method used and quantity purchased. In this light compost is compares more favourably. However, considering that the urban vegetable growers are most likely to buy compost in bagged form, compost still costs slightly more than chicken manure. In view of the fact that the crops did not perform better in the compost amended soil than that amended with chicken manure, the justification and motivation for farmers to adopt this technology on the basis of price advantages alone is questionable.

*Table 7.2 Relative cost of different inputs*

| Material | Application rate | Quantity purchased | price/ha (million cedis) | price for a 10$m^2$ bed (cedis) |
|---|---|---|---|---|
| Chicken manure | 20-25 t/ha | | 1-1.25 | 1000 |
| NPK 15:15:15 | 12g/plant | 1 kg | 2.52 | 2520 |
| | | 25 kg | 1.44 | 1440 |
| | | 50 kg | 1.3 | 1300 |
| | 600 kg/ha | 1 kg | 2.1 | 2100 |
| | | 25 kg | 1.2 | 1200 |
| | | 50 kg | 1.08 | 1080 |
| Teshie compost | 50 t/ha | bagged | 7.5 | 7500 |
| | | bulk | 2.5 | 2500 |
| | 25 t/ha | bagged | 3.75 | 3750 |
| | | bulk | 1.25 | 1250 |
| JT compost | 50 t/ha | bagged | 7.5 | 7500 |
| | | bulk | 3.35 | 3350 |
| | 25 t/ha | bagged | 3.75 | 3750 |
| | | bulk | 1.67 | 1670 |

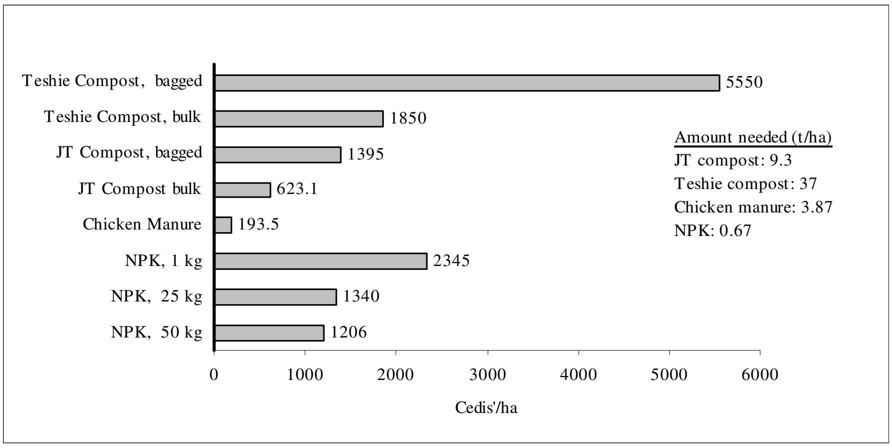
*Source: This thesis*



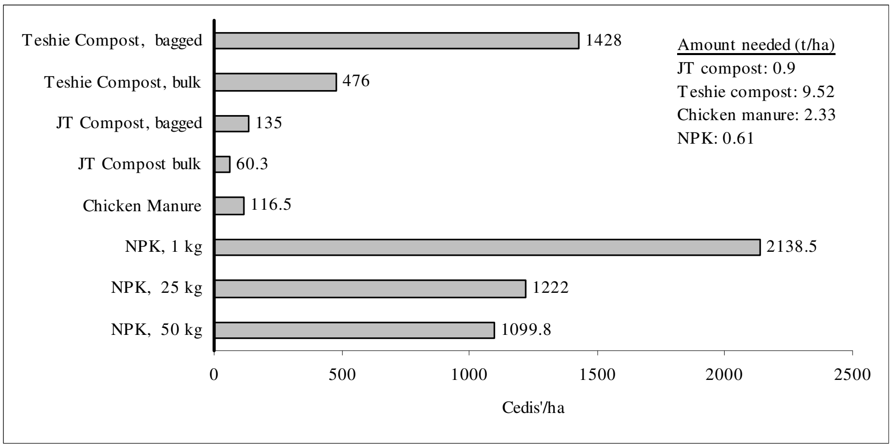

*Graph 7.1 Relative cost of different inputs and application rates*

*Source: This thesis*

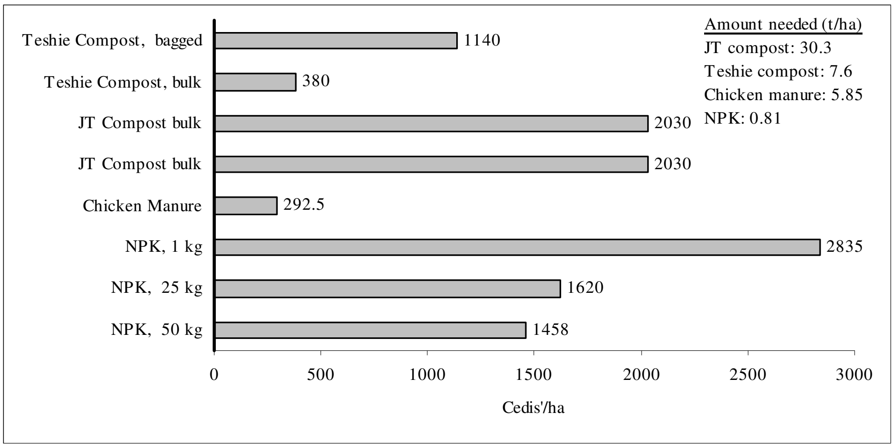
When comparing price in relation to total nutrient supply of the three main plant nutrients (N, P and K), the picture is varied depending on which nutrient is considered (Graphs 7.2-7.4). The cheapest way of supplying nitrogen was clearly through chicken manure. In order to supply an equivalent amount of nitrogen, James Town compost and NPK were similarly priced. With its very low nitrogen content, the Teshie compost emerged as the most expensive option for nitrogen supply. Because of the extremely high phosphorus concentration in the compost from James Town, it came out as the cheapest option for supplying this nutrient. The relatively high potassium content in the Teshie compost meant that, following chicken manure, this material was most cost effective for K supply. On balance, chicken manure was the cheapest option.




*Graphs 7.2 Relative cost of supplying 100 kg N/ha*




*Graphs 7.3 Relative cost of supplying 40 kg P/ha*




*Graphs 7.4 Relative cost of supplying 100 kg K/ha*

*Source: This thesis*

**Would farmers make their own compost?**
The possibility of farmers making their own compost from household and farm wastes was explored with the vegetable growers who participated in the experimentation. Some had experience of this practice from their rural village, others expressed an interest in learning how to do it. In response to that some experimentation with farm waste composting was undertaken. However, the general feeling amongst the experimenting growers and their colleagues who participated in group meetings, was that the potential for them to produce their own compost was limited. They felt that labour was a serious constraint. The majority of urban vegetable growers have other jobs, or study and they did not have any spare time to undertake composting activities, but would rather buy in whatever soil inputs they needed. As they farm commercially they have money to spend on farm inputs and said that they would rather pay for inputs than invest time and effort in making compost. Space was also voiced as a constraint to compost production amongst urban vegetable growers. The areas they cultivate are small and the beds packed in closely together with narrow paths separating them. They felt that they would not have the space required to make compost. A similar constraint was expressed with regards to tools.

## 7.3 The waste management sector

People involved in waste handling view the potential for linking organic waste to agriculture differently to farmers and others in the agricultural sector (see Box 7.1). From this perspective the question of the potential of utilising composted waste in agriculture invariably needs to be modified. The question relevant to pose is: is there strategic potential for composting with the objective of it being used in agriculture?

The stakeholders in the waste management sector play different roles and were considered likely to have different views and degrees of interest in municipal waste composting and use. This croup includes: waste collectors, private and public; waste management managers/officials; formal waste recyclers; informal waste recyclers and scavengers; composting professionals, private or public; community based activity groups; urban residents.

The key informant interviews revealed that the majority of people involved with the practicalities of waste management do not have any real influence in decisions on whether or not to make compost, nor opinions about the relative merits of doing so. The emerging picture is that it is not a priority for them. For example, the waste collectors are sub-contracted or employed with the straightforward mandate to clear the waste off the streets and deliver it to designated dumpsites. Their priority is doing the job that they have been contracted to do so that they can get paid. As such this group, although important in the overall waste management of Accra, does not have a stake in composting or compost use. The same can be said about the recyclers and scavengers that operate in Accra. Apart from the NGO initiated and CBO operated composting initiative in James Town, there are no private composting activities present in Accra.

Composting has a strong ecological appeal. However, a financially constrained municipality struggling to meet the most urgent waste collection demand, will naturally seek to employ the disposal method which offers the lowest cost. Waste management professionals are, at the end of the day, concerned with shifting the waste off the streets and disposing of it in some way. Whether or not one of the methods of disposal involves composting is a matter determined primarily by technical and financial factors. Ultimately, it is a question of how does making compost compare with alternative waste disposal options, and what factors are salient to include in the comparison.

If questions of quality are put to one side for the moment, there still remains the issue of whether or not composting is cost-effective. As noted in Chapter 1, under the prevailing conditions of most cities in developing nations of unregulated dumping and environmental protection, composting does not appear to be cost-effective. Lack of economic viability is one of the most frequently cited constraints to waste composting and its use in agriculture. Production costs are frequently too high in relation to the market demand for waste derived compost. Production costs are affected by the technology used and variables such as transportation costs, labour costs, land prices, degree of contamination of the waste source and difficulties in matching the supply of raw waste with processing capacity (Furedy *et al.*, 1997; Brock, 1999). Although the degree of failure or success vary, and evidence seems to suggest that small-scale decentralised, privately operated schemes can be more profitable because they are able to overcome many of the constraints, the literature available on municipal composting experiences generally conclude that composting initiatives struggle to survive without external funding (Obeng and Wright, 1987; Brock, 1999; Nunan, 2000). This issue will be re-visited later in this Chapter.

This has been the experience of the operation in James Town, (and even more so in the case of Teshie/Nungua). The business model of the James Town operation was configured to: have the minimum of machinery; no capital expenses for equipment, other than running costs; utilise unemployed labour paid the national minimum wage; be subsidised by the municipality in terms of (1) access to rent free land and (2) have the non-recyclable fraction of the waste collected and disposed of free of charge. In spite of this, at the current production volume, they have been unable to produce compost any cheaper than they do (i.e. 5000 cedis/sack of which 1000 cedis is the cost of the sack and 67 000 cedis per tonne when delivered in bulk). This price is still too expensive to the commercial vegetable growers as chicken manure is cheaper and, as my research shows, it is as, if not more, effective. The capital intensive composting operation in Teshie/Nungua has always been heavily subsidised within the overall municipal waste management budget and any revenue accrued from sales of compost has been seen as an additional benefit. Since it was commissioned in 1980, the operation has run below its production and financial revenue capacity.

**Marketing**

Many studies have concluded that a bottleneck to economic viability of composted waste recycling to agriculture is marketing the end product (Lardonis & van de Klundert, 1994b; Visker, 1995; Obeng and Wright, 1987, Furedy *et al.*, 1997; Perla, 1997). Such have been the experiences in the composting operations in Accra too. In the James Town initiative the marketing side was not prioritised, resulting in excess production in relation to sales and falling motivation amongst the staff. This in turn, has led to intermittent supply with subsequent loss of customers for the finished product. With limited sales, keeping the cost of the compost low has proven difficult. One of the reasons for the poor marketing history of the James Town produced compost is simply that it has been overlooked. At the time when the project was conceived, the main objective was to improve waste collection in the densely populated area of James Town. Initially the project was only involved with waste collection and only later expanded to incorporate composting activities. Thus the driving force was health and sanitation and it was always assumed form the onset that there would be a market for the compost.

The situation with regards to the publically operated composting at Teshie/Nungua is similar[44]. This was an initiative very much conceived and operated by waste management professionals with a technical engineering background. Composting has been carried out as a waste management strategy without any active linkages with the agricultural sector. As in the James Town project, it was assumed that there would be a demand for the compost and that the marketing would develop organically. What was not fully appreciated was that the market potential was limited due to the practice of composting mixed waste, as this

---

[44] The municipality in Accra has composted waste from the city since 1980, and apart from the periods when the composting plant has been out of operation, compost has been available for over 20 years. Yet few farmers have tried it or even know about it. This is testimony to the poor marketing efforts made.

adversely affected the quality of the end product. The possibility of separating out the organic fraction of the waste upon arrival to the site, before it is placed into windrows (as done in James Town), has been considered. However, they have concluded that they do not have the resources to invest in such an activity and that they would not recoup the labour investment from compost sales. The view of the manager of the composting site was that as much as they were aware of the positive effects of compost making and would ideally like to ensure that it is made to a high quality standard, they did not have the resources. Furthermore, they are not particularly willing to spend time and effort on marketing. The way they see it is that they are waste engineers, not agriculturalists. They are employed to treat and dispose of waste within an allocated budget. From their way of looking at it composting is only another way of treating waste. The resulting material could just as well be used in landscaping or for capping waste at the dumpsite. This view is somewhat different to that of the private composting operators who depend on sales to make the whole operation viable. Nevertheless, marketing is commonly overlooked in the smaller operations too, as the James Town experience and evidence from numerous cases world-wide is testimony too.

Having said this, there has been some market for the compost, however limited. The managers of both composting plants said that the demand for compost generally exceeded the supply (Awuye and Klaassen pers. comm., August and November 1999). The main consumers have been institutions, government departments and hotels, which all have bought in bulk and used the compost for landscaping. In addition, an important outlet for the James Town compost has been expatriates who have used the compost for gardening. A limited amount of Teshie compost has been sold in bulk to a few larger-scale commercial fruit and vegetable producers in the peri-urban areas of Accra. At the time of the research however, the staff at the James Town plant found it difficult to market their compost. Because of the awkward location of the plant and the intermittent supply of compost, consumers had stopped purchasing the material. They were aware that they needed to invest efforts into marketing. Similarly, the manager at the Teshie plant had been instructed by the AMA that they needed to improve on compost sales if the operation was to receive support in the future. Although the compost produced has eventually been sold in the past, the production has been way below the capacity and the amounts made and sold have not been anywhere high enough to cover the costs. If production volumes were to be increased the option of agriculture as an outlet would have to be considered as the current market is relatively limited.

Initiatives which have experienced marketing difficulties as a constraint to cost-recovery commonly find that the market for the end product has been assumed, without taking agricultural objectives into consideration (Zurbrügg *et al*., 2002). In a World Bank report reviewing and appraising the potential for recycling urban waste for agriculture, it was noted that "*all cases examined that had a clear link between composting urban waste and the agricultural market have been successful in terms of cost-recovery*" (Eitrem and Törnqvist, 1997:31). However, from a waste management professional's point of view, composting may not appear as a very attractive prospect. It involves a lot of extra hard, unpleasant and potentially health hazardous work for relatively limited returns. Points raised by several stakeholders in the waste management sector suggested that this feeling is common (Lamptey, Marquis, Awuye, Klaassen, all pers comm.). Recycling of materials such as metal, glass and cardboard is more lucrative, particularly as the organic waste available for composting from the municipal collection system is of very low quality. By the time the municipal waste arrives at the dumpsite it has already been subject to comprehensive recycling at source and by scavengers along the way (Obeng and Wright, 1987; World Bank, 1996) and what remains is of low quality[45]. Obeng and Wright (1987:57) point out that "*source separation or widespread scavenging would reduce the recycling revenue of the compost plants to almost zero while having only a limited impact on operating costs since sorting of rejects (with no value) must still be carried out*." Considering that the waste also contains a certain amount of faecal matter and that decomposition has already begun by the time it arrives at the dumpsite or composting plant, the task of separating out the organic from the non-organic fraction is both unpleasant and hazardous to health.

The alternative is not to separate the waste but to co-compost it with the non-organic fraction and then sieve it once the organic fraction has decomposed, as done in Teshie/Nungua. However, this method of composting adversely affects the quality of the end product, and thus its agricultural potential. Experiences with composting mixed waste have categorically resulted in poor quality compost which is effectively unmarketable (Eitrem and Törnqvist, 1997; Hogg *et al*., 2002; Furedy *et al*., 1999; Lennartsson, pers.comm., 1998). Eitrem and Tornqvist (1997) note that compost produced from source separated municipal solid waste is 2 to 10 times less contaminated than compost produced from mixed waste. The inferior quality of the Teshie/Nungua compost in comparison with that produced in James Town, further supports this conclusion.

Unless waste separation, preferably at source, is done before composting the potential for using the end product in agriculture appears limited. Low grade compost made from mixed wastes is really only suitable for land reclamation, landscaping and landfill capping. The main user of such compost would be AMA itself, thus the composting operation would not generate any revenue through sales. This raises the question if composting is perceived as a waste management technology, or the production of an agricultural resource.

From the perspective of waste management professionals, waste collection treatment and disposal is the main objective. Composting is a means to an end, not an objective in its own right. As evidenced by the quality assessment of the compost produced in Accra, the quality, particularly that of the compost from the Teshie/Nungua site needs to be improved for it to be safe enough for recommending for use in agriculture. The question from the waste management perspective is: Is it worth it? Is it worth spending, what might amount to a considerably extra resources in improving the quality?

[45] This is evidenced by the small number of waste pickers who work the open dumps at Malam and Teshie

Considering the adverse working conditions and the commercial riskiness of composting municipal waste, some form of support or incentive from the municipality or sponsor to supplement the cost recovery through compost sales, is likely to be required for composting to appear as a viable activity from the perspective of those involved in the handling of waste.

This is largely a policy question and in order to explore this issue it is necessary to broaden the system boundary to consider issues beyond those of the immediate concern of the professionals involved with the day-to-day business of waste management.

Having established that growers need good quality compost at an affordable price (i.e. very cheaply); and that the waste management sector cannot deliver that without support, we come to conclude that composting is a sustainability issue rather than a commercial venture.

## 7.4 Policy makers' perspective

The strategic choices that have to be made in order to decide whether or not to pursue municipal waste composting, and the decisions made which determine the potential for using it in agriculture, lie in the policy arena. Stakeholders operating in this arena are at the municipal, national and international levels, in a variety of sectors including: urban planning; waste management; agriculture; health; environmental protection; financial institutions including foreign government donors and international NGOs

The environmental aspects of waste reuse and recycling has two sides. The first relates to the reduction in waste volume that has to be dumped and the reduction in pollution that results from that. The second relates to the saving of resources, and both the environmental and economic effects of that. (Environmental Systems Reviews, 1993). The sustainability issue of reducing the waste volume that needs landfilling whilst supplying recycled soil fertility inputs is conceived and acted upon at a higher systems level. It is at the policy level that the divergent views and motivations of the different stakeholders can be married together through policies that encourage such developments. As already mentioned, composting has a high ecological appeal but the question for any city governing body is, can we afford to? The question for urban planners and other policy makers is whether or not the benefits of composting outweigh the costs. Furedy *et al.* (1997:14) notes that "*most governments believe that MWDC is an expensive disposal option compared to landfilling. This is because financial rather than economic appraisals are used in most feasibility studies.*"

It is within the framework of financial cost-benefit analysis that the waste management professionals operate. They have an allocated budget from the local government, i.e. AMA and ultimately the government. To a certain extent the AMA also operate at a level whereby financial rather than economic analyses are carried out using financial rather than economic criteria. The overall objective for the local government is to dispose of waste in an acceptable manner, that is still affordable within the constrained economic climate in which they operate. Mechanisms for expanding the field of view and for being decisions on factors other than largely financial ones, are limited at the local government level and there has been limited links with other sectors and issues. Stakeholders interviewed in other sectors, e.g. the Environmental protection Agency (Anku, pers. comm., June 2000) and the health sector (Alliepoe, pers. comm., June 2000), were aware of the links between waste and environment and health, but did not have any concrete suggestions as to what could be done. Whilst aware of cross-linkages they seemed to indicate that waste and/or agricultural issues were not within their domain of responsibility (nor did they have the mandate to act upon issues relating to waste management).

This is by no means a situation peculiar to Ghana. Attahi (1999:11) writes in relation of solid waste management in Abidjan, Cote d'Ivoire: *"Today, the question of urban waste management and, by extension, those of urban environmental planning and management represent some of the major challenges facing urban managers, as a consequence of their effects on human health, sustainable development, and urban finance. If in the past, waste management in African cities has been perceived solely as a technical, organisational, and financial operation, today the realisation is dawning that waste management has an important cultural dimension and gives leverage for power of the highest order."* Experiences such as these suggest that in devising appropriate policies on waste recycling and composting, aimed at sustainable urban development, a broader economic framework for analysis is required. Waste management is intrinsically linked to urban development, thus any policy on waste management needs to take into account indirect factors and use an economic framework of analysis. It is at the higher levels of policy making that there is mandate to implement such policies. It is in the domain of the national government or international donors that policy and investment decisions borne out of an economic framework of analysis are taken. By contrast to financial analysis, an economic framework of analysis takes into account the benefits and costs that affect society as a whole, and the factors that were considered externalities in the financial analysis, and thus excluded, are now incorporated. In the light of such analysis the potential for composting the organic fraction of the urban waste looks more promising.

The economic assessment of composting is a difficult task and there is no one right way of doing it. The relative benefit of composting municipal waste is in part determined by financial and commercial costs and benefits centred on the value of waste reduction and technical logistics issues such as transportation, technology options etc., in part by requirements for compost by the agricultural, horticultural and landscape industries (Environmental Systems Review, 1993). However, in addition to these direct economic and financial considerations, there are indirect costs and benefits that are much less tangible. These are non-quantifiable factors that tend to be classified as externalities at the lower systems level. Examples include:

- *Health aspect* - Are there any positive health impacts on urban residents if the organic waste is composted? Are there any negative health impacts arising from composting (on workers handling the waste) and the use of compost in food production (on farmers and consumers)?
- *Environmental Pollution* - What is the value of the positive impacts from stabilising and sanitising organic waste through composting? Are there any possible costs if compost containing hazardous levels of heavy metals are used on agricultural land?
- *Economic viability* - What is the economic viability in terms of relative costs in relation to alternative waste handling and disposal? What are the long-term costs of landfilling in relation to composting? This assessment needs to consider the acquisition of new land for landfilling, the increased transportation costs as new landfill sites invariably are located further out from the city, the cost of building and maintaining a safe landfill site. At the time of this research the two makeshift disposal sites (at Mallam and Teshie) were overfull and the commission of a new landfill site underway. The project was delayed and over budget as there was difficulty with regards to land acquisition. The new landfill site was going to be 40 km out of the city, seriously increasing the transportation costs. With this in mind, the prospects of saving landfill space to increase the life span of this new site may look like a desirable option. Also, composting activities can impact, both positively and negatively, on land value and quality of life. The land near a composting plant may fall in value. On the positive side is that less land will need to be used for landfilling and the existing landfills are likely to be more sanitary (Obeng & Wright, 1987).
- *Social considerations* - Is composting and compost use socially acceptable? Would people be willing and able to separate their waste at source? Are consumers willing to buy food that has been grown with WDC?
- *Urbanisation aspects* - Waste recycling and composting may be considered a step backwards, ill-fitting with the notion of a modern progressive city. Urban planners may consider waste recycling and composting schemes dotted around the city and urban agricultural activities inappropriate and contradictory to perceived goals of city modernisation and beautification (Furedy *et al*., 1997; Medina, 1997).
- *Job creation* - Composting and other recycling activities have the potential for providing income opportunities for disadvantaged, resource poor people.
- *Preservation of nutrient resources* - What is the value of the nutrient recycling that takes place through composting city waste? Could some of the import costs of chemical fertilisers be reduced through compost utilisation in agriculture?

The extent to which considerations such as the ones mentioned above are incorporated into policy decisions produce different scenarios and different outcomes. The cost of composting is likely to look different depending on the considerations taken into account and the time frames used. Composting for instance may be viewed as more than the production of an agricultural input;

composting turns waste into a resource, thus it is also a waste treatment process. As such, it may be argued that the cost of producing compost should not only be covered by the market value of the compost, but also by the value of the waste treatment that takes place. The question is; what is the value of this? How much is that worth? The question for urban planners and other policy makers is whether or not the benefits of composting outweigh the costs.

The question for any policy maker is to what extent to include externalities and what time frames to use for the analysis. In a relatively poor economy, such as Ghana, the government clearly cannot afford to take the more sustainable, long term approach. As noted in Chapter 1, as so often in discussions on sustainability, there are trade-offs between the ecological and the economic. Practices that are ecologically sustainable in the long term carry an economic cost. Many of the benefits accrued from waste composting are indirect (reduced pollution, improved health, reduced spending on artificial fertilisers) and long term, whilst the costs are direct and immediate. So, although knowledge and appreciation are not lacking of the value of a well executed procedure for composting organic city waste, and of its advantages in terms of long-term sustainability and cost effectiveness, the funds to enable such a procedure to be brought into being may be absent. Resort to stop gap measures in response to pressing needs are commonplace. In the short term it is cheaper to dump all collected waste in a makeshift dumpsite. In the long term it is not. The feasibility and relative cost of composting depends on the framework of analysis used. For example, if the cost of composting is compared with the cost of open air dumping without taking into account any costs of negative side effects of this, then it will appear as an expensive alternative. However, if sanitary landfilling is the alternative for comparison then the equation is likely to look more favourable for composting.

In the past, when funding was allocated to set up and run the composting plant and Teshie/Nungua, environmental and health considerations did influence the decision, underpinned by a notion of sustainable development (Koch pers. comm., March 2000). Similar ideals were behind the thinking of the composting project in James Town (Klaassen, pers comm., November 1999). Both projects received funding from foreign donors (Teshie/Nungua from the German government and James Town from both the German government, through GTZ and UNDP). However, by the time of this research, the external funding sources had come to an end in the case of Teshie and were about to in the case of James Town. The waste management professionals involved with the two composting set-ups were operating within a financial budgetary framework which necessitated the cost of production to be reflected in the selling price of the compost. No fiscal mechanisms for support were in place at the local or national government level.

Composting, or any kind of waste recycling for that matter, was not considered (Koch and Meynel, pers comm., March 2000) a priority within those tiers of decision making. The failure of the Teshie/Nungua plant operated by the WMD, to produce and sell compost according to the design specifications, had resulted in a perception that composting is expensive and does not work. There was a feeling amongst local government officials that composting is ‘old hat’, not befitting a modern city, and that new, fresh approaches to WM are needed. Moreover, there appeared to be a general feeling within the government that decentralisation of waste management had been tried and proven itself not to work. Overriding the decentralisation policy which gave AMA/WMD statutory responsibility for waste management in Accra, the government granted a Canadian private company (C&CW) monopoly in solid waste collection in 1999. A lack of commitment to recycling was reflected in the way the contract was drawn up. Under the contract with C&CW payment was done on the basis of the tonnes of waste collected and weighed in at the dumpsite (Marquis, pers comm., June 2000). As such it was not in the interest of the waste collection company to reduce the waste volume that went to the dumpsite. Quite the opposite, in fact; any recycling activities would reduce their profit making potential. Clearly an example where systems thinking was lacking.

Whilst there is no doubt that waste collection improved under the management of C&CW, this arrangement was in no way cheap, and much criticism was voiced at the government's decision to interfere with the existing decentralised and partly privatised collection system and replace it with an arrangement which, according to several newspaper articles, cost more that the entire annual budget of the AMA. C&CW got paid 212000 cedis per tonne (£22) brought to the disposal sites, whilst prior to the 1999 C&CW take-over, private contractors operating the communal container collection service used to get paid 10 000 cedis/tonne (£1). This case shows that although financial means of the local and national government is of critical importance, it is not the only determining factor. The viability of composting and potential for linking organic municipal waste to agriculture depends substantially on the quality of planning and management by the city government.

## Summary of stakeholders' views

The discussion so far has shown how the main priority of waste management professionals is to collect, treat and dispose of waste and that they may not have any interest in recycling *per se*. Recyclers do but primarily from a business venture point of view. It is not the environmental improvement aspects of recycling that drives them. We have also concluded that the objectives of farmers are to have access to good quality soil improvement inputs at a price affordable to them. They may not be interested in improved waste management and the environmental benefits in cycling nutrients in waste back to the soil *per se*. Whilst the farmers who participated in the experimentation said that they would use MWC in the future, but that the price was prohibitively expensive, composters said that they were unable to provide it any cheaper and that the production was already subsidised. So, based on these testimonies, it appears that municipal waste composting and the use of MWC by farmers, has limited potential.

However, we have also seen that when the systems boundary is widened to include indirect benefits of composting urban waste and cycling organic wastes back to agriculture, the potential may look more promising. What is clear is the overriding importance of strategic policy decisions. It does not matter how good, or bad, the agronomic potential for compost is unless appropriate policies are in place, on the one hand, to regulate quality and use, and on the other, to foster a climate in which the production of MSW is cost-effective to the recycler. So, in a sense an apparently technical issue boils down to political will. The remainder of this chapter will deal with issues relating to governance.

The question of governance in relation to waste management largely depends on the extent of coordination and cooperation between sectors. In other words, how wide the systems boundary is drawn. Political choices of this nature are taken at the highest tiers of government. In Ghana, as in many other countries, there is a poor history of intersectorial linkages in governance, and as seen in Chapter 4, urban development in Accra bears witness to a history of weak planning and a failure to implement strategic planning systems. This in part has resulted from a fragmentation of responsibilities between different ministries and agents. For example, until recently, when the responsibility for sewage treatment was transferred to the WMD of the AMA, solid waste management and sewerage treatment used to be the responsibility of different organisations. The responsibility for road and open drains cleaning and maintenance is also split between different departments, which lead to confusion and lack of accountability. Figure 7.3 illustrates the institutional framework with regards to roles and responsibilities relating to waste management and sanitation in Accra.

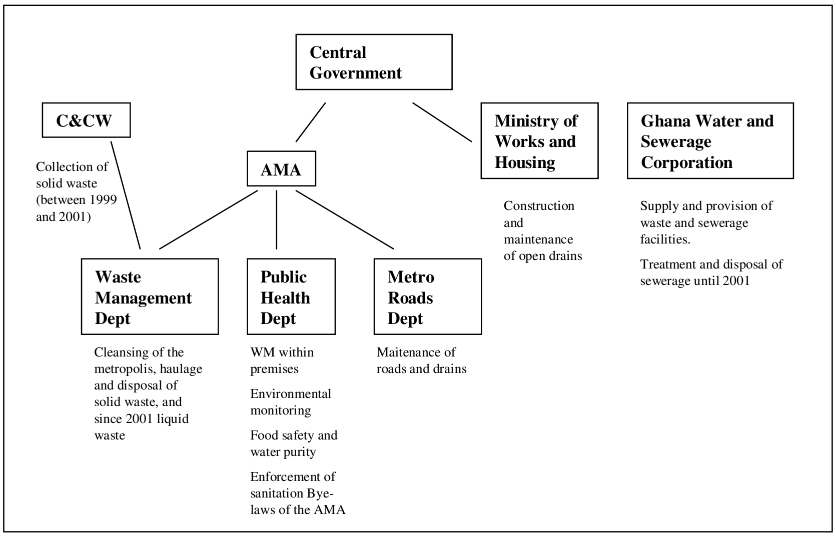



*Figure 7.3 The institutional framework with regards to roles and responsibilities relating to waste management and sanitation in the Accra Metropolitan Area*

*Source: This thesis*

Over the years a series of programmes and projects aimed at improving waste management and address environmental problems have been initiated and implemented on a largely ad-hoc basis. They have been sector oriented without collaboration between stakeholders and as such, limited in scope. This has resulted in duplication of efforts and failure of projects to be implemented to their full potential; in other words overall inefficiency. A look at how waste management has been tackled in the past reveal four problem areas in relation to governance:

1. A lack of an integrated approach to waste management in Accra, notably as witnessed in poor and weak intersectorial collaboration between department and ministries. This can, for example, be seen in the case of 20 years of composting efforts at Teshie without serious efforts (at an appropriate level) being made to link the activities with the agricultural sector. During the course of this research it became clear that the extension service had limited knowledge of the MWC produced and limited interest in exploring the potential for using it in agriculture. In was also clear that whilst senior professionals in the health sector knew of the problems associated with waste, their knowledge of the potential benefits and risks of MWC was limited and considered external to their domain. At the time of this research there was widespread recognition among those interviewed that waste management is intrinsically linked to urban development and environmental health and that indirect factors cannot be excluded when setting policy relating to waste management. The need for intersectoral linkages and collaboration for measures to be appropriate and successful was expressed in numerous policy documents and funding proposals. However, there was limited evidence of it happening.

2. An organisational emphasis on crisis management. Strategies have been of a 'fire-fighting', curative nature rather than anticipatory and preventative. For example, apart from externally funded and initiated composting initiatives, approaches to solid waste management have been directed mainly at efficient waste collection than to sustainable disposal, as witnessed by the environmentally hazardous dumpsites and limited extent of public support for recycling initiatives. Improving waste collection without addressing the issue of sound treatment and disposal is a case of merely shifting the problem rather than solving it. Another example of a 'fire-fighting', stop gap measure is how the upper tier of the central government stepped in to 'rescue' what was seen as a failing WMD, and installed C&CW in charge of waste collection.

3. A failure on the part of the authorities to coordinate complementary donor initiatives so as to maximise the value of scarce donor support. As mentioned in Chapter 4, several externally funded projects in Accra designed to tackle environmental management were at different stages of implementation during the time of this research (Box 7.1). There appeared to be limited information sharing as well as limited managerial and fiscal coordination between these.

4. A failure to collaborate with the private sector. In a report on the environmental profile of Accra Metropolitan Area prepared on behalf of the government as part of the UNCHS (Habitat) programme, it is noted that "*There has been over reliance on the public-sector funding without due recognition to the*

*inertia of the private sector"* (AMA, 1994:127). The lack of integration between the public and private sector can also be seen in the failure of the public authorities to support and encourage private initiatives, such as small-scale recycling schemes. Examples exist where economically feasible private composting initiatives have been abandoned in the planning stages because of an inability to generate sufficient interest and action among the municipal authorities (Meynel, pers. comm., March 2000). During the early days of the composting activities in James Town, permission to access high quality market waste to improve the quality of the substrate mix was turned down by government officials, even though permission had been granted by the traditional market leaders (market queens). The reason for this was never clear to the composting manager (Klaassen, pers. comm., October 2000). According to Asomani-Boateng and Furedy (1996) the uncooperative attitude of some Accra high officials towards small-scale private and community based composting initiatives could be ascribed to a notion that such set-ups does not conform to their notion of modern standards of managing waste.

*Box 7.1 Externally funded projects to tackle environmental management at different stages of implementation in Accra during the time of this research*

- GTZ and Gopa support through the German government for AMA's WMD for solid waste collection, treatment and disposal.
- GTZ and UNDP support for the NGO Growth and the CBO Ashiedu Keteke Community Participation Project for solid waste collection and composting in James Town.
- World Bank support for AMA as part of the Urban Environmental Sanitation Project covering five Metropolitan Assemblies, aimed at improving drainage, waste management and sanitation, as well as strengthening institutional capacity for environmental management.
- UNCHS (Habitat) support to the Ministry of Environment for sustainable development and growth of Accra.
- DFID Aid and Trade Project to provide a sewerage treatment plant, trucks for solid waste collection and the commission of a new landfill site. This project was implemented under the name of ATP-Accra Waste Project.
- DFID support to AMA aimed at improving institutional capacity for public environmental health. Set up to compliment the technology oriented ATP-Accra Waste Project, this project was implemented under the name DFID/AMA Public Health Project.
- Kuwaiti Development Fund support for the Ministry of Works and Housing to dredge and restore the Korle Lagoon and to improve sanitation control in areas immediately adjacent to the lagoon.

Although measures have been attempted to reduce functional fragmentation by vesting authority for all core urban tasks in a single metropolitan authority, namely the AMA, the internal co-ordination between the decentralised departments of the AMA have been ineffective[46] and, importantly, the effectiveness of the AMA have been severely hindered by a lack of legal authority and resources to perform their statutory functions. In a working document of the DFID/AMA Public Health Project (1998:Annex 3/1) it is noted that "*The decentralisation process has been hampered by the fact that the transfer of responsibilities (from Central Government to the Metropolitan Assembly and from the Metropolitan Assembly to the Sub-Metro) has not been supported by the equivalent transfer of appropriate resources – financial, qualified manpower, accommodation, vehicles and plant and equipment. One of the outcomes of this inadequate resourcing is that the image of AMA amongst the media and the general public is poor, and they have been strongly criticised for not delivering services*." [47]

The problems of governance highlight the importance of taking a systemic approach to policy formulation. I would argue that composting does not have to be prohibitively expensive. It depends of the technology chosen[48], the quality of the compost produced, the marketing effort put into it, the economic framework for analysis used, and the support of local government.

The findings of my own research supports the suggestions made in Section 1.1.3 in Chapter 1, that a decentralised integrated approach, integrating the efforts of the private sector, scavengers and local communities could make a considerable contribution towards urban solid waste management. The experience of waste collection in Accra suggests that using private contractors is more effective than relying solely on the public WMD for this service. However, this arrangement carries with it problems of inadequate service in low income areas, indiscriminate dumping of waste, poor working conditions for labourers in terms of environmental health and pay, and lack of investment in equipment. The short period during which the government hired in the services of a foreign company, relying on sophisticated collection vehicles and containers, proved to be too capital demanding and thus inappropriate to the context. Whilst western mechanised systems tend to be too expensive and technologically inappropriate in the densely populated indigenous areas of Accra and the new settlements on the outskirts of the

---

[46] E.g. between the AMA's Waste Management Department and the Public Health Department

[47] The Government's decision to intervene in the solid waste collection service and install a private company with this responsibility, was in part due to public pressure for improvement in the wake of a general perception that the WMD/AMA were incapable of delivering the required service. This was not the first time the government intervened in waste management matters. As a populist measure, following an election, the Rawlins government moved in and ordered the AMA to scrap the pay-as-you-dump fee introduced to recover costs for operating the communal container collection service.

[48] Evidence suggests that the small to medium scale operations are most cost-effective, with limited mechanisation and focus on using clean wastes such as that from markets and the wealthier neighbourhoods, which contains better quality organic waste.

city where roads are poor or inadequate, Accra is a big and growing city which generates vast volumes of waste and a certain degree of efficiency and scale of operation is required. As much as the project in James Town and many of the case studies described in Chapter 1 are promising and provide appropriate solutions in certain circumstances, they operate on too small a scale to represent viable alternatives to mainstream waste collection and disposal. Even if such schemes were multiplied throughout the city, there would still be a need for larger-scale operations and a coordinating body. However, in terms of primary collection, particularly in the low income areas and waste recycling such enterprises have great potential.

With regards to the viability of composting and the potential for using MWC in agriculture, the Accra experience clearly suggests that the small-scale community based operation in James Town is more appropriate than the large scale, mechanised, capital intensive and publically run plant at Teshie/Nungua. Although both operations had experienced a number of problems, the James Town project had the capacity to produce compost to a higher quality standard at a lower price. However, they were relying on the mainstream waste management agent (be it the WMD or C&CW) to remove and dispose of the non recyclable fraction of the waste. What emerges as one of the findings of my research is that there is room for both public and private waste management activities at varying scales of operation. As noted in Chapter 1, it is crucial that the municipality plays an active role. Final disposal and handling of hazardous waste is most appropriately managed by the mainstream operator, and it is important that the municipality has appropriate coordinating, monitoring and policing mechanisms in place to endure adequate coverage of services and the prevention of illegal or hazardous activities. Whilst the overall management should be vested with the municipality, the involvement of different actors, such as community groups, CBOs, NGOs, private entrepreneurs, scavengers and informal recyclers can greatly contribute to a more sustainable waste handling system.

We can also conclude that it is important that robust governance capacities are in place. The authors of a publication (edited by Onibokun, 1999:5) on the waste management issue in Africa, stress the need for appropriate governance along with techno-financial solutions. They point out that "*an increasing interest in public-private-communitive partnerships is evident in the sector, but this is often related to a concern with technical and financial issues, rather than with the political, sociological and environmental relationships involved*". The authors go on to argue that "*efficient and effective service delivery depends on several key elements, the most important of which are managerial and organisational efficiency, accountability, legitimacy*[49]*, and responsiveness to the public, transparency in decision-making, and pluralism or policy options and choices*" (*ibid*: 6).

My research findings also indicate that there is a market for MWC amongst some farmers and growers but, because of the availability of low cost chicken manure,

[49] Onibokun uses this term because they note that in some cases waste recycling and management systems are informal and, in this context therefore, 'illegitimate'.

the market is relatively limited, and sensitive to quality and price. Under the current regulatory and fiscal conditions compost cannot be produced sufficiently cheaply to be an attractive option to farmers and the quality of the material produced is questionable. So, the currently available compost, in terms of its quality and price, has limited potential for utilisation in agriculture.

The situation with regards to chicken manure is that the poultry farmers consider the manure to be a waste with no value. Indeed it represents a problem with a potential cost associated with its disposal. The vegetable growers do poultry farmers a favour by taking it away. One person's waste is someone's waste is someone else's resource, although, as discussed in Section 4.3.4.4 in Chapter 4, not all poultry manure generated is utilised by farmers and growers and much of it represents a pollution problem for poultry farmers.

In contrast, compost makers, whatever the scale of operation, cannot afford to let farmers have the compost for free, since the process of converting the waste into a resource through composting incurs a cost, which needs to be covered somehow. A key question that arises in assessing the potential for composting municipal waste and the use of MWC in agriculture thus is: Who pays? Composting operations designed to meet the costs through sales revenue are not feasible where the market value of compost is lower than the cost of producing it. To expect urban waste composting enterprises to be financially self-sufficient is effectively to ask compost users, i.e. farmers, horticulturists, landscapers and gardeners, to pay for the city's waste management. Waste handling, treatment and disposal costs money and this is a cost incurred by society. Why then should farmers bear that cost? By combining private enterprises, using technologies appropriate to local conditions to minimise costs, with public money to make up the shortfall between production costs and revenue, composting can be a cost effective alternative to landfilling. By looking at it this way the argument can be turned on its head: through cost-effective recycling schemes and associated revenue, the recyclers subsidise the public sector, or urban society, in their waste management costs.

## 7.5 An integrated adaptive approach to managing the links between urban waste and agriculture

The discussion so far has: (1) explored the potential for linking MWC to agriculture from the perspective of different key stakeholder groups, (2) argued that policy decisions determining the potential are in part driven by economic realities, partly determined by political will and the quality of planning and management, and (3) suggested that given an appropriate blend of public-private-community partnerships, scales of operation which harness opportunistic alignments between the needs and objectives of different actors, MWC and its subsequent use in agriculture has potential in contributing towards sustainable development.

What does this suggest? Firstly, it suggests that there is no unique way to configure an appropriate blend of policies conducive to sustainable waste management, and more specifically to MSW composting and use of MWC. Second, it suggests that the choices are also not just economic but political and dependent on the institutional capacity and willingness for cross-sectoral and cross-scale governance.

Drawing on Ravetz' Integrated Assessment Framework as a conceptual device, and returning to the examples of externality factors given in Section 7.4, Figure 7.4 illustrates the interrelated components that influence policy decisions in relation to the potential for composting MSW for use in agriculture. The extent to which different considerations are incorporated into policy decisions produces different scenarios with different outcomes.

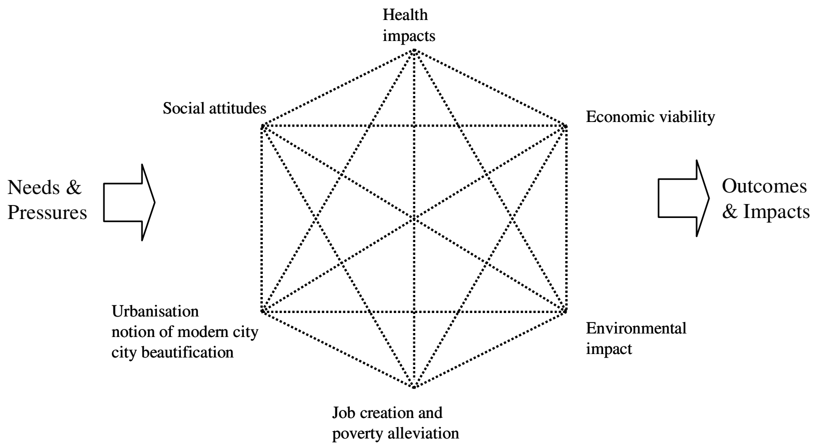



*Figure 7.4 Integrated scenarios showing interdependent components with needs and pressures and outcomes and impacts*

*Source: Adapted from Ravetz, 2000*

Environmental, economic and social needs and pressures lead to action to be taken. What action to take depends on the particular blend of environmental, economic and social needs and pressures and is influenced by the considerations taken into account and the time frames used. Different actions will produce different scenarios, and have different (environmental, economic and social) outcomes and impacts, in the environmental, economic and social realms. This suggests a series of iterative cycles of adaptive management in which policy decisions or action are taken in response to needs and pressures, lead to outcome, that in turn, lead to new needs and pressures and so on, as depicted in Figure 7.5. This has clear parallels with the Kolb learning cycle (1984), the action research cycle outlined in Section 2.3.2 in Chapter 2, and with adaptive management and social learning (Section 2.4 in Chapter 2). It is because of the seemingly inevitability of such cycles in the management of complex systems that adaptive management argues for adaptive, flexible, iterative, even experimental management approaches.

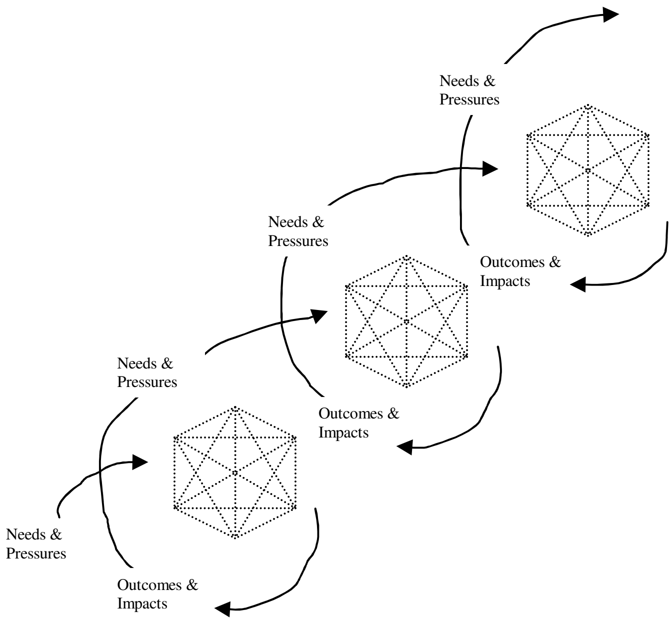



*Figure 7.5 Iterative cycles of adaptive management in a process of casual links driven by chains of cause and effect, (or feedback mechanisms)*

A key element thus in the development of MSW is the creation and maintenance of linkages between the waste management, agricultural and urban planning sectors. Folke *et al.* (1998) draw a parallel with ecological systems: "*Just like[sic] biological diversity seems to play an important role in ecosystem function and resilience, so to does the institutional diversity of management systems*". On the basis of both the secondary and empirical data developed by this research, it is argued that the systemic approach outlined above, using principles of adaptive management, would be a particularly appropriate approach for future urban waste composting development.

## 7.6 Concluding remarks

In view of the preceding discussion it can be concluded that the MCW produced in Accra had limited potential for use in agriculture by farmers and growers under the current conditions. Summarising the main findings it can be seen that:

- Quality

  The quality of the Teshie compost is low. It is low in nutrients and organic matter whilst it is relatively high in PTEs. The practice of composting mixed organic and non-organic waste means that the compost quality cannot be of a standard suitable for agricultural use. The Teshie compost had relatively high concentrations of heavy metals and contained inert contaminants such as glass and plastic, which made it unattractive to farmers. The compost produced in James Town, where they separated the waste before composting, was of higher quality, but it contained a very high proportion of sewage sludge. (Furthermore, the P content of the JT compost is so high that it could represent a problem for repeated applications).

- Performance in vegetable production

  The experiment revealed that the use of compost had a positive effect of crop growth, at the relatively high application rate used. However, urban and peri-urban vegetable producers in Accra primarily use chicken manure as a fertility input and compared with that the compost was slightly inferior. The main areas in which compost compared unfavourably to chicken manure were:

  - The tendency for juvenile plants to burn and die off when grown with compost.
  - The compost treatment needing more watering as the soil dried up quicker when amended with compost compared with chicken manure.
  - The unpredictability of compost. In chicken manure nitrogen is in a readily available form, so following application crop response is almost immediate, making it easier to manage crop fertility balance than with compost where nutrient release and crop response is more unpredictable.

  Despite of these limiting aspects of the compost, growers generally liked it. In particular:

  - They liked the fact that is did not need to be applied to every crop.
  - Those that tried it on nursery beds were very impressed with the outcome.
  - They were of the opinion that it was useful in the rainy season when chicken manure is unsuitable and the need for extra watering would not be an issue.
  - They liked the look of the plants grown in compost. Providing burning did not present a problem, (i.e. the crop was watered sufficiently), the plants grew large and lush with a rich green colour.

  Growers never got paid less for a bed of crops grown in compost amended soil. So, whilst there were problems with burning, it did not affect the price they got for the crop.

- Price

  Along with the contamination of the Teshie compost, price represented an important constraint to use in agriculture. Whilst, this research revealed that urban vegetable growers would be willing to use and pay for MCW, both the Teshie and the James Town composts were too expensive to represent a viable alternative to other fertility inputs. Under current conditions, compost could not be produced and marketed at a lower price.

All these factors combine together to lead to the conclusion that the potential for agricultural utilisation of MWC is relatively limited in Accra under current circumstances. This, in turn, begs the question does composting of urban waste and its use in agriculture have no potential in Accra? I would argue that whilst composting is not a magic bullet and there are many problems that need to be addressed, there are a number of things that can be done to improve the sustainability of organic waste management and that composting as a component in an overall WM strategy, can be viable, given that certain circumstances are in place.

Looking at quality first. In Accra the municipal waste that is collected contains organic material of low quality, which means that the nutrient content of the resulting compost will be low. However, that is not necessarily a problem, as long as it does not contain high levels of PTEs. The practice of co-composting with sewage sludge ensures better nutrient values, and in particular phosphorus. MWC can be mixed with chicken manure to produce a soil fertility input which combines the qualities of high phosphorus content and slow nutrient release of the compost, with the high concentration of soluble nitrogen in chicken manure. A combination of the two could prove very beneficial, and perhaps warrants further research.

However, for compost to have an agronomic value, it is necessary for the organic fraction of the waste to be separated out before composting. Manual separation of mixed municipal waste after collection and transportation to the composting site is both unpleasant, health hazardous and adds expense rendering the composting option non cost-effective. As such, ultimately the production of clean compost necessitates source segregation of waste. However, at this time there is limited potential for source segregation in Accra. Consumer awareness is not developed and it requires a more complex waste collection system than that currently in place. Source segregation at the household level represents a goal to work towards, which requires investment in public education and awareness rising.

Given that household source separation does not appear to be viable in Accra in the shorter term, compost for use in agriculture can be produced from selected wastes. The cleaner kinds of waste such as that from markets and certain industrial outlets as well as that from the wealthier neighbourhoods which contains higher quality organic materials, including garden waste, is suitable for composting. If such waste is collected separately for composting, higher quality compost could be produced at a lower cost. At the moment this cleaner waste is mixed in with the overall waste stream, thus its higher value as an input in compost is lost.

There is also a possibility of composting different kinds of waste for different purposes and uses. If compost is produced as a waste management strategy alone, then it may not be worth the extra effort of separating waste to improve quality. Contaminated compost can be used for capping landfills and certain landscaping. The lower quality organic waste can be used for such purposes, but then it is a waste management strategy, without a link to agriculture. It is questionable whether or not there is political will in Accra to invest in such a solution even though it represents a measure towards a more sustainable management of the urban environment and may prove cost-effective in the long run.

Returning to the price issue; there is an existing, albeit limited market for the existing compost amongst gardeners, landscapers and larger-scale peri-urban vegetable and fruit producers, and the compost that has been produced in the past has usually been sold. Given more effort on marketing, the commercial viability could be improved. However, if composting is to be done more extensively as a serious waste management strategy, then, unless landfilled, an agricultural outlet will be needed. In order to expand the market and harness the potential market that exists amongst commercial vegetable producers the price needs to be lowered.

Whilst there is room to improve the viability of composting and marketing for agricultural use, there are limits to what can be done under the current conditions. This chapter has argued that the potential for linking waste to agriculture is really a policy and governance question. Unless supportive policies and robust governance structures are in place to stimulate compost production and compost use, the potential will remain limited. Improving the viability of composting municipal waste and compost use, does not have to be prohibitively expensive, but some support is need. The relative benefit of composting municipal waste is directly determined by a series of economic factors which are centred on the value of waste reduction and sanitation and requirements for compost by the agricultural, horticultural and landscape sectors. Indirectly, assessment of benefits is influenced by factors such as the relative value of job creation and improved health and environment. Whether or not such policies are put in place depends on how the benefits of composting are perceived in relation to sustainable urban management, health and rural-urban linkages. This ultimately requires political will.

During the course of this research it became evident that management structures in Ghana were based on traditional sectorial divides and procedures for project implementation were in line with conventional linear models. Whilst there was recognition of the systemic, cross-cutting nature of many issues, including waste management, and of the relevance of interactive approaches, the policy climate for it was not fully supportive and, importantly, capacities and instruments for intersectoral collaboration and systemic management were weak.

Ultimately, the reconciliation of composting as a waste management strategy and compost use in agriculture requires imaginary solutions, which stimulate partnerships between stakeholders. There is a need to support measures that opportunistically harness motivations of different stakeholders to create win-win situations that address urban waste and agricultural needs simultaneously. The

CBO operating the composting enterprise in James Town negotiating access to market waste with the market queens at Agbogbloshie market was an example of a mutually beneficial collaboration between stakeholders. The fact that local politicians blocked this development only goes to show that political will for small-scale innovative enterprises aimed at sustainable waste management and income generation for the urban poor is lacking in Accra.

What this research has found is that the potential for linking waste to agriculture is relatively limited in the current economic and political climate in Accra. However, it indicated that with some modest policy support, possibilities for improving quality and financial viability are considerable. Providing quality and price can meet the needs of growers, there is a market for MCW in Accra.

# CHAPTER EIGHT – A CRITICAL REFLECTION ON THE RESEARCH EXPERIENCE

## 8.1 Introduction

My point of departure for this research was that an exploration of the potential for using MCW in agriculture is an endeavour which requires an integrated and adaptive approach, using an interdisciplinary systemic perspective. I attempted to gain a fuller more comprehensive understanding by making a broad attack on the issue, with the aid of a combination of more or less complimentary methods. Some of the methods and tools fit within the participatory and action research traditions. Others are typical of conventional scientific methods of enquiry. The various methods were used together to form a systemic inquiry. Chapter 2 describes the research process and explains the rationale for carrying out the research and the way it was done. This chapter reflects on my experiences of the 'pros and cons' of the broad attack of problems of this kind, and seeks to distil the learning experiences that I, (and others involved in the research) underwent. Chapter 6 ended with a reflective discussion on the research process in relation to the experimentation. I now widen the boundary to reflect on the whole research process, in which the growers' experimentation and the on-farm trial formed only a part.

One of the central research issues for me (and which emerged early on) was to be able to reflect critically on the relative usefulness of applying systems thinking and methodological pluralism as an individual researcher. The PhD process has allowed me to consciously monitor and reflect on these issues. This chapter thus discusses a range of practical and personal issues and considerations that affected the research. It describes and reflects on the personal journey I have gone through and as such is written in a more informal way than the rest of the thesis.

The first part looks at some of the benefits and drawbacks of using methodological pluralism in a truly interdisciplinary setting. It then considers the implications of following an iterative process in a dynamic context and discusses the merits of taking such an approach. This leads in to a discussion on the task of synthesising incommensurate data and information.

## 8.2 Reflection on the theoretical framework and how it informed the research activity and conclusion

The underlying premise of this research was that the issue for study was perceived as sufficiently complex to warrant interdisciplinary systemic research and the deployment of a variety of methods. Embedded in constructionism, the research involved understanding the situation in terms of a series of interrelated sub-questions, explored from within different disciplines and at different scales. Many of the sub-questions thus needed to be addressed by using different methods based in a variety of intellectual and disciplinary traditions.

Involvement in interdisciplinary research is fraught with tensions: it is a complicated and challenging experience to be immersed in. One of these tensions relates to methodological pluralism at the level of philosophy. Some of the methods used make different paradigmatic assumptions. The question that I had to grapple with was how to mix methods from different incommensurate paradigms without getting into a philosophical muddle. The tension between reductionism and constructionism proved particularly problematic to mediate.

Another relates to methodological pluralism at the applied level. The very fact that a range of methods are used to investigate a multitude of issues leaves the researcher struggling with the frustration of spreading herself too thinly and a feeling of not going into sufficiently depth in any one area. A third tension that I found challenging (and which is discussed in Chapter 6), was that of differentiating between the overall PhD project and the practical research. On the one hand the research involved exploring the potential for using WDC in agriculture; on the other hand it involved taking a step back and reflecting on the research process itself. The blurring of the boundary between development and research posed other kinds of tensions. As my research was not nested within an existing project, and I could not identify any farmers who had been using WDC in the past, a large proportion of the fieldwork involved planning and executing the experimentation with growers. I had not realised this in the beginning when I was planning the research. A short way into the fieldwork I was conscious of the fact that what I was doing was more akin to development work than research. Whilst not a problem *per se*, it affected the amount of systematic information on the research process that I could generate within the time frame available. I effectively had to do the development and action in order to then do the research on the action developed. Had I done the research within a larger, ongoing project I may have been able to focus and monitor the aspects of interest for the research in more depth. These tensions will be further discussed at various points in this Chapter.

Reading the work of Midgley (2000) was helpful in orienting my thinking towards the philosophical tension arising in methodologically pluralistic research. He takes the position that methodological pluralism involves the researcher in setting up a new position which encourages learning about other paradigms, but re-interpreted in our own terms. He argues that "*there is no need to claim that we are operating across paradigms – we just have to acknowledge that we are setting up a new position which encourages learning about ideas from other paradigms, but re-interpreted in our own terms*" (*ibid*.:248). My position, as outlined in Chapter 2, was that this research is situated in a constructionist framework but within it methods from a positivist-realist paradigm had to be used for parts of the study. In other words, the various elements of the research were nested together within a constructionist framework. Looking at the research process in retrospect, I can conclude that this was a useful way of approaching the research. Moving between fundamentally different sets of assumptions was, however, demanding. It required me to change my assumptions in order to keep an open mind and take on board the viewpoints of different stakeholders and to be self-conscious as I practised different methods. I moved between research activities which required me to take the position of believing that there is a real world that can be fully known (e.g. collecting hard data from compost analysis) and to embrace an epistemological system which questions the notion that it is possible to establish the nature of a real world or a known truth as an absolute claim to knowledge. I found this experience difficult yet challenging and rewarding. Having gone through this experience I am convinced that it is a useful way to approach any systemic intervention.

However, there are implications in undertaking interdisciplinary research of this nature. Using a systemic approach with a blend of reductionist scientific methods and the softer methods of enquiry used in (constructionist) social research, had implications for me as a researcher, as well as for the outcome of the research. As mentioned in Chapter 2, in the past I had been engaged in both natural and social science activities as part of a team within a multidisciplinary project, but had not undertaken an interdisciplinary project in its entirety. I saw this PhD as an opportunity to embrace such a challenge. I came to realise that it is a rather unusual way of doing research. This section seeks to provide a critical reflection on the outcome. How well has this approach achieved its purpose? The critical question is whether the strengths of the approach outweigh the weaknesses. Was there some degree of methodological complimentarity between scientific positivist realist research and socio-economic constructionist research, or did the difficulties of such a merger outweigh any advantages?

I embraced the fact that I would take a broad-brush approach to exploring the research issue, and as such trade off in-depth research into a narrow field for a more general contextual study. I was happy with the appropriateness of this approach, given the complexity of the situation and the fact that the research object cuts across disciplinary divides and hierarchical levels. However, I was conscious of the fact that I ran the risk of spreading myself thinly. Each method that I used has been used widely before and that I did not attempt to break new ground in the fields of participatory and action research. However, I had to ensure that each mini-study slotted together to contribute to the whole, to provide a comprehensive understanding of the context and the issues related to the research question. I found that indeed there could be a 'synergy of methods' (Midgley, 2000), resulting in a more comprehensive whole. In the words of Midgley (2000:360):

> "*the creative design of methods involves understanding the problem situation in terms of a series of systematically interrelated questions expressing the purposes of agents, each of which might need to be addressed using a different method, or part of a method. A synergy is generated that allows each question to be addressed as part of a whole system of questions*".

As a researcher I had to constantly 'change hat' depending on who I was talking to. My interviews involved people from different disciplines, with different gender, and different levels of education and influence. Some were at the grassroots, others concerned with macro policy. The choice of interview techniques and study methods was guided by the reality of the constraints and opportunities of the situation studied and the people involved. I kept 'balancing the tight rope' of attempting to hold together the technical and methodological aspects of the research with one foot in natural science and the other in social science. I had to keep reminding myself not to focus too much on one aspect at the expense of the other and, as such, compromising the underlying principle of interdisciplinarity.

I found that my approach enabled me to obtain a comprehensive insight into the subject area and the various issues relating to and affecting it. If we accept the theoretical notion of individual world views; i.e. that each person sees and builds his or her own reality based in the interpretation of their experiences (Webber, 2000), then it follows that interacting with a range of stakeholders with different world views and perspectives in relation to the problem issue, is likely to affect your own interpretation of the situation. Through my experience I became conscious that interaction with one set of stakeholders affected the way I viewed the situation, which in turn affected the way I went about interacting with another set of stakeholders. Once I had come to this realisation I consulted the literature and found that this is a common experience amongst practitioners in systemic intervention. For example, Midgley (2000:251) notes that

> "*every time one person listens to another whose thinking is based in another paradigm, he or she can only interpret what they are saying through his or her own terms of reference. However, this does not mean that communication is impossible – just that care is needed not to be either dismissive or to think that full understanding has been achieved. … Learning through the appreciation of other's viewpoints can feed back, via communication, to transform one's own paradigm*."

This has implications for the research process as I will discuss in the next section. I have come to conclude that by the very nature of the way one works, an interdisciplinary research experience changes you as you become influenced by the various stakeholders' world views.

As I built the research through interaction with different actors and the collation of increasing amounts of information, I built an ever richer picture of the situation. Whilst my view of the situation was my own interpretation and did not represent a claim to a universal picture of 'the reality' or the 'truth', the process gave me a comprehensive basis from which to appreciate the complexity of the system and to take into account the various issues that affected it. The benefit, as I see it, is that it puts the researcher in a position of being able to better appreciate the complexity of an issue and different stakeholders' perspectives, which in turn puts him/her in a good position for facilitating change and conflict management.

I would argue, on the basis of the experience presented in this thesis, that development and management projects which purposefully intervene to bring about change, interdisciplinarity and methodological pluralism is crucial for a successful outcome. In my own research project, where the intervention stopped at the point of analysing and reflecting on the research outcomes and the issues affecting the system, the full benefit of interdisciplinarity was not realised. However, it was overall a very satisfying way to work, and the multi-perspective insights gained aided the iterative planning of the research to ensure that nothing crucial was overlooked. I now turn to examining the relative usefulness of using a flexible, iterative approach, and how this was done.

## 8.3 An adaptive, iterative, flexible approach

This research was guided by the action research tradition. Critical reflection on the outcome of research or action may lead to a re-definition of the problem, initiating modification of the action plan, as the research process goes through different cycles of planning, action and critical reflection (Udas, 1998). I found the core principles of responsiveness and flexibility very useful in relation to my own action research. It allowed work to be carried out as an iterative process: preliminary research questions guided the lines of inquiry initially, and new lines of inquiry emerged through cycles of planning, action and reflection (as illustrated in Figure 2.4 in Chapter 2). Lessons learnt throughout the research allowed for emerging issues to guide the subsequent process so that some of the initial intended actions, methods, and questions were abandoned whilst others were added as they emerged as important and relevant to the inquiry. This is different from a reductionist approach where any deviation from a prescribed methodology and stated hypothesis is seen as a trade-off in rigour. There are, as I see it, two vaguely/slightly different reasons for this. One relates to modifications to the research as a result of the learning that takes place; one is a result of emerging issues or unanticipated or changing situations. I now elaborate on each in turn.

A researching process based in an social dynamic needs to evolve on an ongoing basis so as to be responsive to the learning that occurs. The methods we start off with at the onset of a research endeavour before much is known about the social system in which the problem issue is embedded, may turn out to be inappropriate or incomplete. In the words of Midgley (2000:255) again:

> "*we must oppose the usual practice in academia of building a methodology like a castle and then defending it against enemies who want to tear down the castle walls. People with this kind of attitude see the modification of a methodology as a sign of weakness. I view it as a strength, as long as learning is part of a process of construction in which ideas change in relation to (both) practical experience, dialogue with others and theoretical reflection.*"

This perspective on the usefulness of an iterative research process was not all that clear to me before I embarked on this research. However, through my experience it became clear that the learning experiences we go through when conducting research involving multiple stakeholders leads us to take in new ideas and integrate these into our interpretation of the system under study. As a consequence of this 'new way of viewing' the problem situation, the methodology also may need to evolve in order for the research to remain contextually relevant.

The second, to me more transparent reason why an iterative research process is appropriate, relates to emerging issues or changing circumstances. Having chosen to research a complex systemic problem, which cut across disciplinary divides and hierarchical levels, it followed that the exact nature of the research could not be fully known from the onset. Therefore, the methodology needed to be flexible, responsive and adaptive. The open-ended nature of the initial research question needed an approach which could allow for issues to be explored as they unfolded through time. Exactly which sub-question needed to be addressed and exactly which method would be best suited to do so, could not be fully determined in advance. Choices were made as events unfolded through the research process. Figure 8.1 depicts how different activities were included and excluded as the research progressed. These will be covered in more detail below.

As with most fieldwork experiences, things did not go according to plan. Some of the research activities that had initially been anticipated as relevant were abandoned along the way, either because they turned out not to be relevant in the local context, or because they were not logistically feasible to undertake. Other issues were included as they emerged as important as a result of findings generated along the way.

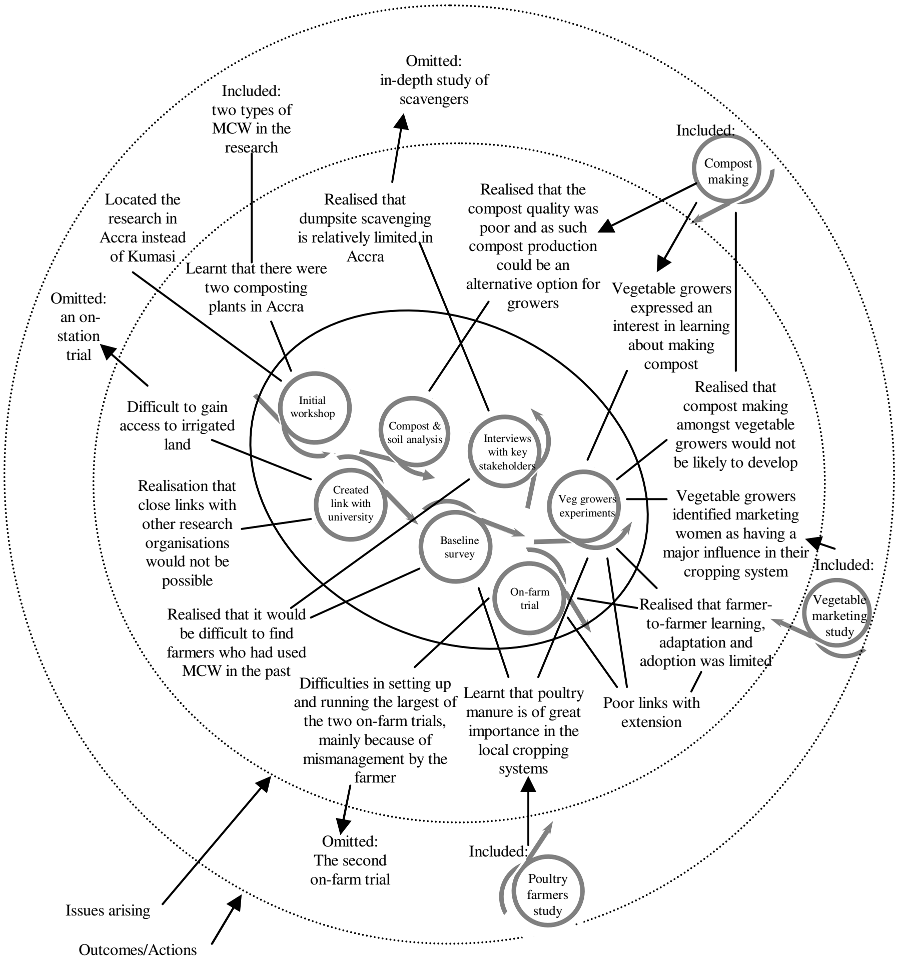



*Figure 8.1 Diagrammatic representation of the research process and how some initially planned or anticipated activities were excluded along the way whilst others were included as a result of new key questions emerging*

*Source: This thesis*

Below are examples of issues arising from the various research activities and of how these outcomes guided the subsequent emerging activities and my thinking about the research.

*Links with other research and development initiatives*

To mark the initiation of the field work I attended a 5-day international workshop in Accra, on urban and peri-urban agriculture. This proved very useful for gaining background information about the subject area and in making valuable contacts. Having initially planned to locate the fieldwork in Kumasi, one of the outcomes of the workshop was that I decided to base it in Accra instead. Whilst there were ongoing project activities in Kumasi with which there was potential for some degree of linkage, Accra had a number of conditions which seemed favourable. Importantly, municipal waste compost was produced by two separate operations which would give me an opportunity to study the potential for use of such material under real life conditions (an important underlying aim of this research). Working in Kumasi would have involved transporting compost from Accra. Like in Kumasi, there were several types of urban and peri-urban farming activities present in and around Accra. However, the potential to build on and contribute to existing work and for acting within a recognised institutional identity, was less in Accra. However, even in Accra the University of Ghana, Legon, offered the possibility for establishing an institutional link. Contact was made with the Metropolitan Director of the Food and Agriculture Department within AMA and I learnt that on-farm trials to test compost from the Teshie/Nungua plant were being planned, and that he was keen for us to join forces. Considering the natural link that this would have to the extension services and the potential for dissemination of information and scaling up, this seemed like a sensible way to proceed.

Once the decision was made to locate the research in Accra, a formal link with the University of Ghana, Legon was established. I explored the possibility of linking up with other research and development initiatives which were in some way complementary to my own research. However, it soon became clear that there were no on-going research or development work relating to my subject area with which I could link. I came to realise that I would work largely in isolation and had to configure my fieldwork activities accordingly.

As time progressed I also gradually came to realise that the link with Legon was not all that useful. There were limited resources at my disposal (e.g. access to library services, laboratory analysis facilities and experimental land for carrying out trials) and the in-country supervisor lacked interest in my research. I came to have less and less involvement with the university as time progressed.

*Links with extension*

I stared off thinking that I was going to be able to stimulate links among stakeholders. I soon came to realise that not only were there no research and development initiatives present into which I could slot in, there was very limited interest within the extension service. Through my initial and ongoing contact with the Director of the Food and Agriculture Department within AMA, I had hoped that a fruitful link with the extension services would be fostered. Considerable time and effort was spent with the extension officers and with the farmer field school (FFS) to try to establish a working relationship. The outcome of these efforts proved very disappointing and, whilst I maintained a certain degree of contact with the extension service and the officers involved in the FFS and the experimental sites throughout the research period, any hopes of developing a fruitful partnership were abandoned along the way. This was a regret as I was convinced of the importance of the involvement of the extension for any research and development initiative to have a lasting, wider impact. I feel that working on my own without the kudos and resources of a larger project behind me, rendered my research activities unattractive to the extension services.

The difficulty in establishing collaborative links affected the research structurally, as well as in terms of activities. I now turn to highlighting some of the changes and re-thinking that occurred as a consequence: Some were activities that I had initially intended to include, but did not because they were not relevant to the local context or were not technically or logistically feasible to undertake. Other activities were processes that I had intended to monitor but which did not emerge as expected.

*On-station trial*

One possibility that I had considered when I first conceived the research was to carry out an on-station trial in parallel with farmer experimentation. Initially it looked as though the link with Legon would enable such a trial to be carried out. However, having explored the options (with both the University and the Ministry of Agriculture), I decided to abandon the idea of carrying out a controlled trial and to focus entirely on working with farmers and growers in their own fields.

*Study of farmers who had previously used WDC*

The fact that municipal waste compost had been available on the Accra market since 1980, and that research on different aspects of WDC had been carried out over the years, I embarked on fieldwork with the expectation of including a study of farmers and growers who had used WDC in the past. As a result of the baseline survey and early discussions and interviews with stakeholders, I began to suspect that it would be difficult to find any such farmers and growers. Throughout the fieldwork period I made relevant enquiries to try to identify and locate such people, but without any luck. I had to abandon the idea that they might form a valuable source of information.

*Scavengers*

Another group of stakeholders who I had anticipated as being of importance were waste scavengers. However, as a result of findings generated along the way, I came to realise that scavenging is a relatively limited activity in Accra (compared with many other cities in the South). They thus offered only limited potential as potential collaborators and they too were dropped from the study.

*Farmer-to-farmer learning and technology adaptation and adoption*

As discussed in Section 6.5 in Chapter 6, one area that I had intended to incorporate in the research was that of the interaction among farmers as they involved themselves in the experimentation process. I expected that some degree of farmer-to-farmer exchange of information would emerge and hoped that there would be some technology adaptation and adoption as a result of the informal experimentation approach used. There was limited evidence that this in fact occurred in spite of the fact that the growers were positive in their appreciation of the impact of the performance of crops grown with compost. As a result this aspect of the research became less important than expected.

Above are some examples of planned research activities which were dropped. Below are examples of issues that were included as they emerged as relevant to the research

*Poultry farming and poultry manure handling*

As a result of the baseline survey and the work with the vegetable growers, it soon became apparent that poultry manure is the most important and favoured fertility input into the various vegetable production systems in and around Accra. The manure is sourced from urban and peri-urban poultry producers and thus it represents a form of urban waste. In the light of this, the decision was taken to include a closer study of poultry farming and its related manure handling in relation to urban waste generation and vegetable production.

*The vegetable marketing system.*

Through working with the vegetable growers, the critically important factor that marketing represents in the vegetable production systems became clear. The marketing women, along with the institutions affecting water access, were consistently identified as the most important institutions affecting the vegetable growers. Specifically, there are concerns amongst consumers, and subsequently marketing women, about the quality of vegetable produce from within Accra, mainly because of the use of wastewater for irrigation. Such concerns are legitimate and may have important implications for the viability of using MCW as a soil improver. The decision was made to include a study of the nature of the vegetable marketing system and how it affects growers. It was also considered relevant to gain information about issues such as willingness to sell food from within the city, seasonality in relation to food availability and pricing structures, perceptions of quality of vegetable produce, and opinions of the market women about different soil fertility inputs.

The above highlights some of the activities and issues that were dropped out and included into the research, partly as a consequence of logistics, partly as a result of findings as the research progressed. Other examples are given in Box 8.1. They show that the fieldwork required constant revision and adaptation. I had to constantly balance the need to keep the research relevant to the local context with the need to ensure the research questions were answered. Whilst there was room for flexibility in terms of style of working, my research topic was specified and I did not have the option of changing it completely to accommodate all the priorities identified by the growers (e.g. water). The fieldwork phase was a roller-coaster ride of ups and downs: things would ‘go wrong’, or not according to plan at any rate, and I and others involved would feel demoralised. My fieldwork diary is full of the worries I had regarding unanticipated situations and problems and that the research had been compromised. Measures were taken to respond to the worries and then suddenly the research process came together again. For example, when the larger on-farm trial was on the verge of collapsing and the second crop in the smaller on-farm trial was completely ruined by grazing goats getting onto the field, it looked as though everything had been lost. However, the farmer in the smaller trial was still keen to carry on and once we got the trial area fenced off, another crop was planted and the trial resumed. The research had to track the reality as it unfolded, in order to hit a moving target. The discipline of critical reflection was essential to achieving this.

*Box 8.1 Additional examples of things that were different than anticipated*

- Teshie compost was of poor quality. In fact, it was more like black soil than compost. The James Town compost contained a lot of P and a large proportion of it was made up of sewerage sludge. As such, it was not typical of compost either.
- The largest of the two on-farm trials had to be excluded from the research after a lot of time, effort and money had been spent on it. The comparisons between a large number of treatments, including chicken manure, under more scientifically controlled conditions were lost.
- There was a lack of water for much of the time in Marine Drive which resulted in crops being lost and the experimental work being suspended. The growers lost all their crops and were demoralised. Under these circumstances the motivation for testing compost was not at the top of their agenda.
- The microbiological analysis carried out in Accra produced results that were unreliable (non-quantifiable) and only of limited use.
- The analysis of soils, manures and composts could not be carried out in Ghana. Instead samples had to be taken to the UK for analysis. While not a major problem, (apart from it being very expensive), it excluded the possibility of gaining meaningful analysis of available N. Also the analysis became a major expense (to the research). Analysis for available N was initially carried out at Legon university, but the procedure and subsequently the results were unreliable.

I do not think that the changes that took place are unusual. However, people do not tend to make it explicit/talk about it, which is a shame as it represents valuable lessons. The beauty of using an iterative approach to the research is that it is OK, expected in fact, that the specifics of the research develops through the process. I found this a useful, in fact the only way to tackle this kind of research. However, I found a need to be explicit about the changes that are made and to be careful not to let it ‘go all over the place and lose the plot’. Whilst the incorporation of new sub-questions and methods suitable to address these is appropriate in systemic research, care needs to be taken not to lose coherence. Unless consideration is given to the purpose and direction of the overall research, there is a danger of the activities becoming too fragmented. It is important to maintain a balance between coherence and openness to new ideas. Otherwise, what may result is a collection of fragmentary methods without a coherent perspective from which to frame a unifying interpretation.

## 8.4 On working alone vs. being part of a larger project

There are benefits and drawbacks to all things, and working on my own and not within a larger project is no exception. I found that it had its benefits, particularly when it came to interacting with farmers and growers, but also when talking to stakeholders within the waste management sector. The benefits were largely threefold. Firstly, it aided the flexible, iterative approach to the research discussed above. It allowed me to make my own choices and 'go with the flow' as issues arose. Informal feedback took place all the time and it was easy for me to respond to that. In a larger project with a lot of actors and a hierarchical or complex chain of command, quick 'off the cuff' decisions about changes to research activities and focus may be more difficult to make. Second, operating at a small scale on my own was beneficial in terms of building relationships. It allowed me to develop a good, trusting, working relationship with the growers. It also, I believe, aided interaction with other stakeholders; a small, humble, student project was non-threatening. People had nothing to win or lose by talking to me and were therefore willing to open up. By the same token, the third benefit was that my research did not attract research directors or other professionals who might have wanted to control it, or change its focus or approach.

The downside of working small–scale in isolation in this way were the limitations in term of time, staff capacity and resources, as well as the limited impact and kudos that the project commanded and as a consequence the restricted ability to engage actors and create links among stakeholders. For example, the researcher and her assistant carried out all the steps needed to implement the experimental component of the research, from introduction to farmer selection, relationship building, design and implementation of the experiments. Getting everything up and started (and running smoothly) took time and it was difficult to achieve anything with lasting or substantial impact in the time available. The same applies to the efforts to link growers and the waste management sector. It felt as though the project only managed to 'dip in and scratch the surface'.

## 8.5 Some words on the experience of synthesising data and information

The research methodology produced data and information of different kinds. Fitting these elements together to address the various sub-questions and ultimately the overall systems inquiry appeared at first to present a daunting challenge. Re-capping from Chapter 3, these challenges included:

- synthesising non-commensurate data and information, from within a single discipline (*e.g. soil sample analysis, and vegetable growers' views of soil quality*)
- synthesising data and information from different disciplines (*e.g. agronomy of vegetable growing, and institutional issues of governance*)
- synthesising understanding that crosses several levels of analysis, and of practice (*e.g. vegetable plots on waste land, farm enterprises, waste collection, municipal governance*)

Different sources of data ands information were used together in different combinations to address different sub-questions. What data and information were helpful for answering a particular question depended on the nature of the question and the level of analysis (system boundary). For example, in order to determine a suitable compost application rate, chemical analysis results, crop harvest data, secondary data, along with information from growers on chicken manure application rates, labour inputs and financial constraints, were used to inform the decision. Similar sources of data and information were consulted in order to explore the agronomic potential for using MCW in the local vegetable growing systems. When exploring the potential of MCW from a financial point of view, information drawn from both farmer interviews (formal and informal) and waste management professionals, as well as secondary data, were used. Figure 3.1 in Chapter 3 illustrates the methods used for the different research activities.

When it came to the analysis, data and information from different methods were combined to ensure rigour and reliability. By cross-checking, drawing on a variety of data and information sources (e.g. different questions, similar questions asked at different times, different respondents and different methodological tools), triangulation was achieved to give more depth to the analysis. For example, qualitative data was used to enrich the quality of the quantitative data. Talking to growers and other stakeholders about the quantitative results was found to be useful; in many cases it served to 'tell the story' that the quantitative data suggested. Sometimes this relationship would work the other way round. For example, when the growers suggested early on that the beds amended with compost dried out more than the other beds; I found that difficult to take on board. My expectation was the opposite; based on the widely held view that one of the positive properties of compost is that it improves soil water retention. Through triangulation it was found that there was convergence in the data and information and that these findings were verified. When synthesising data and information that cut across scales, the complexity was dealt with by grouping topics with similar characteristics or relationships within levels of hierarchy. In fact, the task of synthesising data and information from non-commensurate sources had seemed daunting at first, but I found that it was not as difficult as I had envisaged. I came to realise that it is a natural state of affairs. It is something we do all the time in our everyday lives. We consider complex systemic problems and issues, we respond to feedback loops, and we base our actions on whether we consider long or short term consequences.

What I did find more challenging, however, was the question of attribution. Unless an obvious event led to a new finding, I found it difficult to determine the exact sources of the information that led to certain ‘knowledge’ or a conclusion or finding. Most knowledge is evolved from a variety of experiences, sources and events. Pinpointing the (precise) moments, events or triggers that led me to expand my knowledge or cause a shift in my thinking was difficult and I can see that there is room for improvement here. On my journey towards becoming a reflective and responsive practitioner this is something I want to work on. However, this is a slight digression, as the purpose of this research was to look at the potential for using MCW in agriculture, not researching the pedagogy of human interaction and social learning.

The purpose of this reflection on the challenge of synthesising non-commensurate data and information and also to assess how well this study has met the challenge. Bearing in mind the purpose of this study, I feel that it has. I feel that there was methodological complementarity between the scientific positivist-realist components of the research and the social and constructionist parts. The components all went towards answering the research questions (of how to and the appropriateness of using MCW). Each part (mini-study) either ran in parallel, was intertwined or was nested within another, to together provide a comprehensive picture of the complex problem issue in a way that contributed to furthering knowledge.

This research began with the assumption that a good methodology is one which satisfies the objective of the research, given the boundary of available time and resources. This sounds obvious, but in my experience from the case studies I have reviewed over the years, it is not unusual for research to be guided by a theory and associated methodology. I was clear from the start that I did not want to limit the research problem to fit a certain methodology (and the theory in which it was born). I did not want to focus the research on ‘doing science’ or ‘doing action research’ or ‘applying soft systems methodology’. Rather this research was guided by the research problem, and the methodology used was designed to satisfy the objective of the research in an efficient manner. The techniques selected were ones which I thought would best achieve this end. In other words, relevance to the problem was the driving criterion for achieving rigour. This led to a mixture of methods being employed. I see this as a strength of the research since it produced an outcome which did not inhibit collaboration between natural and social scientists and between action researchers and scientists.

## One concluding thought on PhD research

As a PhD researcher, who supposedly is meant to gain in-depth knowledge of something specific, I have been left with the feeling that I know a little about an awful lot of things, but not a lot about anything specific. This reflection leads me onto a major conclusion I have come to draw from this experience. Throughout the research I was struggling with the tension of balancing the practicalities of research to explore WDC, and more reflective research on the research process itself. I came to believe that for development research and management intervention purposes a systemic interdisciplinary approach is very useful. It is in my view, the only sensible way to go about it. However, is it sufficient for the purposes of academic research? It depends. It has dawned on me gradually that interdisciplinary academic research can really only be ‘research on the research’, or in other words methodological research. This is not what I had entered into this PhD to do. Had the research been methodological from the onset, then the investigation into the potential for using WDC in agriculture and the experimentation with growers, would effectively have become case studies for researching the research approach. This for me has been a major insight which has profoundly affected the way I think about interdisciplinary research and development

# REFERENCES


Ackoff, R.L. 1957. 'Towards a Behavioural Theory of Communication', pp.209-218. In: Buckley, W. (ed.). *Modern Systems Research of the Behavioural Scientist*. Aldine Chicago, USA.

Ackoff, R.L. 1981. *Creating the Corporate Future*. Wiley, New York, USA.

Adriaanse, A., Bringezu, S., Hammond, A., Moriguchi, Y., Rodenburg, E., Rogich, D.and Schütz, H. 1997. *Resource Flows: The material basis of industrial economies*. World Resources Institute, Washington DC, USA.

Akuffo, S.B. 2000. 'Urban Sanitation – a problem for professionals'. Newspaper article in the *Metro News, Daily Graphic* March 20, 2000, p. 14.

Ali, M. 1997. 'Understanding Solid Waste in Low-income Economies of Asia'. *Warmer Bulletin*, 54:14-15.

Alimi, F.G. 2000. 'AMA can't pay bills'. Newspaper article in the *Statesman*, March 12, 2000.

Allison, M., Harris, P.J.C., Hofny-Collins, A.H. and Stevens, W. 1998. *A Review of Urban Waste in Peri-Urban Interface Production Systems*. The Peri-Urban Interface Production Systems, NRI/ODA, ODA The Henry Doubleday Research Association, Coventry, UK.

Alsop, R. and Farrington, J. 1998. 'Nests, Nodes and Niches: a system for process monitoring, information exchange and decision making for multiple stakeholders'. *World Development*, 26(2):249-260.

Altieri, M.A. 1987. *Agroecology: the scientific basis of alternative agriculture*. Westview/ITP, London, UK.

AMA. 1994. *Managing the Sustainable Growth of Accra; an environmental profile of Accra Metropolitan Area*. July 1994. Prepared by Consortium (CIHSD) in collaboration with Engman and Amozu on behalf of the Government of Ghana with assistance from UNCHS (Habitat).

Amanor, K. and Annan, J. 1999. Linkages between Decentralisation and Decentralised Cooperation in Ghana. ECDPM Discussion Paper No. 9. European Centre for Development Policy Management, Maasticht, The Netherlands.

Anku, S.E.K. 1997. Solid Waste Management Policies and Strategies in Ghana: a position paper. Environmental Protection Agency, Accra, Ghana.

Anku, S.E.K., 1998. Sanitation Bye-Laws and the Regulatory Environment in Ghana. Paper presented at private sector solid waste management forum, Novotel Accra, 15th April 1998. Environmental Protection Agency, Accra, Ghana.

Appiahene-Gyamfi, J. 2002. 'An analysis of the broad crime trends and patterns in Ghana'. *Journal of Crime and Justice,* 30:1-15.

Argenti, O. 1996. 'Approvisionment et distribution alimentaries des villes de l'Afrique francophone'. Seminaire sous-regional. FAO, Rome.

Argyris, C. and Schön, D. 1974. *Theory in Practice: Increasing Professional Effectiveness*. Jossey-Bass, San Fransisco, USA.

Argyris, C. and Schön, D. 1996. Or*ganisational Learning II:Theory, Method and Practice*, Organisational Development Series. Addison-Wesley Publishing Company, New York.

Armar-Klemesu, M. and Maxwell, D. 1998. *Urban Agriculture in the Greater Accra Metropolitan Area*. Final Report to IDRC. Nutrition Unit, Noguchi Memorial Institute for Medical Research, University of Ghana, Legon, Ghana.

Asenso-Okyere, W.K., Osei-Akoto, I., Anum, A. and Appiah, E.N. 1997. 'Willingness to Pay for Health Insurance in a Developing Economy. A pilot study for the informal sector of Ghana using contingent valuation'. *Health Policy,* 42:223-237.

Ashby, W.R. 1956. *Introduction to Cybernetics*. Wiley, Cirenchester, UK.

Asomani-Boateng, R. and Furedy, C. 1996. 'Community Composting in West Africa'. *Biocycle*, January 1996:70-71.

Asomani-Boateng, R. and Haight, M. 1999. 'Reusing Organic Solid Waste in Urban Farming in African Cities: a challenge for urban planners', pp. 138-154. In: Smith O.B. (ed.). *Urban Agriculture in West Africa: Contributing to food security and urban sanitation*. IDRC, Ottawa, Canada.

Attahi, K. 1999. Abidjan, Côte d'Ivoire, Chapter 2. In: Onibokun, A.G. (ed.). *Managing the Monster; Urban Waste and Governance in Africa*. IDRC, Ottawa, Canada.

Atta-Krah, A.N. 1994. 'Linking Researchers and Farmers through Developmental On-farm Research, pp. 235-238. In: Scoones, I. and Thompson, J. (eds.). *Beyond Farmer First; Rural people's knowledge, agricultural research and extension practice*. IT Publications, UK.

Awal, I., 1999. 'Population Explosion: the bane of Accra'. Newspaper article in *The Daily Graphic*, July 5 1999. Accra.

Bailey, K.D. 2000. 'Towards Unifying Science: Applying concepts across disciplinary boundaries'. *Systems Research and Behavioural Science*, 18:41-62.

Baird, J., Hutton, M., Savage, A., Hipkin, A., Cruz, P. and MacLeod, I. 2005. *The Use of Stabilised Biowaste in the Restoration of Former Landfill Sites*. Scottish Environmental Protection Agrncy. (http://www.scottland.gov.uk/Publications/2005/06/1483953/39542)

Baker, A. 1997. 'Waste Management in Mali'. *Warmer Bulletin,* 57:16-17.

Barrientos, C. 1989. 'Recycling of Domestic Waste in Guatemala City; a case study with neighbourhood participation'. *Gate*-GTZ, 3:11-14.

Baskerville, G. L. 1995. 'The Forestry Problem: Adaptive lurches of renewal', Ch. 2, pp.37-102. In: Gunderson, L.H., Holling, C.S. and Light, S.S. (eds.). *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Columbia University Press, New York, USA.

Basler, A. 1995. 'Vegetable production in peri-urban areas in the tropics and subtropics. Food, income and quality of life'. Workshop Report. *Fruits*, Vol. 50(4):311-317.

Bateson, G. 1972. *Steps to an Ecology of Mind*. Jason Aronson, Northvale, NJ, USA.

Bateson, G. 1979. *Mind and Nature: a necessary unit*. Wildwood House, London, UK.

Batley, R. 2001. 'Public-private partnership for urban services', pp.199-214. In: Freire, M. and Stren, R (eds.). *The Challenge of Urban Government; Policies and Practices*. The World Bank, Washington DC, USA.

Bawden, R. 1991a. 'Systems Thinking and Practice in Agriculture'. *Journal of Dairy Science,* 74:2362-2373.

Bawden, R. 1991b. *On Systemics and Farming Systems Research:* A Critique. Presented at Workshop on " Implications of FSRE in the Indian Context". National Academy of Agricultural Research Management, Hyderabad. November 1991.

Bawden, R. 1995. 'On the Systems Dimension in FSR'. *Journal of Farming Systems Research-Extension,* 5(2):1-18.

*Beall, J. 1997.* 'Social capital in waste – a solid investment?' *Journal of International Development, Vol. 9(7): 951-961.*

Beall, J. 2000. 'From the Culture of Poverty to Inclusive Cities: Re-framing urban policy and politics'. *Journal of International Development*, 12:843-856.

Beer, S. 1959. *Cybernetics and Management*. English University Press, Oxford, UK.

Beernaerts, I. 2000. Wastewater Irrigation for safe Vegetable Production in Accra Metropolitan Area. Poster presented at the 'International Workshop on Urban and Peri-Urban Agriculture', FAO/AMA, Accra, August 1999.

Bell, S. 1998. 'Self-reflection and Vulnerability in Action Research: Bringing fourth new worlds in our learning'. *Systemic Practice and Action Research*, 11(2):179-191.

Benneh, G., Songsore, J., Nabila, J.S., Amuzu, A.T., Tutu, K.A., Yangyuoru, Y. and McGranahan, G. 1993. *Environmental Problems and the Urban Household in the Greater Accra Metropolitan Areas (GAMA) – Ghana*. Stockholm Environment Institute, Stockholm, Sweden.

Berger, P. and Luckmann. T. 1967. *The Social Construction of Reality. a treatise in the sociology of knowledge*. Harvard University Press, Cambridge MA.

Berkes, F. 2001. 'Building Capacity to adapt to change'. In: Berkes, F., Colding, J. and Folke, C. (eds.). *Navigating Nature's Dynamics: Building Resilience for Adaptive Capacity in Social-Ecological Systems*. Cambridge University Press, Cambridge, UK.

Berkes, F. and Folke, C. 1998. 'Linking Social and Ecological Systems for Resilience and Sustainability', Ch.1. In: Berkes, F., Folke, C. and Colding, J. (eds.). *Linking Social and Ecological Systems: Management practices and social mechanisms for building resilience.* Cambridge University Press, UK.

Berkes, F., Colding, J. and Folke, C. 2000. 'Rediscovering of Traditional Ecological Knowledge as Adaptive Management'. *Ecological Applications*, 10(5):1251-1262.

Bertalanffy, L. von 1950. 'The Theory of Open Systems in Physics and Biology'. *Science*, 111:23-29.

Bertalanffy, L. von 1956. 'General Systems Theory'. *General Systems Yearbook*, 1:1-10.

Bertalanffy, L. von 1968. *General Systems Theory*. Penguin, London, UK.

Biggs, S. 1989. *Resource Poor Farmers Participation in Research: a synthesis of experience from nine national agricultural research systems*. OFCOR Comparative Study Paper No. 3, ISNAR, The Hague.

Biggs, S. 1995. *Participatory Technology Development; a critique of the new orthodoxy*. AVOCADO series 06/95. Olive Organisation Development and Training, Durban, South Africa.

Birley, M.H. and Lock, K. 1998. Health and peri-urban natural resource production. Proceedings of the Internet Conference on Integrated Bio-Systems. (http://www.ias.unu.edu/proceedings/icibs/)

*Bohrt, J.P. 1993. Urban agriculture in Latin America: record, capacities and opportunities. CFP Report Series* No 7. IDRC, Canada.

Böhrt, J.P. 1994. 'Working with waste in Latin America'. *ILEIA Newsletter*, December 1994:21.

Boulding, K. 1956. 'General Systems Theory: the skeleton of science'. *Management Science*, 2:127-208.

Bowler, I.R. 1999. 'Recycling Urban Waste on Farmland: an actor-network interpretation'. *Applied Geography*, 19:29-43.

Brady, N.C. (1984). *The Nature and Properties of Soil*. MacMillan, New York, USA.

Briggs, J. and Yeboah, I.E.A. 2001. 'Structural Adjustment and the Contemporary sub-Saharan African City'. *Area*, 33(1):18-26.

Brock, B 1999. 'Actual and Potential Contribution of Urban Agriculture to Environmental Sanitation: a case study in Cotonou'. In: Smith, O.B. (ed.). Urban Agriculture in West Africa – contributing to food security and sanitation. CRDI and CTA, Canada and Netherlands.

Bronte-Stewart, M. 1997. 'Using Diagrams and Muller-Merbach's Framework to Teach Systems Theory'. *Systemist*, 19(3):174-186.

Bruntland, G. (ed.) 1987. *Our Common Future: The World Commission of Environment and Development*. Oxford University Press, UK.

BS4156, 1990, UK standard nutrient extraction.

Businelli, M., Gigliotti, G. and Giusquiani, P.L. 1996. 'Trace Element fate in Soil Profile and Corn Plant after Massive Applications of Urban Waste Compost: a six-year study'. *Agrochimica*, Vol.XL(4):145-152.

Byrelee, D.K. and Collinson, M.P. 1980. *Planning Technologies Appropriate to Farmers: Concepts and Procedures*. CIMMYT, Mexico.

Byrelee, D.K., Harrington, L. and Winkleman, D.L. 1982. 'Farming Systems Research: Issues in research strategy and technology design'. *American Journal of Agricultural Economics*, 64(5):897-904.

Byrne, R. 1995. Community co-operation on waste collection. *Warmer Bulletin*, 45:18.

Campbell, C.L. and Heck, WW. 1997. 'An Ecological Perspective on Sustainable Development', pp. 47-66. In: Munchett, F.D. (ed.) *Principles of Sustainable Development*. St. Lucie Press, Delray Beach, Florida.

Capra, F. 1996. *The Web of Life*. Harper Collins, London, UK.

Carr, W. and Kemmis, S. 1986. *Becoming Critical: Education, Knowledge and Action Research*. Falmer Press, London, UK.

Cencosad. 1994. Urban market Gardens in Accra. Accra: Center for Community Studies, Action and Development, and Mega Cities Project.

Chambers, R. 1983. Rural Development: Putting the last first. Longmans, London, UK.

Chambers, R. and Ghildyal, B.P. 1985. 'Agricultural Research for Resource Poor Farmers: the farmer first and last model'. *Agricultural Administration and Extension*, 20:1-30.

Chambers, R. and Jiggins, J. 1986. 'Agricultural Research for Resource Poor Farmers: a parsimonious paradigm'. *IDS Discussion Paper* 220, Brighton, UK.

Chambers, R., Pacey, A. and Thrupp, L.A. (eds.). 1989. *Farmer First; Farmer Innovation and Agricultural Research*. IT Publications, UK.

Chaney, R.L. and Giordano, P.M. 1977. 'Microelements as related to plant deficiencies and toxicities', pp.234-279. In: Ellot, L.F. and Stevenson, F.J. (eds.) *Soils for Management of Organic Wastes and Wastewaters*. American Society of Agronomy, Madison, Wisconsin, USA.

Checkland, P.B. 1981. *Systems Thinking, Systems Practice*. John Wiley & Sons, Chichester, UK.

Checkland, P.B. 1988. 'Images of Systems and the Systems Image'. *Journal of Applied Systems Analysis*, 15:37-43.

Checkland, P.B. 1994. 'Systems Theory and Management Thinking'. *American Behavioral Scientist*, 38(1):75-91.

Checkland, P.B. 2000. 'Soft Systems Methodology: a thirty-year retrospective'. *Systems Research and Behavioural Science*, 17:11-58.

Checkland, P.B. and Holwell, S. 1998. 'Action Research: its nature and validity'. *Systemic Practice and Action Research*, 11(1):9-17.

Checkland, P.B. and Scholes, J. 1990. *Soft Systems Methodology in Action*. John Wiley & Sons, Chichester, UK.

Chilliers, P. 1995. 'Postmodern Knowledge and Complexity (or why anything does not go)'. *South African J. of Philospohy*, 14(3):124-132.

Churchman, C.W. 1968. *The Systems Approach*. Dell, New York, USA.

Churchman, C.W. 1971. *The Design of Inquiring Systems*. Basic Books, New York, USA.

Churchman, C.W. 1979. *The Systems Approach and its Enemies*. Basic Books, New York, USA.

Ciavatta, C., Govi, M., Simoni, A. and Sequi, P. 1993. 'Evaluation of Heavy Metals during Stabilization of Organic Matter in Compost Produced with Municipal Solid Wastes'. *Bioresource Technology*, 43:147-153.

Clairon, M. 1979. *Etude des possibilities d'utilisation agronomique des composts d'ordures menagwrs en milieu tropical.* Rapport de fin de rccherche. Station d'Agronomie INRAAG, Domaine Dulcos, 97170 Petit-Bourg, Guadeloupe.

Cohen, M. 2001. 'The Impact of the Global Economy of Cities', pp. 5-17. In: Freire, M. and Stren, R (eds). *The Challenge of Urban Government; Policies and Practices*. The World Bank, Washington DC, USA.

Collins, M.A. 1999. *The Potential of User and Stakeholder Participation in the Design and Configuration of Telecommunications Infrastructure in Rural Jamaica: a preliminary investigation*. Ph.D. Thesis, Department of Engineering, Warwick University, UK.

Collinson, M. and Lightfoot, C. 2000. 'The Future of Farming Systems Research', Ch 12. In: Collinson, M (ed). *A History of Farming Systems Research*. CABI Publishing, Wallingford, UK.

Conway, G. 1985. 'Agroecosystem Analysis'. *Agricultural Administration*, 20:31-55.

Conway, G. 1990. 'Agroecosystems'. In: Jones, J.G.W. and Street, P.R. (eds.). *Systems Theory Applied to Agriculture and the Food Chain*. Elsevier Applied Science Publications, New York.

Conway, G.R., 1994. 'Sustainablilty in Agricultural Development: trade-offs between productivity, stability and equitability'. *Journal of Farming Systems Research-Extension*, 4(2):1-14.

Cooke, G.W. 1975. *Fertilizing for Maximum Yield*. Granada Publishing, UK

Cornish, G.A., Mensah, E. and Ghesquire, P. 1999. Water Quality and Peri-urban Irrigation: an assessment of surface water quality for irrigation and its implications for human health in the peri-urban zone of Kumasi, Ghana. Report OD/TN 95, September 1999, HR Wallingford Ltd, Wallingford, UK. 44pp.

Cornwall, A., Guit, I. and Welbourn, A. 1994. 'Acknowledging Process: Challenges for agricultural research and extension methodology'. In: Scoones, I. and Thompson, J. (eds.). *Beyond Farmer First; Rural people's Knowledge, Agricultural Research and Extension Practice*. IT Publications, UK.

Cornwall, A., I. Guijt, I. and A. Welbourn, A. 1993 Acknowledging Process: Challenges for agricultural research and extension methodology. *IDS Discussion Paper* 333. IDS. Brighton.
Dalzell, H.W., Biddlestone, A.J., Gray, K.R. and Thurairajan, K. 1987. Soil Management: Compost production and use in tropical and Sub-tropical Environments. *FAO Soils Bulletin 56*, Soil Resources, Management and Conservation Service, FAO Land and Water Development Division.
Deelstra, T. 1989. 'Can cities survive? Solid waste management in urban environments'. *AT Source*, Vol.18(2):21-27.
Denzin, N. and Lincoln, Y. (eds.) 2000. *Handbook of Qualitative Res*earch. Thousand Oaks, CA.
DFID, 2000 Urban Waste and Soil Management: Improving access and opportunities in Hubli-Dharwad, India. DFID Natural Resources Systems Programme, UK.
DFID/AMA. 1998. Public Health Project 1998-2000. Unpublished Document.
DHV Environment and Infrastructure. 1997. *Composting in the European Union*. DHV, Amersfoort, The Netherlands.
Diaz, L.F. 1997. 'Managing Solid Wastes in Marginal Areas'. *Biocycle*, June 1997:52.
Dick, *B. 1993. You Want to do an Action Research Thesis? How to conduct and report action research*. Interchange, Brisbane, Australia.
Dixon, J., Gulliver, A. and Gibbon, D. 2001. *Farming Systems and Poverty: Improving farmers' livelihoods in a changing world*. FAO and World Bank, Rome and Washington.
Dozeyem, J.K. 1998. 'Urban Food and Distrubution Systems in Ghana'. In: Sackey, D. (ed.) 1998. A Report on the National Seminar on Food Supply and Distribution Systems. AMA & FAO., Accra, Ghana.
Drakakis-Smith, D. 1992. 'Strategies for Meeting Basic Food Needs in Harare', pp. 258-283. In: Baker, J. and Pederson, P.O. (eds.). *The rural-urban interface in Africa: expansion and adaptation*. Scandinavian Institute for African Studies, Uppsala, Sweden.
Drakakis-Smith, D., Bowyer-Bower, T. and Tevera, D. 1995. 'Urban Poverty and Urban Agriculture: an overview of the linkages in Harare', pp. 183-194. In: Drakakis-Smith, D. (guest editor). *Urban agriculture and cities in the developing world*, Habitat International. Special issue,Vol.19(2).
Drechsel, P. 1996. 'Applied research for peri-urban areas'. *IBSRAM Newsletter*, No. 42:5-7.
Drinkwater, M. 1994. 'Knowledge, Power and Agriculture; towards a theoretical understanding'. In: Scoones, I. and Thompson, J. (eds.). *Beyond Farmer First; rural people's knowledge, agricultural research and extension practice*. IT Publications, UK.
Dzomeku, B.M. and Enu-Kwesi, L. 1997. 'Ecological Study of a Section of the Accra Plains'. *UNEP Desertification Control Bulletin*, 31:24-29.
Edwards, J.H., Walker, R.H., Burt, E.C. and Raper, R.L. 1995 'Issues Affecting Application of Non Composted Organic Waste to Agricultural Land', Chapter 11. In: Karlen, D.L., Wright, R.J. and Kemper, W.O. *Agricultural Utilization of Urban and Industrial By-Products*. ASA Special Publication No 58. American Society of Agronomy Inc. Winsconsin, USA.
Egziabher, A.G. 1994. 'Urban Farming Cooperatives and the Urban Poor in Addis Ababa', pp. 85-104. In: Egziabher, A.G., Lee-Smith, D., Maxwell, D.G., Memon, P.A., Mougeot, L.J.A. and Sawio, C.J. (eds.). *Cities Feeding People; an examination of urban agriculture in East Africa.* IDRC, Canada.
Eitrem, G. and Törnqvist, A. 1997. Recycling urban waste for agriculture: creating the linkages organic household waste for agriculture. A study prepared for RVD, World Bank, Washington D.C., U.S.A.
Ellis, F. and Sumberg, J. 1998. 'Food Production, Urban Areas and Policy Responses'. *World Development*, 26(2):213-225.
Engel, P. 1995. *Facilitating Innovation: An Action-oriented Approach and Participatory Methodology to Improve Innovative Social practice in Agriculture*. PhD. Dissertation, Agricultural University of Wageningen, Netherlands.
Engel, P. 1997. *The Social Organization of Innovation: A focus on stakeholder interaction*. Royal Tropical Institute, Netherlands.

Engel, P., Salomon, M. and Fernandez, M. 1994. *Strategic Diagnosis for Improving Performance in Extension, RAAKS Manual,* Version 5.0, Wageningen, Netherlands.
Environmental Systems Reviews No 33. 1993. Environmental Systems Information Center, Asian Institute of Technology, Bangkok, Thailand.
Erenstein, O. 1990. *On-Farm Research: A review of the concepts and practices*. M.Sc. dissertation. Department of Tropical Crop Science, Agricultural University of Wageningen, Netherlands.
Euroconsult 1989. *Agricultural Compendium: For Rural Development in the Tropics and Subtropics*. Elsevier, Amsterdam, The Netherlands.
European Environment Agency, 2005. Municipal Waste Generation (CSI 016) – May 2005 assessment. (http://themes.eea.eu.int)
Farnworth, C.R. and Jiggins, J. 2003. Participatory Plant Breeding and Gender Analysis. CGIAR/PRGA Participatory Plant Breeding Monograoh No. 4. PRGA. CIAT. Cali, Colombia.
Farrington, J. (ed.) 1988. *Experimental Agriculture*, 24(3):269-342. Special issue on farmer participatory research.
Farrington, J. and Martin, A. 1988. 'Farmer Participation in Agricultural Research: a review of concepts and recent work'. *Agricultural Administration and Extension*, 29:247-264.
Fekade, W. 2000. 'Deficits of Formal Urban Land Management and Informal Responses under rapid Urban Growth, and International Perspective'. *Habitat International*, 24:127-150.
Flood, R.L. 1990a. *Liberating Systems Theory*. Plenum Press, New York, USA.
Flood, R.L. 1990b. 'Liberating Systems Theory: Toward Critical Systems Thinking'. *Human Relations*, 43(1):49-75.
Flood, R.L. 1999. *Rethinking the Fifth Discipline: Learning with the unknowable*. Introduction. Routhledge, London, UK.
Flood, R.L. and Jackson, M. 1993. *Creative Problem Solving: Total System Intervention*. Wiley, New York, USA.
Flynn-Dapaah, K. 2001. 'Land Negotiations and Tenure Relationships: Accessing land for urban and peri-urban agriculture in Sub-Saharan Africa'. *CFP Report Series* No 36. IDRC, Ottawa, Canada.
Fobil, J.N. 2000. Mu*nicipal Solid Waste Charecterization for Intergrated Management in the Accra Metropolis*. M.Phil Thesis, submitted to the Env Science Programme, University of Ghana.
Folke, C., Pritchard, L. Jr., Berkes, F., Colding J. and Svedin, U. 1998. *The Problem of Fit between Ecosystems and Institutions*. IHDP Working Paper No.2. International Human Dimensions Program on Global Environmental Change, Bonn, Germany.
Forrester, J.W. 1961. *Industrial Dynamics*. MIT Press, Cambridge, AM.
Fred-Mensah, B.K. 1999. 'Capturing Ambiguities: Communal conflict management alternative in Ghana'. *World Development,* 27(6):951-965.
Freeman, D.B. 1991. *A City of Farmers: Informal urban agriculture in the open spaces of Nairobi, Kenya*. McGill-Queen's University Press, Montreal and Kingston, Canada.
Freeman, D.B. 1993. 'Survival Strategy or Business Training Ground? The significance of urban agriculture for the advancement of women in African cities'. *African Studies Review*, 35(3):1-22.
Freire, M. 2001. 'The Challenges of Urban Government', Introduction. In: Freire, M. and Stren, R. (eds.). *The Challenges of Urban Government: policies and practices*. WBI Development Studies. The World Bank, Washington DC, USA.
Furedy, C. 1992. *Solid waste management: exploring non-conventional options in Asian cities*. Paper presented at the International Workshop 'Planning for Sustainable Development - Cities and Natural Resource Systems in Developing Countries', 13-17 July, Cardiff, UK.
Furedy, C., Maclaren, V., and Whitney, J. 1999. 'Reuse of Waste for Food Production in Asian Cities: Health and economic perspectives'. In: Koc, M., MacRae, R. Mougeot, L.J.A. and Welsh J (eds.). *For Hunger-proof Cities; Sustainable urban food systems*. IDRC, Ottawa, Canada.

Furedy, C., V. Maclaren and J. Whitney. 1997. *Food from Waste: Urban pressures and opportunities for food production in Asian cities*. International Conference on Sustainable Urban Food Systems, Ryerson Polytechnic University, 22-25 May, Toronto, Canada.

Gebre-Egziabher, A. 1996. 'Understanding Urban Survival Strategies: urban agriculture, the ultimate stage in household survival'. *UNCHS Habitat Debate*, 2(2):21-22.

Ghana Statistical Service (GSS), 1987. 1984 Population Census of Ghana; Demographic and Economic Characteristics Report. Ghana Statistical Service, Accra.

Ghana Statistical Service (GSS), 1995. Analysis of Demographic Data, Volume 1; Preliminary Analysis Reports.

Ghana Statistical Service (GSS), 1998. Core Welfare Indicators Questionaire (CWIQ) Survey 1997. Report. Ghana Statistical Service, Accra.

Ghana Statistical Service (GSS), 2000a. Population and Housing Survey, provisional results. Report. Ghana Statistical Service, Accra.

Ghana Statistical Service (GSS), 2000b. Ghana Living Standards Survey; Report of the Fourth Round (GLSS4). Ghana Statistical Service, Accra.

Gilbert, A. and Gugler, J. 1992. *Cities, Poverty and Development: Urbanization in the third world.* 2nd edition. Oxford University Press, UK.

Gimble, R. and Wellard, K. 1997. 'Stakeholder Methodologies in Natural Resource Management: A review of principles, contexts, experiences and opportunities'. *Agricultural Systems*, 55(2):173-193.

Giradet, H. 1992. *The Gaia Atlas of Cities: New Directions of Sustainable urban Living*. Anchor Books, New York.

Giraut, F. 1997. 'Contemporary Dynamics in Small Towns in West Africa'. In: Baker, J. (ed). *Rural-Urban Dynamics in Francophone Africa*. Nordiska Afrikainstitutet, Uppsala, Sweden.

Gleick, J. 1987. *Chaos: Making a new Science.* Heinemann, London, UK.

Greenland, D.J., Wild, A. and Adams, D. 1992. "Organic Matter Dynamics in Soils of the Tropics – from myth to complex reality, Ch. 2, pp. 17-33. In: Lal, R. and Sanchez, P.A. (eds.). *Myth and Science of Soils in the Tropics*. Soil Science Society of America, Special Publication No. 29. Madison, WI, USA.

Guba, E.G. and Lincoln, Y.S. 1994. 'Competing Paradigms in Qualitative Research', Chapter 6. In: Denzin, N.K. and Lincoln, Y.S. (eds.). *Handbook of Qualitative Research*. Sage Publications.

Gubbels, P. 1997. 'Strengthening Community Capacity for Sustainable Agriculture'. In: Van Veldhuizen, L., Waters-Bayer, A., Ramirez, R., Johnson, D.A. and Thompson, J. (eds.). *Farmers' Research in Practice; Lessons from the field*. IT Publications, London, UK.

Guijt, I. 1996. *Participation in Natural Resource Management; Blemished past or hopeful future?* Unpublished paper presented at OFI forest policies that work course, July 1996.

Gunderson, L.H. 1999. 'Resilience, Flexibility and Adaptive Management - antidotes for spurious certitude?' *Conservation Ecology, 3(1):7*. (http://www.consecol.org/vol3/iss1/art7)

Gunderson, L.H., Holling, C.S. and Light, S.S. (eds.). 1995. *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Columbia University Press, New York, USA.

Habermas, J. 1984a. *The Theory of Communicative Action*, *Vol.1: Reason and the rationalising society.* Polity Press, Cambridge, UK.

Habermas, J. 1984b T*he Theory of Communicative Action, Vol.2: The critique of functionalist reason.* Polity Press, Cambridge, UK.

Haddad, L., Ruel, M.T. and Garrett, J.L. 1999. 'Are Urban Poverty and Undernutrition Growing? Some newly assembled evidence'. *World Development*, 27(11):1891-1904.

Hagmann, J. and Chuma, E. 2002. 'Enhancing the Adaptive Capacity of the Resource Users in Natural Resource Management'. *Agricultural Systems,* 73:23-39.

Harris P.J.C. and Smith G. 1997. *The Use of Composted Urban Wastes in Integrted Management Systems to Control Pests and Pathogens in peri-urban Agriculture*. Technical Report. HDRA, Ryton-on-Dundmore, UK.

Harris, P.J.C., Lloyd, H.D., Hofny-Collins, A.H., Barrett, H.R. and Browne, A.W. 1997. *Organic agriculture in sub-Saharan Africa: farmer demand and potential for development, a study to inform policy*. Report prepared by HDRA for DFID, UK.

HDRA 1998. Researching the Use of Compost in Agriculture; Report of work for 1997. HDRA Consultants Ltd. UK.
HDRA 1999. Researching the Use of Compost in Agriculture; Report of work for 1998. HDRA Consultants Ltd. UK.
HDRA Consultants Ltd, 1999. Guidelines for the Compost Analysis and Testing Service (CATS). Internal working document, Ryton-on-Dunsmore, UK.
Heckrath, G.J. 1998. *Phosphorus Accumulation and Leaching in Clay Loam Soils of the Broadbalk Experiment*. PhD Dissertation Agrarwissenschaftlichen Fakultät der Christian-AlbrechtsUniversität zu Kiel.
Heimlich, R.E. 1989. *Landuse Transition in Urbanising Areas*. Proceedings of a workshop, ERS/USDA, Washington DC, USA.
Helmore, K. and Ratta, A. 1995. 'The surprising Yields of Urban Agriculture'. *Choices; The human development magazine*, 4(2):22-26.
Heron, J. 1996. *Cooperative Inquiry: Research into the human condition*. Sage, London, UK.
Hildebrand, P.E. and Poey, F. 1985. *On-farm Agronomic Trials in Farming Systems Research and Extension*. Lynne Reiner Publ. Boulder.
Hinchcliffe, F., Thompson, J., Pretty, J., Guijt, I. and Shah, P. 1999. *Fertile Ground: The impacts of participatory watershed management*. IT Publications, London, UK.
Hogg, D., Barth, J., Favoino, E., Centemero, M., Caimi, V., Amlinger, F., Devliegher, W., Brinton, W. and Antler, S. 2002. *Comparison of Compost Standards within the EU, North America and Austalasia*. Main Report. The Waste and Resources Action Programme (WRAP), Banbury, UK.
Hoitink, H.A.J., Stone, A.G. and Han D.Y. 1997. 'Suppression of Plant Diseases by Composts'. *Horticultural Science*, 32(2):184-187.
Holland, D. and Silva, C. 2000. Learning to Participate; Agricultural research communities and farming communities face the same challenges. Paper presented at ALARPM/PAR Congress, University of Ballarat, Australia.
Holland, J. and Blackburn, J. (eds.). 1998. *Whose voice? Participatory research and policy change*. IT Publications, UK.
Holling, C.S. (ed.). 1978. *Adaptive Environmental Assessment and Management*. John Wiley and Sons, London, UK.
Holling, C.S. 1995. 'What barriers? What bridges?' Chapter 1, pp. 3-34. In: Gunderson, L.H., Holling, C.S. and Light, S.S. (eds.). B*arriers and Bridges to the Renewal of Ecosystems and Institutions*. Columbia University Press, New York, USA.
Holling, C.S., Berkes, F. and Folke, C. 1998. 'Science, Sustainability, and Resource Management', Ch.13, pp.342-362. In: Berkes, F. and Folke, C. (eds.). *Linking Social and Ecological Systems: Management practices and social mechanisms for building resilience*. Cambridge University Press, UK.
Holling. C.S. 1986. 'The Resilience of Terrestrial Ecosystems: Local surprise and global change', pp. 292-317. In: Clarke, W.E. and Munn, R.E. (eds.). *Sustainable Development of the Biospher.* Cambridge University Press, Cambridge, UK.
Holmberg, J., Bass, S. and Tibmerlake, L. 1991. *Defining the Future: A guide to sustainable development.* IIED/Earthchan, London, UK.
Honghai, D. 1992. *Urban Agriculture as Urban Food Supply and Environmental Protection Sub-systems in China*. Paper presented at the International Workshop 'Planning for Sustainable Development - Cities and Natural Resource Systems in Developing Countries', 13-17 July, Cardiff, UK.
Horton, R. 2001. 'Ghana: Defingng the African challenge'. *The Lancet*, 358:2141-2149.
Hubbard, M. and Onumah, G. 2001. 'Improving Urban Food Supply and Distribution in Developing Countries: The role of city authorities'. *Habitat International*, 25:431-446.
Hyatt, G.W. 1995. 'Economic, Scientific and Infrastructure basis for using Municipal Composts in Agriculture'. Chapter 3. In: Karlen, D.L., Wright, R.J. and Kemper, W.O. (eds.). *Agricultural Utilization of Urban and Industrial By-Products*. ASA Special Publication No 58. American Society of Agronomy Inc. Winsconsin, USA.
Iglesias-Jimenzes, E. and Alvarez, C.E. 1993. 'Apparent Availability of Nitrogen in Composted Municipal refuse'. *Biology and Ferility of Soils*, 16:313-31

Inglesias-Jimenez, E. and Garcia, V.P. 1992. 'Relationship between Organic Carbon and Total Organic Matter in Municipal Solid Wastes and City Refuse Composts'. *Bioresource Technology*, 41:265-272.
IRDC. 1998. 'Program initiative program summary 1997-2000'. *CFP Report Series* No. 22. IDRC, Ottawa, Canada.
Ishag, S.O., Al Fakie, O.H., Adam, M.A., Adam, Y.M., Bremer, K.W. and Mogge, M. 1997. 'Extension through Farmer Experimentation in Sudan'. In: Van Veldhuizen, L., Waters-Bayer, A., Ramirez, R., Johnson, D.A. and Thompson, J. (eds.). *Farmers' Research in Practice; Lessons from the field*. IT Publications, London, UK
Ison, R. L. and Russel D. 2000. *Agricultural Extension and Rural Development: Breaking out of traditions*. Cambridge University Press, UK.
Jackson, M.C. 1982. 'The Nature of 'Soft' Systems Thinking: the work of Churchman, Ackoff and Checkland'. *Journal of Applied Systems Analysis*, 9:17-29.
Jackson, M.C. 1985. 'Social Systems Theory and Practice: the need for a critical approach'. *International Journal of General Systems*, 10:135-151.
Jackson, M.C. 1987. 'New Directions in Management Science'. In: Jackson, M.C. and Keys, P. (eds.). *New Directions in Management Science*. Gower, Aldershot, UK.
Jackson, M.C. and Keys, P. 1984. 'Toward System of Systems Methodologies'. *Organization Studies*, 12:109-127.
Jacobi, P. 1997. *Importance of Vegetable Production in Dar es Salaam, Tanzania*. A report of the Urban Vegetable Promotion Project, Ministry of Agriculture and Co-operatives, and GTZ. Tanzania.
Jalan, J.K., Sushil, D., Srivastava, V.K. 1995. The Emerging Priority for Disposal, Use and Recycling of MSW in India. *Wastes Management,* April 1995: 17-18.
Jansen, H.G.P., Midmore, D.J., Binh, P.T., Valasayya, S. and Tru L.C. 1995. *Peri-urban Vegetable Production in Ho Chi Minh City, Vietnam.* Asian Vegetable Research and Development Center, Working Paper No. 11.
Jeannin, M. 1972. L'agriculture et les habitants Makelekele. pp. 19-46. In: *Dix etudes sur l'approvisionnement des ville*s. Bourdeaux, GEGET.
Johansson, C., Kron, E., Svensson, S.E., Carlsbæk, M. and Reeh, U. 1997. *Compost Quality and Potential for Use*. AFR report 154, Swedish Environmental Protection Agency.
Karki, A., Gautam, U., Gautam, K and Karki, A. 1997. 'Solid Waste Management in Kathmandu Valley'. *Warmer Bulletin*, Vol. 53:4-5.
Kasanga, K., Cochrane, J., King, R. and Roth, M. 1996. Land Markets and Legal Contradictions in the Peri-urban Area of Accra, Ghana; Interviews and secondary data investigation. Research Paper No. 127. Land Tenure Center, Madison,
Kemmis, S. and Taggart, R. (eds.) 1998. *The Action Research Planner*, third edition. Deakin University, Victoria, Australia.
Keraita, B.N. and Drechsel, P. 2004. 'Agricultural use of untreated urban wastewater in Ghana', Chapter 9. In: Scott, C., Faruqui, N.I. and Raschild, L. (eds.). *Wastewater Use in Irrigated Agriculture; Confronting the livelihood and environmental realities*. CABI/IWMI/IDRC, Ottawa, Canada.
King, C.A. 2000. *Systemic Processes for Facilitating Social Learning: Challenging the legacy*. Agraria 233, Doctoral Thesis, Department of Rural Development Studies, Swedish University of Agricultural Sciences, Uppsala, Sweden.
King, K. and McGrath, S. 1999. 'Africa's Urban Informal Economies: between poverty and growth'. In: Jones, S. and Nelson, N. (eds.). *Urban Poverty in Africa: from understanding to alleviation*. Intermedieta Technology Publications, UK.
Kironde, J.M.L. 1999. Dar es Salaam, Tanzania, Chapter 4. In: Onibokun, A.G. (ed.). *Managing the Monster; Urban waste and governance in Africa*. IDRC, Ottawa, Canada.
Koc, M., MacRae, R. Mougeot, L.J.A. and Welsh J (eds.) 1999. *For Hunger-proof Cities; Sustainable urban food systems*. IDRC, Ottawa, Canada.
Kolb, D. 1984. *Experiential Learning*. Prentice Hall, Hemel Hempstead, UK.
Konadu-Agyemang, K. 2001. 'A Survey of Housing Conditions and Characteristics in Accra, an African City'. *Habitat International*, 25:15-34.
Kramer, N.J. and de Smit, J. 1987. *Systeemdenken*. Stenfert Kroese, Leiden.

Kreibich, V. and Tamakloe, E.K.A. 1996. *The Growth Impact of Accra; an analysis of the rural-urban fringe and linkages in the north-east corridor of the Greater Accra Region*. Spring Research Series No 17, SPRING Center, University of Dortmund, Germany.
Kundu, N. 1995. 'Urban solid waste recycling through vegetable cultivation and rag picking – a study in Calcutta', pp. 233-238. In: R95 Congress Proceedings: Recovery, Recycling, Reintegration, Vol. 4, 1-3 Feb. 1995, Geneva.
Lado, C. 1990. 'Informal urban agriculture in Nairobi, Kenya'. *Land Use Policy*, 7/3:257-266.
Landin, C. 1994. 'Earthworms Earn their Credit'. *ILEIA Newsletter*, October 1994.
Larbi,W. O. 1996. 'Spatial Planning and Urban Fragmentation in Accra'. *Third World Planning Review*, 18(2):193-215.
Lardinois and van de Klundert 1994a. 'Recycling urban organics in Asia and Africa'. *Biocycle*, June 1994:56-58.
Lardinois, I. and Klundert van de, A. .1994b. 'Recovery of organic waste in cities'. *ILEIA Newsletter*, Oct/94:6-7.
Lee, K.N. 1993. *Compass and Gyroscope: Integrating Science and Politics for the Environment.* Washington Island Press, Washington DC, USA.
Lee-Smith, D. and Memon, P.A. 1994. 'Urban agriculture in Kenya'. In: Egziabher, A.G., Lee-Smith, D., Maxwell, D.G., Memon, P.A., Mougeot, L.J.A. and Sawio, C.J. (eds.). *Cities Feeding People; an examination of urban agriculture in East Africa.* IDRC, Canada.
Leita, L. and Nobili, M. 1991. 'Heavy metals in the environment; water-soluble fractions of heavy metals during composting of municipal solid waste'. *Journal of Environmental Quality*, 20:73-78.
Levin, C.E., Ruel, M.T., Morris, S.S., Maxwell, D.G., Armar-Klemesu, M. and Ahiadeke, C. 1999. 'Working Women in an Urban Setting: Traders, vendors, and food security in Accra'. *World Development,* 27(11):1977-1991.
Lewcock, C.P. 1994. Case study of the use of urban waste by near-urban farmers of Kano, Nigeria. Visit report 23 Jan - 7 March 1994; NRI, UK
Lewin, K. 1947. 'Frontiers in Group Dynamics'. *Human Relations*, 1:2-38.
Lewin, K. 1948. *Resolving Social Conflict*. Harper and Row, New York, USA.
Leybourne, S.L and Grant, M., 1999. 'Bottlenecks in the Informal Food-Transportation Network of Harare, Zimabwe'. In: Koc, M., MacRae, R. Mougeot, L.J.A. and Welsh J (eds.). *For Hunger-proof Cities; Sustainable urban food systems.* IDRC, Ottawa, Canada.
Long, N. and Long, A. (eds.) 1992. *Battlefields of Knowledge: The interlocking of theory and practice in social research and development*. Routledge, London, UK.
Lopez-Real, J.M. 1995. Visit to Dar es Salaam, Tanzania, December 1995. Report to Natural Resources Institute, Chatham, UK.
Luhmann, N. 1989. *Ecological Communication.* Polity Press, Cambridge.
Luhmann, N. 1990. 'The Autopoiesis of Social Systems'. In: Luhman N. *Essays on Self-reference*. Columbia University Press, New York.
Lyon, F. 2000. 'Trust, Networks and Norms: The Creation of Social Capital in Agricultural Economics in Ghana'. *World Development*, 28(4):663-681.
Maarleveld, M and Dangbégnon, C., 1999. 'Managing Natural Resources: A social learning perspective'. *Agriculture and Human Values*, 16:267-280.
MAFF 2000. Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209). 7th edition. Ministry of Agriculture, Food and Fisheries, UK.
Martin, A.M. and Sherington, J. 1997. 'Participatory Research Methods; Implementation, effectiveness and institutional context'. *Agricultural Systems*, 55(2):195-216.
Maruyama, M. 1963. 'The Second Cybernetics'. *American Scientist*, 51:164-179.
Marvil, J., Pinochet, J. and Rodriguez-Kabana, R. 1997. 'Agricultural and Municipal Composts Residues for Control of Root-knot Nematodes in Tomato and Peppers'. *Compost and Utilization,* 5(1): 6-15.
Massey, R. 1991. Re-using refuse in Benin. *Source*, Vol.3(1):24-27.
Mattingly, M., 1999. ' The role of the Government of Urban Areas in the Creation of Urban Poverty'. In: Jones, S. and Nelson, N.. *Urban Poverty in Africa: From understanding to Alleviation*. IT Publications, UK.

Maturana, H.R. and Varela, F.J. 1980. *Autopoesis and Cognition: The realisation of the living*. Reidel, Dordrecht.
Maturana, H.R. and Varela, F.J. 1987. *The Tree of Knowledge: The biological roots of human understanding*. Shambala Press, Boston.
Maturana, H.R. and Varela, F.J. 1992. *The Tree of Knowledge: The biological roots of human understanding*. Revised edition. Shambhala Press, Boston.
Maxwell, D. Larbi, W.O., Laptey, G.M., Zakariah, S and Armar-Klemesu, M. 1998. Farming in the Shadow of the City: Changes in land rights and livelihoods in peri-urban Accra. *CFP Report Series* No 23. IDRC, Canada.
Maxwell, D.G. and Zziwa, S. 1992. *Urban farming in Africa: the case of Kampala*. African Centre for Technology Studies, Nairobi.Kenya.
Maxwell, D.G. and Zziwa, S. 1993. 'Urban Agriculture in Kampala: Indigenous adaptive response to the economic crisis'. *Ecology of Food and Nutrition*, Vol.29:91-109.
Maxwell,D., Levin, C. and Csete, J. 1999. 'Does Urban Agriculture help Prevent Malnutrition? Evidence from Kampala'. *Food Policy,* 23(5):411-424.
May, J. and C.M. Rogerson. 1995. 'Poverty and sustainable cities in South Africa: the role of urban cultivation', pp. 165-182. In: Drakakis-Smith, D. (guest editor). *Urban agriculture and cities in the developing world*, Habitat International. Special issue,Vol.19(2).
Mbiba, B. 1995. *Urban Agriculture in Zimbabwe*. Avery Ashgate Publ. Ltd. Aldershot, England.
Meadows, D.H., Meadows, D.L. and Randers, J. 1992. *Beyond the Limits to Growth*. Ghelsea Green, Post Mills.
Medina, M. 1993. 'Collecting recyclables in Metro Manila'. *Biocycle*, June 1993:51-53.
Medina, M. 1997. 'Supporting scavenger co-ops'. *Biocycle*, June 1997:45-47.
Mettrick, H. 1993. *Development Oriented Research in Agriculture: an ICRA textbook*. ICRA, Wageningen, The Netherlands.
Midgeley, G. 2000. *Systemic Intervention: Philosophy, Methodology and Practice, contemporary systems thinking*. Kluwer Academic / Plenum Publ. New York, USA.
Midgley, G.1992. 'The Sacred and Profane in Critical Systems Thinking', *Systems Practice*, 5:5-16.
Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well Being; Synthesis*. Island Press, Washington DC.
Miller, J.G. 1978. *Living Systems*. McGraw-Hill, New York, USA.
Mingers, J.C. 1980. 'Towards an Appropriate Social Theory for Applied Systems Thinking: Critical theory and soft systems methodology'. *Journal of Applied Systems Analysis*, 7:41-50.
Mingers, J.C. 1984. 'Subjectivism and Soft Systems Methodology: a critique'. *Journal of Applied Systems Analysis,* 11:85-103.
Ministry of Food and Agriculture (MOFA) 1999. Gender and Agricultural Development Strategy. Unpublished working document for the Government of Ghana.
Morriniere, J.L. 1972. La region maraichere intra et peri-urbaine de Yaounde. pp 49-80. In: *Dix etudes sur l'approvisionnement des villes*. Bourdeaux, GEGET.
Mosha, A.C. 1991. 'Urban farming practices in Tanzania'. *Review of Rural and Urban Planning in S & E Africa*, 1/1991:83-92.
Mosse, D. 1993. Authority, Gender and Knowledge; Theoretical reflections on the practice of participatory rural appraisal. Network Paper No. 44. Agricultural Administration Network, ODI, London, UK.
Mougeot, L.J.A. 1994. 'African city farming from a world perspective'. In: Egziabher, A.G., Lee-Smith, D., Maxwell, D.G., Memon, P.A., Mougeot, L.J.A. and Sawio, C.J. (eds.). *Cities Feeding People; an examination of urban agriculture in East Africa.* IDRC, Canada.
Müller, M. 1983, Handbuch ausgewahter Klimastationen der Erde, Universität Trier. (http://www.stadtklima.de/cities/africa/accra)
Munsell. 1990. Soil Colour Charts. Balimore, USA.
Neumann, J. von 1966. *Theory of Self-Reproducing Automata*. Edited and completed by Author W. Burks. University of Illinois Press, USA.

Ngnikam, E., Vermande, P. and Rousseaux, P. 1993.Traitement des dechets urbains. Une unite de compostage des ordures menageres dans un quartier d'habitat spontane a Yaounde (Cameroun). *Cahiers Agricultures*, 2:264-269.
Norman, J.C. 1992. *Tropical Vegetable Crops*. Arthur H. Stockwell Ltd., Devon, UK.
Norton, A. 1995. Poverty Assessment in Ghana using Qualitative and Participatory Research mehods. *PSP Discussion Paper Series*, World Bank, Washington, USA.
Nunan, F. 2000. 'Urban organic waste markets: responding to change in Hublu-Dharwad, India', *Habitat International,* 24:347-360.
Nurah, G.K. 1999. A Baseline Study of Vegetable production in Ghana. Unpublished report within the National Agricultural Research project (NARP).
O'Meara, M. 2001. 'Exploring a new vision for Cities', pp. 337- 355. In: Freire, M. and Stren, R (eds.). *The Challenge of Urban Government; Policies and Practices*. The World Bank, Washington DC, USA.
Obeng, L.A., and Wright, F.W. 1987. The co-composting of domestic solid and human wastes. *World Bank Technical Paper* No. 57. UNDP Project Management Report No. 7, IBRD/World Bank.
Obirih-Opareh, N. and Post, J., 2002. 'Quality Assessment and Private Modes of Solid Waste Collection in Accra, Ghana'. *Habitat International.* 26:95-112.
Obosu-Mensah, K. 1999. *Food Production in Urban Areas; a study of UA in Accra, Ghana*. Ashgate, UK.
Obuobie, E. 2003. *Institutional Aspects of UA and Wastewater Use in Accra, Ghana*. MSc Thesis Wageningen University, Netherlands.
Obuobie, E., Danso, G. and Drechsel, P. 2003. 'Access to land and water for urban vegetable farming in Accra'. *Urban Agriculture Magazine,* 11:15-17.
Onibokun, A.G. (ed.) 1999. *Managing the Monster; Urban waste and governance in Africa*. IDRC, Ottawa, Canada.
Owusu, S.K. and Mensah, E.1998. Wastewater Irrigation in the Peri-Urban Communities in Ghana; A cse study in Accra and Kumasi. Project report, School of Engineering, University of Science and technology, Kumasi, Ghana.
Panjwani, N. 1985. *Citizen Organisations and Food Energy Alternatives in Indian Cities*. Food Energy Nexus Programme, United Nations University, Tokyo, Japan.
Pearce, D., Barbier, E. and Markandya, A. 1989. Sustainable Development and Cost benefit Analysis. *Env. Economics Discussion Paper* DP88-03, IIED, UK.
Pearson, C.J. and Ison, R.L 1997. Ag*ronomy of Grassland Systems*, 2nd Edition. Cambridge University Press, Cambridge, UK.
Pepper, D. 1986. *The Roots of Modern Environmentalism*. London. Routledge.
Perla, M. 1997. 'Community composting in developing countries'. *Biocycle*, June 1997:48-51.
Polprasert, C. 1996. *Organic Waste Recycling: Technology and management*. John Wiley and Sons Ltd, Chichester, UK
Powell, N. 1998. Co-management in Non-equilibrium Systems; Cases from Namibian rangelands. Doctoral Thesis, Department of Rural Development Studies, Swedish University of Agricultural Sciences, Uppsala, Sweden.
Pretty, J. 1995. *Regenerating Agriculture: Policies and practice for Sustainability and Self Reliance*. Earthscan Publications Ltd., London.
Pretty, J. 2000. 'Supportive Policies and Pracice for Scaling up Sustainable Agriculture', pp. 23-45. *In:* Röling, N.G. and Wagemakers, M.A.E (eds.). *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*. Cambridge University Press, Cambridge, UK.
Pretty, J. and Chambers, R. 1993. *Towards a Learning Paradigm: New Professionalism and the Institutions of Agriculture*. IDS Discussion Paper 334, Brighton, UK.
Pretty, J. and Shah, P. 1999. 'Soil and Water Conservation: A brief history of coercion and control', Ch. 1. In: Hinchcliffe, F., Thompson, J., Pretty, J. Guijt, I. and Shah, P. (eds.). *Fertile ground: The impacts of participatory watershed management*. IT Publications, London.
Pretty, J., Ball, A., Lang, T and Morison, J. 2005. 'Farm costs and food miles; an assessment of the full cost of the UK weekly food basket'. *Food Policy*, 30(1):1-19.

Rakodi, C. 1988. 'Urban Agriculture: research questions and Zambian evidence'. *Journal of Modern African Studies*, Vol.26:495-515.

Ravetz, J. 2000. 'Integrated Assessment for Sustainability Appraisal in Cities and Regions'. *Environmental Impact Assessment Review*, 20:31-64.

Reason, P. (ed.) 1994. *Participation in Human Inquiry*. Sage Publications, London, UK.

Reason, P. 1988. *Human Enquiry in Action: Developments in New Paradigm Research*. Sage, London, UK.

Reason, P. and Heron, J. 1995. 'Co-operative Enquiry'. In: Smith, J.A., Harré, R. and van Lagenhove, L. (eds.). *Rethinking Methods in Psychology*. Sage, London, UK.

Reijntjes, C., Haverkort, B. and Walters-Bayer, A. 1992. *Farming for the Future: An introduction to low-external-input and sustainable agriculture*. ILEIA, Netherlands.

Rogerson, C.M. 1993. 'Urban agriculture in South Africa: policy issues from the international experience'. *Development Southern Africa*, 10(1):33-44.

Röling, N.G. 1988. *Extension Science; Information Systems in Agricultural Development*. Cambridge University Press, Cambridge, UK.

Röling, N.G. 1990. 'The Agricultural Research-Technology Transfer Interface: a knowledge system perspective', Ch 1, pp. 1-42. In: Kaimowitz (ed.). *Making the Link: Agricultural Research and Technology Transfer in Developing Countries*. Westview Press, Boulder.

Röling, N.G. 1997. 'The Soft Side of Land: Socio-economic sustainability of land use systems'. *ITC Journal*, Nos. 3 and 4, Special congress issue, pp.248-262.

Röling, N.G. and Jiggins, J. 1998. 'The Ecological Knowledge System', Ch. 6, pp. 283-311. In: Röling, N.G. and Wagemakers, M.A.E. (eds.). *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*. Cambridge University Press, Cambridge, UK.

Röling, N.G. and Wagemakers, M.A.E. 1998. 'A New Pracice: Facilitating sustainable agriculture', Ch. I, pp. 3-22. In: Röling, N.G. and Wagemakers, M.A.E (eds.). *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty*. Cambridge University Press, Cambridge, UK.

Rosario, A. 1994. Solid waste management – decentralised approach. Paper presented at: 'In Local Hands', International conference on community based development at 4.8 July 1994, Falmer, Brighton, UK.

Russel, D.B. and Ison, R.L. 1991. *The Research-Development Relationship in Rangelands; An opportunity for contextual science*. Plenary Paper for 4th International Rangelands Congress, Montpellier, France.

Sackey, D. 1998. 'The role, policy constraints, action programmes and suggestions of the central and local authorities of Ghana in food supply and security in Accra'. In: Sackey, D. (ed.) 1998. A Report on the National Seminar on Food Supply and Distribution Systems. AMA & FAO., Accra, Ghana.

Sanchez, P.A. 1976. *Properties and Management of Soils in the Tropics*. Wiley, New York.

Sanio, M.R., Burack, D. and Siddiqui, S. 1998. *Program Framework for Progressive Action*; Phase 1 report. World Engineering Partnership for Sustainable Development. Unpublished internal document.

Sanyal, B. 1986. *Urban Cultivation in East Africa: People's response to urban poverty*. Food Energy Nexus Programme. United Nations University, Tokyo, Japan.

Sanyal, B. 1987. 'Urban cultivation amongst modernisation: how should we interpret it?' *Journal of Planning Education and Research*, 6(3):187-207.

Sawio C.J. 1994. Who are the farmers of Dar es Salaam, pp. 25-46. In: Egziabher, A.G., Lee-Smith, D., Maxwell, D.G., Memon, P.A., Mougeot, L.J.A. and Sawio, C.J. (eds.). *Cities Feeding People; an examination of urban agriculture in East Africa*. IDRC, Canada.

Sawio, C.J. 1993. Urban agriculture research in East and Central Africa: record, capacities and opportunities. *CFP, Report Series* No. 1. IDRC, Canada.

Schertenleib, R. and Meyer, W. 1992. Municipal Solid Waste Management in Developing Countries: Problems and issues; need for future research. *IRCWD News*, No. 26:2-8.

Schertenleib, R. and Meyer, W. 1993. 'Community Involvement in Municipal Solid Waste Management'. *Gate-GTZ,* 1/93:25-28.

Schön, D.A. 1983. *The Reflective Practitioner: How Professionals Think in Action*. Basic Books, New York, USA.

School of Public Policy, University of Birmingham; Centre for Arid Zone Studies, University of Wales, Bangor; and University of Agricultural Sciences and SDM College of Engineering and Technology, Dharwad, India. 1998. *Improved utilisation of urban waste by near-urban farmers in the Hubli-Dharwad city-region: Inception report*. School of Public Policy, University of Birmingham, UK.
School of Public Policy, University of Birmingham; Centre for Arid Zone Studies, University of Wales, Bangor; and University of Agricultural Sciences and SDM College of Engineering and Technology, Dharwad, India. 2000. *Urban Waste and Soil Management: Improving access and opportunities in Hubli-Dharwad, India*. DFID natural Resources Systems Programme, UK.
Schweitzer, F. 1989. Turning household waste into compost. *Gate/GTZ*, 3/89:14-16.
Scoones, I. and Thompson, J. (eds.) 1994. *Beyond Farmer First; Rural people's knowledge, agricultural research and extension practice*. Intermediate Technology Publications. London.
Seifert, R. 1992. 'Composting as a Municipal Responsibility'. *Gate/GTZ*, 3/89:15-17.
Senge, P.M. and Sterman, J.D. 1992. *Systems Thinking and Organisational Learning: Acting locally and thinking globally in the organisation of the future*. Elsevier Science Publications.
Shaner, W., Philipp, P. and Schmehl, W. 1982. *Farming Systems Research and Development: Guidelines for developing countries*. Westview Press, Boulder, CO.
Sheath, G.W. and Webby, R.W. 2000. 'The Results and Success Factors of a Farm Monitoring and Study Group Approach to Collective Learning in New Zealand'. In: Cerf, M., Gibbon, D., Hubert, B., Ison, R., Jiggins, J., Paine, M., Proost, J. and Röling, N. (eds.). *Cow up a Tree; Knowing and learning for change in agriculture, case studies from industrialised countries* INRA, Paris, France.
Shields, S. 1999. *A Feasibility Study of the Introduction of Processes and Quality Standards for Compost in the UK*. The Composting Association, HDRA, UK.
Shiralipour , A., McConnell, D.B. and Smith, W.H. 1992. 'Uses and Benefits of MSW Compost: A review and an assessment'. *Biomass and Bioenergy*, 3:3-4:267-28.
Shiva, V. 1989. *The Violence of the Green Revolution: Ecological degradation and political conflict in Punjab*. Dehra Dun Research Foundation for Science and Ecology, India.
Silverman, D. 1970. *The Theory of Organisations*. Heinemann, London, UK.
Simpson, M. 1993. 'Lapaks and Bandars convert MSW in Indonesia'. *Biocycle*, June 1993:78-80.
Skinner, W. 1981. 'Vegetable supply and marketing in Chinese cities', pp. 215-280. In: Plucknett, D.L. and Beemer, H.L. (eds.). *Vegetable Farming Systems in China*. Westview Press, Boulder, Colorado, USA.
Skyttner, L. 1998. 'The Future of Systems Thinking'. *Systemic Practice and Action Research*, 11(2):193-206.
SLIM 2004. Social Learning of the Integrated Management and Sustainable use of Water and Catchment Scale. Framework document. (http://slim.open.ac.uk)
SLIM Policy Briefing No.4 May 2004. Facilitation in Policy Processes: Developing new Professional Skills. (http://slim.open.ac.uk)
SLIM Policy Briefing No.6 May 2004. The Role of Learning Processes in Integrated Catchment Management and the Sustainable use of Water. (http://slim.open.ac.uk)
SLIM Policy Briefing No.7 May 2004. Guidelines for Capacity Building for Social Learning in Integrated Catchment Management and Sustainable use of Water. (http://slim.open.ac.uk)
Smit, J. and J. Nasr 1992. 'Urban Agriculture for Sustainable Cities: Using wastes and idle land and water bodies as resources'. *Environment and Urbanisation,* 4(2):42-61.
Smit, J., Ratta, A. and Nasr, J. 1996. *Urban Agriculture: Food, Jobs and Sustainable Cities*. UNDP, Habitat II Series, The Urban Agriculture Network (TUAN), Washington DC; USA.
Soil Association, The. 1999. *Standards for Organic Farming and Food*. The Soil Association, Bristol, UK.

Songsore, J. and McGranahan, G. 1993. 'Environment, Wealth an Health; Towards an analysis of intra-urban differentials within the Grater Accra Metropolitan Area, Ghana. *Environment and Urbanization*, 5(2):10-34.
Spedding, CRW. 1979. *An Introduction to Agricultural Systems*. Applied Science Publ., London, UK.
Steffen, W., Sanderson, A., Tyson, P.D., Jäger, J., Matson, P.A., Moore III, B., Oldfield, F., Richardson, K., Schellnhuber, H.J., Turner, B.L. and Wasson, R.J. (eds.) 2004. *Global Change and the Earth System; A Planet Under Pressure*. Executive Summary. Springer-Verlag, Berlin, Heidelberg, New York. (http://www.igbp.kva.se)
Stolzenbach, A. 1997. 'The craft of farming and experimentation'. In: Van Veldhuizen, L., Waters-Bayer, A., Ramirez, R., Johnson, D.A. and Thompson, J. (eds.). *Farmers' Research in Practice; Lessons from the field*. IT Publications, London, UK
Stöppler-Zimmer, H., Gottschall, R. and Bahlke, A. 1992. 'Kompost mit gütezeichen für Ihren wein und obstbau'. *Gartenbau-Betrieb*. Gütegemeinschaft Kompost Region Südwest. Köln, Germany.
Streiffeler, F. 1987. 'Improving Urban Agriculture in Africa: a social perspective'. *Food and Nutrition Bulletin*, 9(2):8-13.
Stren, R. 2001. 'Managing the Urban Environment; Editor's introduction', pp.329-336. In: Freire, M. and Stren, R (eds.). *The Challenge of Urban Government; Policies and Practices*. The World Bank, Washington DC, USA.
Tabatabai, H. 1988. 'Agricultural Decline and Access to Food in Ghana' *International Labour Review*, 127(6):703-734.
Tanner, P.D. and Murwira, L. 1984. 'Effectiveness of Communal Area Manures as Sources of Nutrients for Young Maize Plants'. *Zimbabwe Agricultural Journal,* 81:31-35.
Tenywa, J.S., Nyende, P., Kidoido, M., Kasenge, V., Oryokot, J. and Mbowa, S. 1999. 'Prospects and Constraints of Finger Millet Production in Eastern Uganda'. *African Crop Science Journal*, 7(4):569-583.
Toye, J. 1991. 'Ghana'. In: Moseley, P., Harrigen, J. and Toye, J. (eds.). *Aid and Power; The World Bank and policy-based lending*, vol. 2. Routledge, London, UK.
Tripp, R., Anandajayasekeram, P. Byerlee, D. and Harrington, L. 1990. 'Farming Systems Research Revisited'. In: Eicher, C.K. and Staatz, J.M. (eds.). *Agricultural Development in the Third World*. The Johns Hopkins University Press, Baltimore, USA.
Trist, E.L., Higgin, G.W., Murray, H. and Pollock, A.B. 1963. *Organisational Choice*. Travistock, London, UK.
Udas, K. 1998. 'Participatory Action Research as Critical Pedagogy'. *Systemic Practice and Action Research, 11(6):599-628.*
UESP, 1996. Urban Environmental Sanitation Project, Staff Appraisal Report. Internal Report No. 15089, Annex 9, pp. 1-8. Infrastructure and Urban Development Division, West Central Africa Department, Africa Regional Office, World Bank.
Ulrich W. 1987. 'Critical Heuristics of Social Systems Design'. *European Journal of Operational Research*, 31:276-283.
Ulrich, W. 1983. *Critical Heuristics of Social Planning: a new approach to practical philosophy*. Haupt, Berne.
Ulrich, W. 1988. 'Systems Thinking, Systems Practice and Practical Philosophy: a program of research'. *Systems Practice*, 1:137-163.
Ulrich, W. 1994. 'Can we Secure the Future; Responsive management through systems thinking and design?' *Interfaces*, 24:26-37.
Ulrich, W. 2001. 'The Quest for Competence in Systemic Research and Practice'. *Systems Research and Behavioural Science*, 18:3-28.
United States Environmental Protection Agency (USEPA), 2003a. Municipal solid waste generation, recycling and disposal in the United States; Facts and figures 2003. (http://www.epa.gov/osw)
United States Environmental Protection Agency (USEPA), 2003b. Environmental Regulations and Technology; Control of pathogens and vector attraction in sewage sludge. Ch 2 pp. 8-19. In: USEPA. *Sewage Sludge and Pathogens*. (http://www.epa.gov/osw)

Veldhuizen van, L, Walters-Bayer, A. and De Zeeuw, H. 1997. *Developing Technology with Farmers: a trainer's guide for participatory learning*. Zed Books Ltd, London, UK.
Vennettier, P. 1961. 'La vie agricole urbaine à Pointe Noire'. *Cahiers d'Outre-Mer*, 14/52:60-84.
Vickers, G. 1965. *The Art of Judgement*. Chapman and Hall, London, UK.
Vickers, G. 1970. *Freedom in a Rocking Boat*. Allen Lane, London, UK.
Visker, C. 1995. 'Using agro-industrial by-products'. *Biocycle,* June 1995: 67.
Wallace,P.A. 1996. Field Trials of Compost for Agriculture; the technical aspects of controlled waste management – Research Report No. CWM 158/96. The Environment Agency, UK.
Walters, C.J. 1986. *Adaptive Management of Renewable Resources*. McGraw Hill, New York, USA.
Walters, C.J. 1997. 'Challenges in Adaptive Management of Riparian and Coastal Ecosystems'. *Conservation Ecology*, 1(2):1-18.
Waste Management Department, 1995. Internal Report of the WMD of the AMA, Accra.
Webber, L. 2000. 'Co-researching: Braiding theory and practice for research with people'. In: Ison, R. L. and Russel D. (eds.). *Agricultural Extension and Rural Development: Breaking out of traditions*. 2000. Cambridge University Press, UK
Werlin, H. 1991. 'Ghana and South Korea: Lessons from World Bank case studies'. *Public Administration and Development*, 11:245-255.
Werner, J. 1993. *Participatory Development and Agricultural Innovations: Procedures and methods of on-farm research*. GTZ, Eschborn, Germany.
Whyte, W.F. (ed.) 1991. *Participatory Action Research*. Sage Publications, Newbury Park, CA.
Wiener, N. 1948. *Cybernetics*. Wiley, New York, USA.
World Bank, 1991. *Urban Policy and Economic Development; an agenda for the 1990s*. Washington DC USA.
World Bank. 2000. *World Development Indicators, 2000* (a World Bank Publication), Washington DC, USA.
Wright, J. 2005. Falta Petroleo! Perspectives on the emergence of a more ecological farming and food system in post-crisis Cuba. Wageningen: Published Doctoral Dissertation.
Yeung, Y.M. 1985. *Urban Agriculture in Asia; a substantive and policy review*. Food Energy Nexus Programme. Report No. 10, United Nations University, Tokyo, Japan.
Yeung, Y.M. 1988. 'Agricultural Land Use in Asian Cities'. *Land Use Policy*, Vol.5:79-82.
Zakariah, S., Lamptey, G.M. and Maxwell, D. 1998. 'Urban agriculture in Accra; a descriptive analysis'. In: Armar-Klemesu, M. amd Maxwell, D. 1998. *Urban Agriculture in the Greater Accra Metropolitan Area*. Final Report to IDRC. Nutrition Unit, Noguchi Memorial Institute for Medical Research, University of Ghana, Legon, Ghana.
Zurbrügg, C., Drescher, S., Rytz, I., Sinha, M. and Enayetullah, I. 2002. Decentralised Composting in Dhaka, Banglasesh; Production of compost and its marketing. Paper submitted to ISWA Annual Congress, Istanbul, July 8-12, 2002. (http://www.sandec.ch/SolidWaste/Documents/01-Composting/composting-dhaka-ISWA2002.pdf)

**Personal Communication**

Adama, pers. comm. March 2000. Vegetable grower in Accra.
Aggreyfin, pers. comm. October 2000. Acting Director of Statistical Research and Information Directorate of the Ministry of Agriculture.
Alliepoe, pers. comm. June 2000. Senior Officer, Ministry of health, Accra. Formerly with the AMA Public health Department.
Alorvov, pers.comm. October 2000. Senior Officer, Livestock Association, Ministry of Agriculture, Accra.
Anku, S.E.K. pers. comm. June 2000. Senior Programme Officer, Environmental Protection Agency, Accra.

Armah, pers.comm. November 1999. Manager for the Waste Management Department of the AMA.
Awuye, J. pers. comm. August 1999. Manager of the Teshie Composting Plant, AMA Waste Management Department.
Brookes, P. pers.comm. 2001. Professor at the Soils Science Department, Rothamsted Experimental Station, Harpenden, UK.
Klaassen, W.P. pers. comm. November 1999, June and October 2000, Co-ordinator for Growth Integrated Development Programme
Koch, pers. comm. March 2000. Seconded from Gopa to the Centre for International Migration, AMA. Formerly with Gopa on the Waste management Programme.
Lamptey, E. pers. comm. June and October 2000. Manager of the James Town composting operation, Asiedu Keteke Community Participation Project.
Lennartsson, M. pers. comm. 1998 and 2000. Head of International Research, HDRA, UK.
Marquis, J., pers. comm. June 2000. Manager of Town and City Waste, Accra.
Mead, A., pers. comm. 2002. Statistician, Wellesbourne Horticultural Research Centre, UK.
Meynel, pers. comm. March 2000 and June 2000. Private waste management entrepreneur. Formerly with Gopa on the Waste management Programme.
Ruby, pers. comm. 2001. Vegetable grower in Accra
Sackey, pers. comm. October 2000. Metropolitan Director of Food and Agriculture Department, AMA.

# APPENDIX A – ANALYSIS DONE ON SOIL, COMPOST, MANURES

*A 1.1 Analysis done on soil, compost, manures (Analytical results on dry matter basis)*

| | Unit | Composts & manures | Soil |
|---|---|---|---|
| pH [1] | | ✔ | ✔ |
| Density [2] | kg/m3 | ✔ | |
| Dry matter [2] | % | ✔ | |
| Dry density [2] | kg/m3 | ✔ | |
| Extractable Chloride [2] | mg/l | ✔ | |
| Extractable Phosphorus [2] | mg/l | ✔ | |
| Extractable Potassium [2] | mg/l | ✔ | |
| Extractable Magnesium [2] | mg/l | ✔ | |
| Extractable Calcium [2] | mg/l | ✔ | |
| Extractable Sodium [2] | mg/l | ✔ | |
| Extractable Ammonia-N [2] | mg/l | ✔ | |
| Extractable Nitrate-N [2] | mg/l | ✔ | |
| Total Extractable Nitrogen [2] | mg/l | ✔ | |
| Extractable Sulphate [2] | mg/l | ✔ | |
| Extractable Boron [2] | mg/l | ✔ | |
| Extractable Copper [2] | mg/l | ✔ | |
| Extractable Manganese [2] | mg/l | ✔ | |
| Extractable Zinc [2] | mg/l | ✔ | |
| Extractable Iron [2] | mg/l | ✔ | |
| Available Phosphorus [3] | mg/l | | ✔ |
| Exchangeable Potassium [4] | meq/100g & mg/l | | ✔ |
| Exchangeable Magnesium [4] | meq/100g & mg/l | | ✔ |
| Exchangeable Calcium [4] | meq/100g & mg/l | | ✔ |
| Exchangeable sodium [4] | meq/100g & mg/l | | ✔ |
| CEC [4] | meq/100g | | ✔ |
| Total Nitrogen [5] | % w/w | ✔ | ✔ |
| Total Carbon | % w/w | ✔ | |
| C:N ratio | | ✔ | |
| Total Phosphorus | % w/w or mg/kg | ✔ | ✔ |
| Total Potassium | % w/w or mg/kg | ✔ | ✔ |
| Total Calcium | % w/w | ✔ | |
| Total Magnesium | mg/kg | ✔ | ✔ |
| Total Iron | mg/kg | ✔ | |
| Total Manganese | mg/kg | ✔ | |
| Total Cadmium | mg/kg | ✔ | ✔ |
| Total Copper | mg/kg | ✔ | ✔ |
| Total Lead | mg/kg | ✔ | ✔ |
| Total Chromium | mg/kg | ✔ | ✔ |
| Total Nickel | mg/kg | ✔ | ✔ |
| Total Zinc | mg/kg | ✔ | ✔ |
| Total Mercury | mg/kg | ✔ | ✔ |
| Organic Matter [6] | % w/w | ✔ | ✔ |
| Electrical Conductivity [7] | uS/cm | ✔ | |
| Exchangeable Aluminium [8] | mg/l | | ✔ |
| Exchangeable Hydrogen [8] | mg/l | | ✔ |

<u>*Comments on method of analysis*</u>

1. *measured in water 1:6 ratio*
2. *According to BS4156 1990 (British Standard)*
3. *measured in a sodium bicarbonate soil extract at pH 8.5 – "Olsens"*
4. *Ammonium Acetate, CEC in pH 7.0*
5. *Kjeldahl*
6. *Wet oxidation and Walkley Black on soils, loss on ignition on composts and manures*
7. *1:6 ratio*
8. *1N KC1 – Titration, only done if pH < 5.5*

# APPENDIX B – IMPLICATIONS FOR USING COMPOST IN AGRICULTURE WITH PARTICULAR REFERENCE TO HEAVY METALS

Composting is the biological degradation of organic materials by a variety of microorganisms to form a soil–like, stable material. Everything organic, be it of plant or animal origin, can be composted. The process involves microbial activity in the presence of oxygen and moisture. As a result of the microbial activity a temperature increase occurs, followed by a cooler period as the material s digested and the activity is reduced. The quality of compost can be variable depending in part on the chemical and physical characteristics of the raw materials that went into making it, and in part, on the processing system used. The higher the concentration of nutrients in the wastes, the higher the fertilisation value of the compost (Polprasert, 1996). However, compost is typically low in nutrients compared with unprocessed wastes and other organic soil amendments, such as animal manures, slurries and sludge, and most of the nutrients that are present in compost are locked up in organic forms and thus unavailable for plant uptake.

In the case of nitrogen, for example, much of the nitrogen present in the unprocessed waste material is lost through volatilisation and stabilised through microbial assimilation and humification during the composting process. Consequently, compost is typically low in nitrogen (typically 1%) and of the total amount, almost all is combined with organic substances and has to be mineralised to inorganic ammonium or nitrate before it is available to plants (Polprasert, 1996). Only a fraction is in a form available for plant uptake in the first year following application to land (Lennartsson, pers.comm.). The rate of nitrogen mineralisation is dependent on the compost composition and the environmental conditions during and after the initial application. It is commonly estimated that in temperate climates, of the total N present in compost, 10% is available for plant uptake in the first year, 5% in the following year and 2% in the remaining years (Hyatt, 1995). However the mineralisation rate of N is faster in hot humid climates where decomposition of organic matter is accelerated compared to more temperate climates (Greenland *et al*., 1992).

Because of the relatively low nutrient content and the slow nutrient release, compost is considered more of a soil improver than a fertiliser. Commonly perceived benefits of compost include:

- improved chemical and physical soil properties such as porosity, aggregate stability, water-holding capacity, pH buffering capacity and CEC.
- a positive influence on soil micro-organisms and soil enzyme activities, and thus indirectly nutrient release to plants.
- the potential for reducing (soil borne pathogens and diseases) phytopathogenic fungi levels and nematode plant parasite populations

primarily through the introduction of compounds inhibitory and microorganisms antagonistic to plant pathogens that are present in mature compost (Hoitink *et al*., 1997; Marvil *et al*., 1997).

- the gradual release of nutrients over a prolonged period

Set against the benefits of compost to soil and subsequent plant growth is the potential for negative effects. In relation to compost derived from municipal wastes, these could be serious and cannot be overlooked.

- of concern is the presence of heavy metals which can be harmful to plant and animal health
- The potential presence of pathogens in inappropriately composted wastes can pose a health threat to people handling the compost and consumers of uncooked foodstuffs grown in compost amended soils (e.g. lettuce)
- Negative effects associated with a decrease in yield can be caused by the application of immature, i.e. insufficiently stabilized, compost. Such compost can cause immobilization of N and, if used at high concentrations (such as in container growing), phytotoxic affects on plant growth due to high conductivity (high concentrations of soluble salts).

The risk of high concentrations of heavy metals is covered in more detail below.

**Heavy metal concentrations**

One of the concerns about using compost derived from urban waste as a soil amendment is the risk of supplying heavy metals and increasing the overall soil concentration of such elements over time through regular compost applications. High concentrations of heavy metals in soils can be toxic to plants or, the metals can be taken up by plants and be toxic to animals and humans consuming them. The degree of toxicity of heavy metals varies. Of the elements analysed, cadmium (Cd), chromium (Cr) and mercury (Hg) are extremely poisonous, lead (Pb) and nickel (Ni) moderately so, whilst copper (Cu) and zinc (Zn) are relatively low in toxicity (Brady, 1984).

Heavy metals are generally bound by soil constituents and they do not tend not to break down or leach away from the soil (Cooke, 1975; Brady 1984; Bowler, 1999). As such there is concern that repeated applications to land can lead to a build up over time that may reach harmful levels. Therefore, the presence of heavy metals in compost, or any other organic material used in agriculture for that matter, is an important consideration in terms of evaluating the potential for use.

The mobility of heavy metals vary from one element to another. Johansson *et al*., (1997:12) state that "*Cu, Cr and Pb are the most strongly bound elements and are accumulated in the topsoil following application*". They remain immobile in the soil, neither readily entering into solution (as water pollution) nor into a biological cycle (the food chain) (Bowler, 1999:34). Hg is also bound in the top layer of the soil, but is usually rather mobile (*ibid.:*12). Other elements such as Cd and Zn are relatively mobile and can be taken up by plants (*ibid*.).

The behaviour of heavy metals in soil depends on many factors such as pH of the soil solution, OM content, CEC and microbiological activity (Ciavatta *et al*., 1993). Soil pH is a major influencing factor on the fate of these elements. Only in moderate to strongly acid soils is there significant movement down the profile from the layer of application (Brady, 1984). Cd and Zn, for example, are mobilised relatively easily with reduced pH (<7) (Larsen *et al*., 1996 in Johansson *et al.*, 1997), and according to Chaney and Giordano (1977) can readily move to plant tops when added to soil. Lead too, which is very tightly bound becomes available under acid soil conditions (Deportes *et al*., 1995).

In addition to pH, OM and clay content (i.e. CEC), influence the mobility and thus bioaccessibility of heavy metals, whereby a high clay and/or organic matter content reduce mobility (Johansson *et al*. 1997; Ciavatta *et al*., 1993). According to Cooke (1975) the availability of these metals to plants varies from one manure to another. Leita & Nobili (1991:73) note that "*the degree of stabilisation achieved by OM of sludges and composts before additions to soils is an important factor in determining the impact of added materials on soil properties, and is often neglected in studies on the subject.*"

Plants vary in their degree of tolerance to phytotoxic conditions and their take-up of heavy metals. Bowler (1999:34) notes that "com*mon grasses and grain, for instance, are more tolerant of PTEs than leafy vegetables*". Deportes *et al.* (1995) point to the fact that several studies have shown that Ni appears to be readily absorbed in plants, especially vegetables.

The fact that (1) different elements vary in their mobility in terms of leaching and plant up-take, (2) different plants vary in terms of tolerance to, and ability to take up these elements and (3) that environmental conditions (such as pH and soil type) matter, suggests that the critical soil concentration threshold levels ('safe limits') established for the contamination levels of heavy metals should take into account type of soil (acidic soils are less retentive) and the crop being farmed.

However, the knowledge on the movement of heavy metals is incomplete and in relation to compost only limited information is available on the water extractable fraction of heavy metals in compost and their evolution during the composting process and following application to soil.

Most analysis of heavy metal content of organic materials is done on the total content, by means of a strong acid digestion. This procedure 'release' even the most strongly bound element that are inaccessible to plants and animals (Johansson *et al*., 1997). Quoting research findings, Johansson *et al.* (1997:13) point out that "*less than one percent of the total content of the heavy metals in compost are directly available, 20-40% of Cd and Zn are exchangeable, and 50-70% of Cd and Zn and 20-40% of Cu and Pb in compost may be potentially available*." Analysis of total heavy metal contents of soil amendments by means of extraction with acid, provides information of the maximum possible capacity of the amendment to supply heavy metals to the soil. What the analysis does not provide is information on the adverse effects that they may or may not have. The unclarity of the fate of heavy metals once added to soil and their possible effect when taken up by plants and ingested by animals and humans, is reflected in the discrepancy, or simply lack of regulation, with regards to heavy metal inputs in agricultural production.

**Standards for permissible concentrations of PTEs in composts and other organic materials**

There are currently no general standards, or recommendations for maximum heavy metal concentrations in soil amendments and safe application levels, and there are great variations between countries and regulatory bodies. As Hogg *et al.* (2002:8) highlight "*each situation has its own specific characteristics, and each system functions within a background 'policy framework' which implies that the approach undertaken in one country is not necessarily suitable for adoption in another*". The large differences between the standards (Table B2.1) can, in part, be ascribed to differences between materials for which the values were set and the purpose for which they are intended to be used (e.g. fertiliser or soil improver, in agriculture or landscaping). For example, as Shields (1999) points out, in Spain compost is classed as a fertiliser which is applied at a much lower rate than a soil improver, thus the permitted heavy metal concentrations has been set higher. Some countries (e.g. Austria and the Netherlands) have standards for different types of compost depending on their quality and intended use. The discrepancy is also symptomatic of the fact that there is lack of knowledge, thus differing scientific opinions, about the fate and harmful effects of these elements once supplied to soils through organic amendments. Assessments of sustainability and, in this case, risk in relation to heavy metals introductions to the soil and wider environment, is subjective at the best of times, and is not made easier by the fact that there is limited knowledge about the fate of these elements. Furthermore, Hogg *et al.* (2002:8) note that there are differences in scientific opinion, and consequently in approach "*regarding how (and therefore at what levels) limit values for PTEs should be established, and the approaches to testing composts for various characteristics*".

Until very recently few countries had a national standard for compost quality, although private or industrial standards which complimented the legal framework existed in several countries (Shield, 1999). In the last few years a growing number of countries have introduced statutory standards for compost (and composting) quality relating to all or several of the following considerations:

- harmful substances and impurities such as heavy metals, pathogens, organic pollutants, inert materials and weed seeds
- nutrient content, organic matter content, electrical conductivity and stability/maturity of the compost
- input materials
- processing and hygene

Table B2.1 gives some different European examples of permitted levels of heavy metals in composts. The German RAL standard is a frequently cited standard for compost (Bywater, pers comm., 2001), and has, along with the EU Ecolabel standard for soil improvers, been used as a guide when assessing the heavy metal contents for the composts used in this research (see Graphs B2.1 a-g). The EU Ecolabel for Soil Improvers is the only pan-European standard applicable to compost (Shields, 1999). The EC regulations 2092/91 on organic production, the Austrian class A for organic farming standards and the UK UKROF (the UK Register of Organic Food Standards) standards are very stringent and have been subject to criticism as many organic amendments fail to comply with these parameters (HDRA, 1998).

*Table B2.1 Examples of permitted levels of heavy metals in compost (various sources), (mg/kg dry matter)*

| Standard | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| **EU** Ecolabel for soil improvers (2001/688/EC) [1] | 1 | 100 | 100 | 100 | 50 | 300 | 1 |
| **EU** 'eco-agric' (2092/91 EC-1488/98 EC) [1] | 0.7 | 70 | 45 | 70 | 25 | 200 | 0.4 |
| **Sweden** guideline values for Quality Assurance System [1] | 1 | 100 | 100 | 100 | 50 | 300 | 2.5 |
| **Germany** (RAL standard (GZ-251) [1] | 1.5 | 100 | 150 | 100 | 50 | 400 | 1 |
| **UK** UKROF (organic farming) [1] | 0.7 | 70 | 45 | 70 | 25 | 200 | 0.4 |
| **UK** Composting Associations Quality Label [1] | 1.5 | 200 | 150 | 100 | 50 | 400 | 1 |
| **Austria** class A (organic farming)[1] | 0.7 | 70 | 45 | 70 | 25 | 200 | 0.4 |
| **Austria** class B (agriculture and hobby gardening) [1] | 1 | 150 | 120 | 70 | 60 | 500 | 0.7 |
| **Belgium** (VLACO) [1] | 1.5 | 90 | 120 | 70 | 20 | 300 | 1 |
| **Italy** (DPR 915/82) [1] | 10 | 600 | 500 | 500 | 200 | 2500 | 10 |
| **Finland** (Decision 46/94) [1] | 3 | 600 | 150 | | 100 | 1500 | 2 |
| **Denmark** (Plantedirectory) [1] After 1.6.2000 (DHN:15) | 0.4 | 1000 | 120 | 1000 | 30 | 4000 | 0.8 |
| **Netherlands** (BRL K256/02 VGF) [1] | 1 | 60 | 100 | 50 | 20 | 200 | 0.3 |
| **Netherlands** (BRL K526/02 high quality VGF) [1] | 0.7 | 25 | 65 | 50 | 10 | 75 | 0.2 |
| **Spain** (Royal Decree 1110/1991) (sewage sludge in agriculture) [2] | 40 | 1750 | 1200 | 750 | 400 | 4000 | 25 |

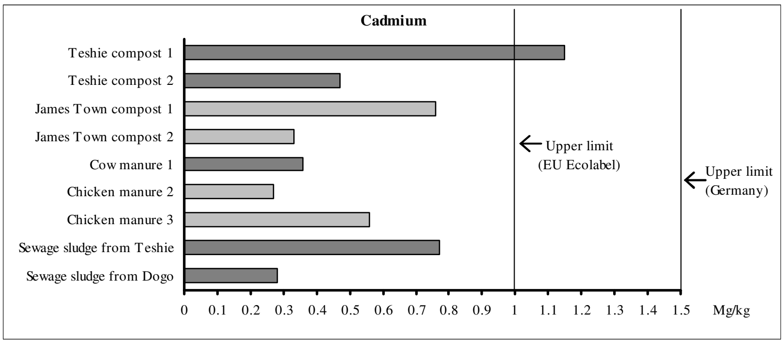
*Sources: 1. Hogg et al., 2002*
*2. DHV Environment and Infrastructure, 1997*

By ensuring that the feedstock is clean problems of high heavy metal concentrations in the resulting compost should not present a problem. It is widely recognised (Hogg *et al*., 2002) that source separation of the waste is the best way of ensuring the production of good quality compost. Years of experience in Europe and USA has shown that composting done with source separated waste produces a cleaner end product than that done with central separation. In reviewing research into the difference between heavy metal contents in centrally separated and source separated household waste in Europe and USA, Johansson *et al*. (1997) report that the heavy metal content was 2-9 times higher in compost derived from centrally separated waste compared with that which had been source separated.

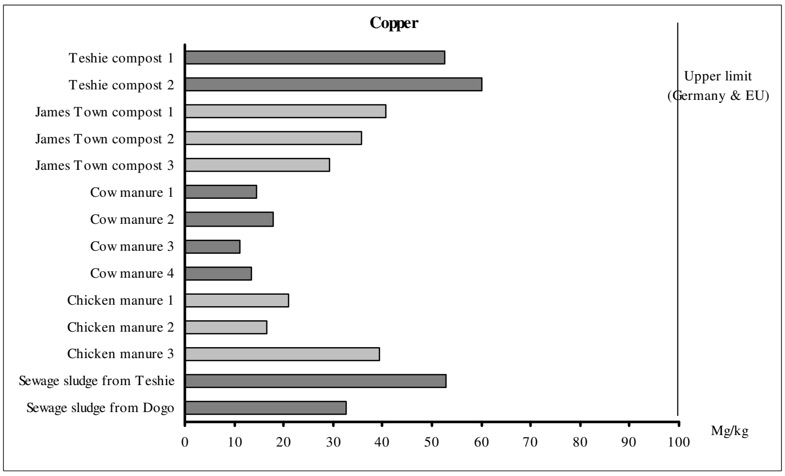
However, source separation requires a high degree of public awareness and willingness as well as resources for an elaborate collection system. Mainstream waste management services in countries in the South are struggling to provide adequate collection in the face of limited resources and growing waste generation levels, thus source separation presently remains an ideal to strive towards rather than a feasible option. Having said that, a considerable amount of source separation already takes place in many of these nations, in that householders and scavengers remove anything of value from the waste stream. This includes the most nutrient rich organic wastes, resulting in a generally low quality of organic waste being collected by the waste management services. Clearly, in relation to composting this has implications.

In Accra the waste collection was mixed. That which was collected by the Ashiedu Keteke Community Participation Project from households in James Town and taken to the James Town composting site was separated upon arrival and the organic fraction piled up for composting. At the Teshie site on the other hand, the waste was not separated upon arrival, but rather put into windrows, capped with digested sewage sludge and left to degrade. This meant that the organic fraction of the waste was left to decompose mixed with other, non-organic wastes. Not until the organic material had degraded and stabilised was the material sieved and the compost separated out. This process resulted in an end product somewhat more akin to black soil than compost, and carried a high risk of producing an end product with high concentrations of heavy metals.

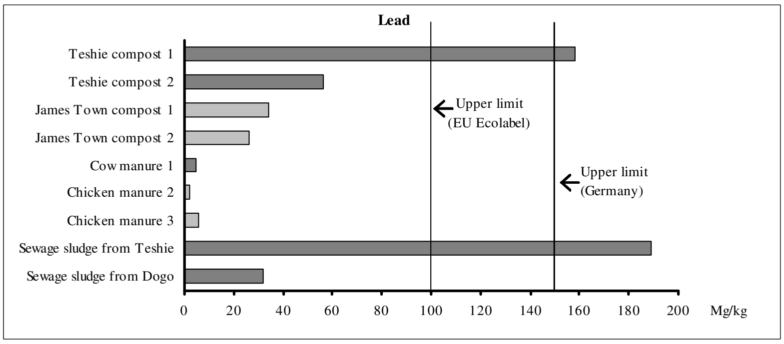
Graphs B2.1 a-g show the heavy mental concentrations in the different composts, manures and sludges sampled and how these relates to the upper limits according to the Ecolabel and the German RAL standards.



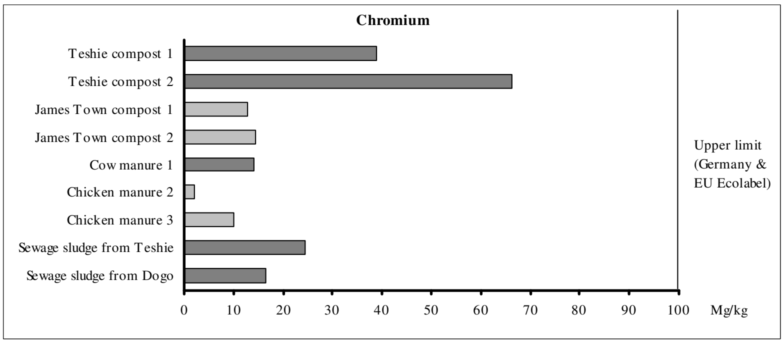
Cadmium
Teshie compost 1
Teshie compost 2
James Town compost 1
James Town compost 2
Cow manure 1
Chicken manure 2
Chicken manure 3
Sewage sludge from Teshie
Sewage sludge from Dogo
Upper limit (EU Ecolabel)
Upper limit (Germany)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5
Mg/kg

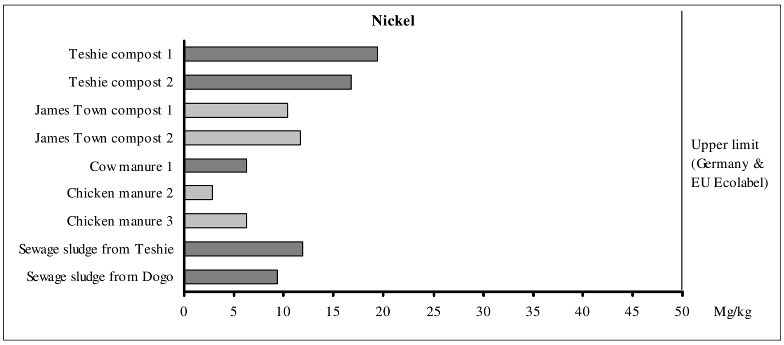
Copper
Teshie compost 1
Teshie compost 2
James Town compost 1
James Town compost 2
James Town compost 3
Cow manure 1
Cow manure 2
Cow manure 3
Cow manure 4
Chicken manure 1
Chicken manure 2
Chicken manure 3
Sewage sludge from Teshie
Sewage sludge from Dogo
Upper limit (Germany & EU)
0 10 20 30 40 50 60 70 80 90 100
Mg/kg

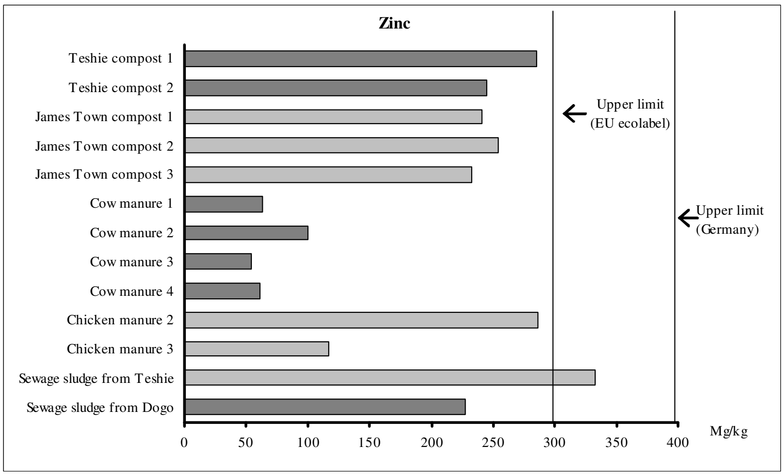



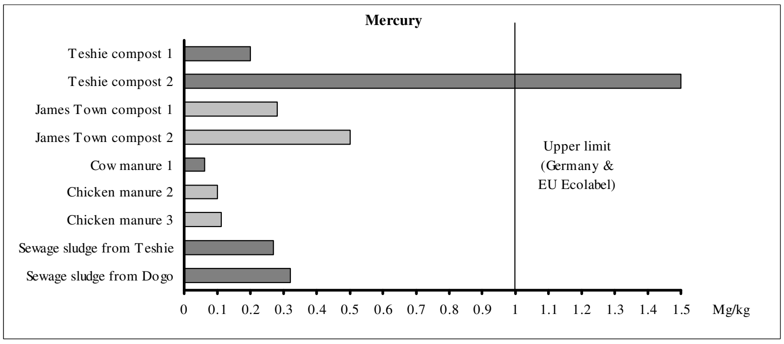
Lead
Teshie compost 1
Teshie compost 2
James Town compost 1
James Town compost 2
Cow manure 1
Chicken manure 2
Chicken manure 3
Sewage sludge from Teshie
Sewage sludge from Dogo
Upper limit (EU Ecolabel)
Upper limit (Germany)
0 20 40 60 80 100 120 140 160 180 200
Mg/kg

Chromium
Teshie compost 1
Teshie compost 2
James Town compost 1
James Town compost 2
Cow manure 1
Chicken manure 2
Chicken manure 3
Sewage sludge from Teshie
Sewage sludge from Dogo
Upper limit (Germany & EU Ecolabel)
0 10 20 30 40 50 60 70 80 90 100
Mg/kg




*Graphs B2.1 a-g Heavy metal content of the different composts, manures and sludges and the maximum permissible levels according to the EU Ecolabel and German RAL standards*

*Source: This research*

# APPENDIX C – HEAVY METAL BUILD-UP IN SOILS: A PROJECTION OF HEAVY METAL LOADING RATES IN THE ON-FARM TRIAL SOIL OVER TIME

Appendix B provided information about permitted levels of heavy metals in soil amendments. In this Appendix the maximum permissible levels, or annual loading rates in agricultural soils for different European countries are given. As with the standards for soil amendments there are large differences between the countries, with some being very stringent while other standards are more lenient. No regulation in relation to heavy metal loading in soils exists in Ghana. As such comparisons with regulation within Europe were used as a guideline to ascertain the levels which may be considered hazardous. Whilst regulation of compost quality is variable and in its infancy in many European countries, all countries have legislation limiting the loading of heavy metals per unit area of land.

Regulations or guidelines of two types exist in relation to this:

1. On the one hand are limits to the maximum content of heavy metals in soil. Most European countries have laid down soil quality criteria for soils when application of sewage sludge is intended (Johansson *et al.*, 1997). In Table C3.1 the limits from several European countries are shown. As can be seen, the limits laid down by the different countries are in two categories; one more restrictive than the other. Some countries base their criteria on (knowledge about) bioaccumulation of heavy metals, or toxicity to plants and of human health considerations. Other countries have adopted more stringent limits whereby a more ecological approach is taken. Here criteria related to eco-toxicological soil quality considerations based on the effects on micro-organisms, plants and invertebrates and on knowledge of bioaccumulation are used (*ibid.*).

2. The other type of regulation is concerned with limits to the maximum annual loading of heavy metals to agricultural land. Again, most of these regulations have been devised for sewage sludge, but are also used for compost amendments. These regulations vary greatly between countries (Table C3.2). Johansson *et al.* (1997) note that a difference factor of 100 is common, and conclude that the much lower difference (a factor of 5, Table C3.1) between the limits to heavy metal content in soil implies that there is consensus regarding what the safe limits are, but that opinions of how fast pollution may take place vary considerably.

*Table C3.1 Maximum permitted level in soil according to different European countries, (mg/kg dry soil/matter)*

| Standard | | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|---|
| **EU**[1] | | 1-3 | 50-140 | | 100-150 | 30-75 | 150-300 | 1-1.5 |
| **UK** (Soil Association) [2] | | 2 | 50 | 100 | 150 | 50 | 150 | 1 |
| **Germany**[1] | | 1.5 | 60 | 100 | 100 | 50 | 200 | 1 |
| **France**[1] | | 2 | 100 | 100 | 150 | 50 | 300 | 1 |
| **Spain**[1] | | 1 | 50 | 50 | 100 | 30 | 150 | 1 |
| **Ireland**[1] | | 1 | 50 | 50 | - | 30 | 150 | 1 |
| **Sweden** | | 0.5 | 40 | 40 | 30 | 15 | 100 | 0.5 |
| **Denmark**[1] | | 0.5 | 40 | 40 | 30 | 15 | 100 | 0.3 |
| **Finland**[1] | | 0.5 | 100 | 60 | 200 | 60 | 150 | 0.2 |
| **Netherlands**[1] | | 0.8 | 36 | 85 | 100 | 35 | 140 | 0.3 |
| Baseline soil sample from on-farm trial field (Aug, 1999) | 0-15 cm | 0.23 | 19 | <0.01 | 75 | 25 | 22 | 0.05 |
| | 15-30 cm | 0.2 | 22 | <0.01 | 79 | 28 | 31 | 0.06 |

*Sources: 1 Saabye 1995 in Johansson et al., 1997*
*2 Soil Association, 1999*

*Table C3. 2 Maximum permissible average annual rate of heavy metals allowed to be spread on arable land over a set period according to EU and different European countries, (kg/ha/yr)*

| Standard | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| **EU** (Ecolabel) [1] | 0.08 | 3.8 | 7 | 7 | 1.5 | 7.5 | 0.05 |
| **UK** (Sludge regs, 1989) [1] | 0.15 | 7.5 | 15 | (15) | 3 | 15 | 0.1 |
| **Germany** [2] | 0.017 | 1.3 | 1.5 | 1.5 | 0.33 | 4.1 | 0.013 |
| **France** [2] | 0.06 | 3 | 2.4 | 3 | 0.3 | 9 | 0.03 |
| **Spain** [2] | 0.06 | 3 | 2.3 | 3 | 0.9 | 7.5 | 0.048 |
| **Ireland** [2] | 0.04 | 2 | 1.5 | - | 0.6 | 5 | 0.032 |
| **Sweden** (SNSF1994:2MS72 regulation) [3] | 0.00175 | 0.6 | 0.1 | 0.1 | 0.05 | 0.8 | 0.0025 |
| **Sweden** (KRAV regulation, 1995) [3] | 0.001 | 0.5 | 0.05 | 0.05 | 0.05 | 0.7 | 0.001 |
| **Norway** [2] | 0.004 | 1 | 0.1 | 0.13 | 0.08 | 0.7 | 0.005 |
| **Denmark** [2] | 0.008 | 10 | 1.2 | 1 | 0.3 | 40 | 0.008 |
| **Finland** [2] | 0.002 | 0.6 | 0.1 | 0.3 | 0.1 | 1.5 | 0.001 |
| **Netherlands** [2] | 0.003 | 0.2 | 0.2 | 0.15 | 0.06 | 0.6 | 0.002 |

*Sources: 1 HDRA, 1999*
*2 Saabye 1995 in Johansson et al., 1997*
*3 AFR 154 1999 in Johansson et al., 1999*

Sweden has two regulations for the maximum annual dosage of heavy metals that are allowed to be spread (over a 7 year period) on agricultural land. One is devised by the Swedish Environmental Protection Agency (SNV), the other, more strict regulation, by KRAV, (which is) the Swedish regulatory body for organic farming. Whilst the Swedish standards work on a 7-year period, others (e.g. UK sludge regulations and EU Ecolabel) work on a 10-year period.

Table C3.3 gives some examples of heavy metal contents in some different northern European soils. It is included here as a guideline against which to compare the Accra soil analysed. Reference to this table in made in Section 6.2.1. in Chapter 6

*Table C3.3 Total heavy metal content in soils from different parts of northern Europe, median values in mg/kg dry soil*

| Country | Soil type and no of soils sampled | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|---|
| **Denmark** | sandy, all (N=226) | 0.13 | 6 | 11 | 6 | 3 | 18 | 0.03 |
| | clayey, all (N=167) | 0.22 | 9 | 12.1 | 17 | 10 | 43 | 0.05 |
| **Sweden** | all soils (N=361) | 0.22 | 15 | 16 | 16 | 9 | 59 | - |
| **England & Wales** | arable, (N-192-1521) | 0.5 | 18 | 37 | 54 | 24 | 80 | 0.09 |
| **Holland** | sandy, arable (N=63) | 0.3 | 11 | 21 | 26 | 5 | 44 | 0.2 |
| | clayey, arable (N=248) | 0.5 | 23 | 43 | 78 | 33 | 117 | 0.2 |
| **Schleswig Holstein** | sandy, arable (N129) | 0.1 | 7 | 13 | 8 | 4 | 25 | 0.04 |

*Source: Johansson et al., 1997*

## A projection of heavy metal loading rates in the on-farm trial soil over time

Heavy metal analysis was only carried out on the initial baseline soil sample and on each compost and manure sample to ascertain the status of the soil in relation to heavy metal concentrations prior to compost amendments. Since heavy metals are generally stable and remain in the soil once added, the loading to the soil over time is a more important consideration than the actual concentration in any one sample of compost or manure (HDRA, 1998). In this Appendix a projection of increases in heavy metal concentrations in the soil following different application regimes over time is presented.

Assuming no losses through plant take-up or leaching, the amounts of heavy metals supplied to the soil through compost applications with the application rates used in the trial were calculated. The amounts are displayed in Table C3.4. The loading rates through cow manure applications, assuming the heavy metal concentrations of the first (and only) cow manure sample that was analysed for these elements, are also displayed in the table.

*Table C3.4 Assumed loading rates of heavy metals in the on-farm trial soil, (kg/ha)*

| | **Cd** | **Cu** | **Pb** | **Cr** | **Ni** | **Zn** | **Hg** |
|---|---|---|---|---|---|---|---|
| Teshie Compost 1 | 0.048 | 2.207 | 6.628 | 1.632 | 0.818 | 11.956 | 0.0084 |
| James Town Compost 1 | 0.013 | 0.711 | 0.598 | 0.225 | 0.182 | 4.211 | 0.0049 |
| Supplied in year 1 | 0.061 | 2.918 | 7.226 | 1.857 | 1.0 | 16.167 | 0.0133 |
| James Town Compost 2 | 0.005 | 0.528 | 0.391 | 0.212 | 0.171 | 3.744 | 0.0074 |
| James Town Compost 3 | 0.007 | 0.479 | 0.523 | 0.252 | 0.205 | 4.259 | 0.0058 |
| Supplied in year 2 | 0.012 | 1.007 | 0.857 | 0.437 | 0.353 | 7.537 | 0.0126 |
| **Total supplied over 2 years** | **0.074** | **3.924** | **8.082** | **2.294** | **1.353** | **23.704** | **0.0259** |
| | | | | | | | |
| Cow manure 1 | 0.006 | 0.241 | 0.075 | 0.235 | 0.104 | 1.042 | 0.001 |
| Cow manure 2 | 0.006 | 0.319 | 0.08 | 0.250 | 0.111 | 1.770 | 0.0011 |
| Supplied in year 1 | 0.012 | 0.560 | 0.155 | 0.485 | 0.215 | 2.812 | 0.0021 |
| Cow manure 3 | 0.008 | 0.250 | 0.101 | 0.315 | 0.140 | 1.200 | 0.0013 |
| Cow manure 4 | 0.088 | 0.326 | 0.110 | 0.34 | 0.152 | 1.493 | 0.0015 |
| Supplied in year 2 | 0.096 | 0.576 | 0.211 | 0.655 | 0.292 | 2.693 | 0.0028 |
| **Total supplied over 2 years** | **0.029** | **1.137** | **0.365** | **1.143** | **0.507** | **5.505** | **0.0049** |

*Source: This research*

Compost and manure were applied twice a year during the two years of the trial period. In the first year the total application of compost (50 + 25 tonnes) was almost twice that of the second year (20 + 20 tonnes). Conversely cow manure applications in the first year were lower (20 + 20 tonnes) than in the second year (30 + 30 tonnes). With the high application rates used, the heavy metals delivered through compost applications were in excess of the maximum permissible level according to the EU Ecolabel standard for lead in the first year and for zinc in the second. The very high concentration of lead in the compost from Teshie, which was used in the first, highest application, resulted in the high loading rate for this element. If compost from James Town had been used instead, the delivery of lead would have been considerably lower and not exceeded the EU Ecolabel limit (See scenario in Tables C3.6 and C3.7 below). Zinc, however, would have exceeded the annual average limit regardless of compost, at the high application rates used.

According to the criteria set by the more lenient UK sludge regulations, only zinc in the first year of compost application fell above the acceptable limits. However, when averaging out the application over the 2-year period, the zinc supplied did comply with the UK regulation. According to the Danish limit, which has the most lenient regulation for zinc, the amount delivered did not exceed the limit. According to the French, Spanish and Irish regulations, the heavy metals delivered during the trial period were within acceptable limits for about half the elements, but failed to meet the standards for the others.

The general trend was a heavy metal delivery which complied with the less stringent regulations of UK and EU, and to a lesser extent, France, Spain and Ireland, and which failed to comply with the more stringent regulation laid down by Sweden, Norway, Finland, Netherlands, Denmark and Germany. According to the Swedish sludge standards, for example, all the heavy metals supplied through the compost applications in both years failed to meet the acceptable limits. In fact, even the cow manure failed to comply with these standards for all heavy metals except copper and mercury in the first (but not second) year. The fact that the manure came from cows that were free ranging and the application rate used was in line with the recommended rates from the agricultural extension service, raises the question of what organic amendment may ever comply with the Swedish standard.

If compost had been applied at a rate not to exceed the Swedish maximum limit, it would have had to be applied at 4.2 t/ha for James Town compost and 1.1 t/ha for Teshie compost. The amount of primary nutrients that the rates under this scenario would have supplied, (using the average nutrient concentrations in the samples analysed), are shown in Table C3.5. Apart from the P delivered from the James Town compost, application rates like these would not be able to supply sufficient nutrients to provide a good crop response, nor would it deliver much organic matter to the soil. In fact, for the James Town compost, the limiting factor in determining the application rate would be P loading rates, rather than heavy metals. The analysis results reveal that unless the most stringent standards for heavy metal loading rates are applied, even a relatively contaminated compost like the ones produced from urban waste in Accra, can be applied at sufficiently high rates to supply crop nutrients without risking soil contamination from heavy metals.

*Table C3.5 Amount of compost that can be applied annually in order not to exceed the limits to heavy metal loading rates according to the EU, UK and Swedish standards and the amount of nutrients that this compost application rate would supply*

| | James Town compost | | | | Teshie compost | | | |
|---|---|---|---|---|---|---|---|---|
| | Amount of compost (t/ha/yr) | Amount of nutrients supplied through this application rate (kg/ha/yr) | | | Amount of compost (t/ha/yr) | Amount of nutrients supplied through this application rate (kg/ha/yr) | | |
| | | N | P | K | | N | P | K |
| UK sludge standard: | 78.9 | 667 | 2719 | 204 | 65.8 | 164 | 238 | 747 |
| EU Ecolabel standard: | 39.5 | 334 | 1360 | 102 | 32.9 | 82 | 119 | 374 |
| Swedish sludge standard: | 4.2 | 36 | 145 | 11 | 1.1 | 3 | 4 | 12 |

*Source: This research*

In order to ascertain the safety of using the waste derived composts produced in Accra on agricultural land in the long term, a scenario of the soil build-up of heavy metals was permutated. The following assumptions were used:

- Either compost from the James Town or the Teshie operation is used, but they are not used together as in the trial.
- The average heavy metal concentrations and dry matter content in the three compost samples from the James Town compost and the two samples from the Teshie compost are used
- The first and second years application rates are those used in the on-farm trial, i.e. 50 + 25 t/ha.
- The application rates in subsequent years are twofold: Scenario 1: the same as in the second year, i.e. 20 + 20 t/ha, and Scenario 2: halved, i.e. 10 + 10 t/ha.
- No losses from leaching and plant removal are assumed

*Table C3.6 Loading rates over a 10-year period using two different application rate scenarios of compost from James Town*

**James Town Compost**

**Scenario 1** 40 t/ha in years 3-10

| Year | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| **1** | 0.030 | 2.07 | 1.75 | 0.80 | 0.65 | 14.25 | 0.022 |
| **2** | 0.047 | 3.18 | 2.68 | 1.23 | 1.00 | 21.85 | 0.033 |
| **3** | 0.063 | 4.28 | 3.62 | 1.66 | 1.34 | 29.46 | 0.045 |
| **4** | 0.079 | 5.39 | 4.55 | 2.09 | 1.69 | 37.06 | 0.056 |
| **5** | 0.095 | 6.50 | 5.48 | 2.52 | 2.04 | 44.66 | 0.068 |
| **6** | 0.111 | 7.60 | 6.42 | 2.95 | 2.38 | 52.26 | 0.079 |
| **7** | 0.128 | 8.71 | 7.35 | 3.38 | 2.73 | 59.86 | 0.091 |
| **8** | 0.144 | 9.81 | 8.28 | 3.81 | 3.08 | 67.46 | 0.102 |
| **9** | 0.160 | 10.92 | 9.22 | 4.24 | 3.42 | 75.06 | 0.114 |
| **10** | 0.176 | 12.02 | 10.15 | 4.67 | 3.77 | 82.66 | 0.125 |

**Scenario 2** 20 t/ha in years 3-10

| Year | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| **1** | 0.03 | 2.07 | 1.75 | 0.80 | 0.65 | 14.25 | 0.022 |
| **2** | 0.05 | 3.18 | 2.68 | 1.23 | 1.00 | 21.85 | 0.033 |
| **3** | 0.05 | 3.73 | 3.15 | 1.45 | 1.17 | 25.65 | 0.039 |
| **4** | 0.06 | 4.28 | 3.62 | 1.66 | 1.34 | 29.46 | 0.050 |
| **5** | 0.07 | 4.84 | 4.08 | 1.88 | 1.52 | 33.26 | 0.062 |
| **6** | 0.08 | 5.39 | 4.55 | 2.09 | 1.69 | 37.06 | 0.073 |
| **7** | 0.09 | 5.94 | 5.02 | 2.31 | 1.86 | 40.86 | 0.085 |
| **8** | 0.10 | 6.50 | 5.48 | 2.52 | 2.04 | 44.66 | 0.096 |
| **9** | 0.10 | 7.05 | 5.95 | 2.74 | 2.21 | 48.46 | 0.108 |
| **10** | 0.11 | 7.60 | 6.42 | 2.95 | 2.38 | 52.26 | 0.119 |

*Source: This research*

*Table C3.7 Loading rates over a 10-year period using two different application rate scenarios of compost from Teshie*

**Teshie Compost**

**Scenario 1** 40 t/ha in years 3-10

| Year | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| **1** | 0.052 | 3.63 | 6.91 | 3.39 | 1.17 | 17.09 | 0.055 |
| **2** | 0.080 | 5.57 | 10.60 | 5.20 | 1.79 | 26.21 | 0.084 |
| **3** | 0.108 | 7.51 | 14.29 | 7.00 | 2.41 | 35.32 | 0.113 |
| **4** | 0.136 | 9.45 | 17.98 | 8.81 | 3.04 | 44.44 | 0.143 |
| **5** | 0.164 | 11.39 | 21.67 | 10.62 | 3.66 | 53.56 | 0.172 |
| **6** | 0.192 | 13.33 | 25.35 | 12.43 | 4.28 | 62.67 | 0.201 |
| **7** | 0.219 | 15.27 | 29.04 | 14.24 | 4.90 | 71.79 | 0.230 |
| **8** | 0.247 | 17.20 | 32.73 | 16.04 | 5.53 | 80.90 | 0.260 |
| **9** | 0.275 | 19.14 | 36.42 | 17.85 | 6.15 | 90.02 | 0.289 |
| **10** | 0.303 | 21.08 | 40.10 | 19.66 | 6.77 | 99.14 | 0.318 |

**Scenario 2** 20 t/ha in years 3-10

| Year | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| **1** | 0.052 | 3.63 | 6.91 | 3.39 | 1.17 | 17.09 | 0.055 |
| **2** | 0.080 | 5.57 | 10.60 | 5.20 | 1.79 | 26.21 | 0.084 |
| **3** | 0.094 | 6.54 | 12.45 | 6.10 | 2.10 | 30.77 | 0.099 |
| **4** | 0.108 | 7.51 | 14.29 | 7.00 | 2.41 | 35.32 | 0.113 |
| **5** | 0.122 | 8.48 | 16.13 | 7.91 | 2.72 | 39.88 | 0.128 |
| **6** | 0.136 | 9.45 | 17.98 | 8.81 | 3.04 | 44.44 | 0.143 |
| **7** | 0.150 | 10.42 | 19.82 | 9.72 | 3.35 | 49.00 | 0.157 |
| **8** | 0.164 | 11.39 | 21.67 | 10.62 | 3.66 | 53.56 | 0.172 |
| **9** | 0.178 | 12.36 | 23.51 | 11.52 | 3.97 | 58.11 | 0.186 |
| **10** | 0.192 | 13.33 | 25.35 | 12.43 | 4.28 | 62.67 | 0.201 |

*Source: This research*

| | Cd | Cu | Pb | Cr | Ni | Zn | Hg |
|---|---|---|---|---|---|---|---|
| Permitted to apply over 10 years according to: | | | | | | | |
| *EU Ecolabel* | *0.8* | *38* | *70* | *70* | *15* | *75* | *0.5* |
| *UK sludge regs* | *1.5* | *75* | *150* | *-* | *30* | *150* | *1* |
| Permitted to apply over 7 years according to | | | | | | | |
| *Swedish sludge regs* | *0.01225* | *4.2* | *0.7* | *0.7* | *0.35* | *5.6* | *0.0175* |

The forecasting of these scenarios show that after 10 years of annual compost application at two different rates, only Zn delivery in the scenario with the heaviest application rate exceeds the limit set by the EU Ecolabel standard. According to the UK sludge regulation neither application rate in neither compost exceeds the limit for any of the heavy metals. Heavy metal delivery is however, way over the limit according to the very stringent Swedish criteria. In fact, for all elements except copper, the maximum dosage allowed over 7 years was exceeded already in the first year, for both composts.

This scenario illustrates how the Teshie compost delivers a higher amount of heavy metals than the James Town compost. It supplies about twice the amount of Cu, Ni and Hg and four times as much Pb and Cr. Also Cd and Zn are delivered at a higher amount compared with the James Town compost, but the difference is less dramatic.

Even though the heavy metal concentrations in these composts are higher than in compost produced and used in Europe, the scenario used as an example here illustrates that, with the exception of zinc, even if used at moderately high rates over an extended period of time, it would still be safe in terms of heavy metal build-up in the soil. Using the EU Ecolabel and UK sludge regs as guidelines, Table C3.8 illustrates how many years it would take (using 100 years as a cut-off point) to exceed the limits using the application rates of the Teshie and James Town compost respectively. In addition to zinc for both composts, additional concern would be the Hg and Pb delivery from the Teshie compost.

*Table C3.8 Number of years that compost from Teshie and James Town can be applied at both application rate scenarios before exceeding the maximum permissible soil concentration according to the EU Ecolabel and UK Sludge Regulation criteria*

| | | EU Ecolabel Standard | | UK Sludge Reg | |
|---|---|---|---|---|---|
| | Scenario | James Town compost | Teshie compost | James Town compost | Teshie compost |
| **Cd** | 1 | 49 | 39 | 92 | 55 |
| | 2 | 95 | 56 | 0k | 81 |
| **Cu** | 1 | 34 | 20 | 67 | 39 |
| | 2 | 65 | 37 | >100 | 76 |
| **Pb** | 1 | 75 | 19 | >100 | 41 |
| | 2 | >100 | 36 | >100 | 80 |
| **Cr** | 1 | >100 | 39 | n/a | n/a |
| | 2 | >100 | 76 | n/a | n/a |
| **Ni** | 1 | 43 | 24 | 86 | 49 |
| | 2 | 83 | 46 | >100 | 96 |
| **Zn** | 1 | 9 | 8 | 19 | 16 |
| | 2 | 15 | 14 | 35 | 30 |
| **Hg** | 1 | 43 | 17 | 83 | 35 |
| | 2 | 87 | 32 | >100 | 67 |

*Source: This research*

# APPENDIX D – ON-FARM TRIAL RESULTS

## Crop Performance

### Tomatoes

*Pre-Harvest Assessment*

The tomatoes were picked once a week over a period of five weeks. The first harvest was on 27 October 1999, 64 days (9 weeks) after transplanting. The crop had suffered somewhat from lack of water as the rain had been sparse and the plants looked dry. The tomato plants were assessed for viability height and width and uniformity on the day of the first harvest. There was a clear visual difference between the control plants and the plants treated with manure and compost, with the control plants looking visibly smaller and thinner than the plants in the other two treatments.

During the cropping period the weather was unusually dry for the season, resulting in a rather poor crop. In terms of general observations the farmer did not notice any differences in weed occurrence between the three treatments, nor with regard to water infiltration, holding capacity or demand. There were no pest and disease problems and the crop was not sprayed.

The compost treatment performed better than both the cow manure and the control treatments. Slightly more plants survived and grew into viable plants in the compost treatment, but the difference between the three treatments was insignificant. Upon visual inspection (on an overall plot level), the tomato plants grown without any fertility input appeared smaller than the ones given compost or cow manure (Table D4.1). The plant height and width measurements showed that although the height did not differ very much, the width of the plants were clearly different with the control plants being much less ‘bushy’ than the plants in the other two treatments (Table D4.3). In terms of uniformity there were no clear differences (Table D4.2).

*Table D4.1 Plant survival assessed on the first day of harvest and average height and width of tomato plants, based on the average measurement of 11 plants per plot (treatment average)*[50]

| | **No of dead/missing plants** (out of 70x4 plants) | **Survival rate** (%) | **Plant height** (cm) | **Plant width** (cm) |
|---|---|---|---|---|
| Compost | 9 | 97 | 44.8 | 50.8 a |
| Cow Manure | 11 | 96 | 43.6 | 49.4 a b |
| Control | 22 | 92 | 41.9 | 38.2 b |

Significant at 10%
LSD = 8.6

*Table D4.2 Uniformity of tomato plants, (1=not, 2= fairly even/uneven, 3=even)*

| | **Block 1** | **2** | **3** | **4** | **Mean** |
|---|---|---|---|---|---|
| **Comp** | 2 | 1 | 2 | 3 | 2 |
| **Cow Man** | 1 | 1 | 3 | 3 | 2 |
| **Control** | 2 | 1 | 2 | 2 | 1.75 |
| **Mean** | 1.67 | 1 | 2.33 | 2.67 | |

*Table D4.3 Bushiness of tomato plants, (1=very small, 2=small, 3=medium, 4=big, 5=very big)*

| | **Block 1** | **2** | **3** | **4** | **Mean** |
|---|---|---|---|---|---|
| **Comp** | 4 | 3 | 5 | 4 | 4 |
| **Cow Man** | 3 | 5 | 5 | 4 | 4.25 |
| **Control** | 2 | 1 | 2 | 2 | 1.75 |
| **Mean** | 3 | 3 | 4 | 3.33 | |

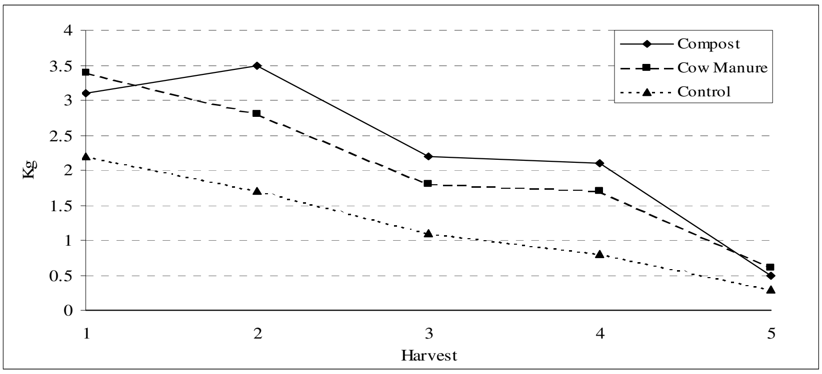
### *Harvest results*

According to the farmer, because of water limitation, the overall yield in all treatments was poor with the plants producing mainly small tomatoes. However, there were clear differences between treatments. The difference was significant ($P>0.05$) for both number of tomatoes picked and the weight. As expected both the cow manure and compost treatments performed better than the control. Whilst crop response to cow manure and compost were fairly similar, the effect of the compost was significantly higher than that of cow manure in terms of count. In terms of weight, there was no significant difference between the compost and the manure

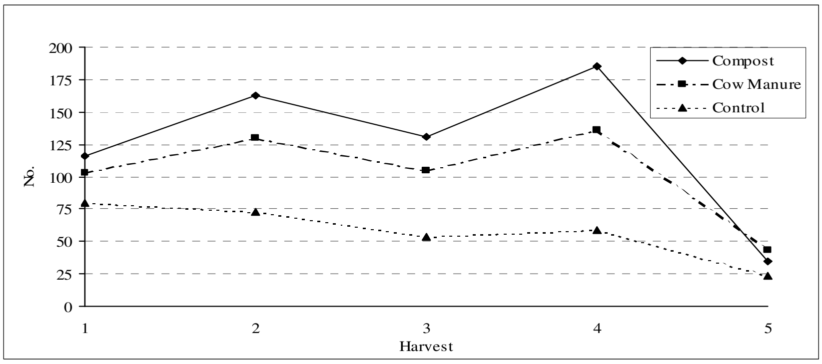
[50] The letters denote where there are significant differences between treatment means. Values with the same letter means that the difference is not statistically significant

treatments, but both were significantly higher than the control treatment. As Graphs D4.1 and D4.2 show, the compost treatment consistently produced more tomatoes except in the last picking when the plant performance dropped off more rapidly than the other two treatments.

From the fourth harvest the plants produced very small tomatoes. This is clear from Graphs D4.1 and D4.2 where the number of tomatoes picked went up whilst the harvested weight declined.

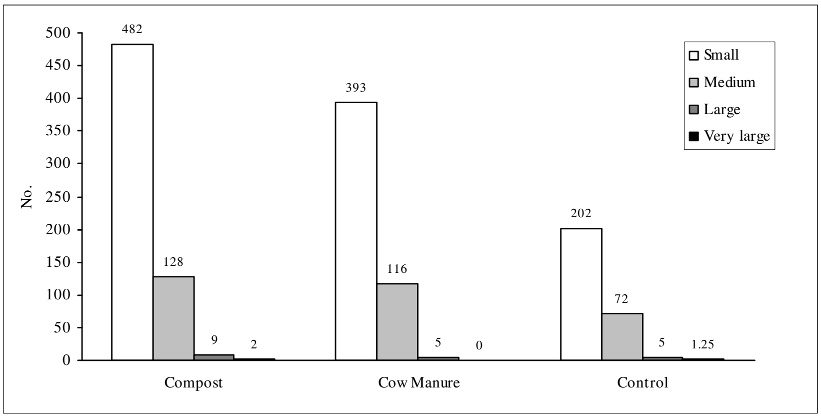



*Graph D4.1 Weight of tomatoes harvested at each picking date, (plot average, kg)*




*Graph D4.2 Number of tomatoes harvested at each harvest date in all size categories, (plot average)*

Graph D4.3 illustrates that whilst the compost treatment produced more tomatoes than both the cow manure and the control treatments, the tomatoes were smaller. This explains why the difference between the compost and cow manure treatments were significant for count but not for weight.




*Graph D4.3 Total number of tomatoes harvested in the different size categories, (plot average)*

## Chilli Pepper

### *Pre Harvest Assessment*

There were no pest and disease occurrences and the crop was not sprayed. No differences in weediness were observed between treatments. The farmer noted that the compost treatment required more water in order to perform well. He was giving the same amount of water to all treatments, but noticed that the compost treatment dried out faster and would probably have benefited from receiving more water.

As in the tomato crop the compost treatment performed best, but the differences between treatments were less clear-cut. The survival rate pf plants ranged between 86% and 73% with plants in the compost and NPK treated beds performing better than the ones in the cow manure and control beds (Table D4.4). The differences were however, not statistically significant. Again, in terms of height and width of the chilli plants at maturity, there were no statistically significant differences between treatments.

*Table D4.4 Plant survival and height and width of chilli plants, at the fifth picking, when the plants were fully matured, (based on the average measurement of 10 plants/plot)*

| | **No of dead/missingplants** (out of 40x4 plants) | **Survival rate** (%) | **Height** (cm) | **Width** (cm) |
|---|---|---|---|---|
| Compost | 23 | 85.6 | 38.3 | 38.3 |
| Cow Manure | 43 | 73.1 | 37.6 | 35.8 |
| NPK | 27 | 83.1 | 35.1 | 32.2 |
| Control | 39 | 75.6 | 37.5 | 37 |

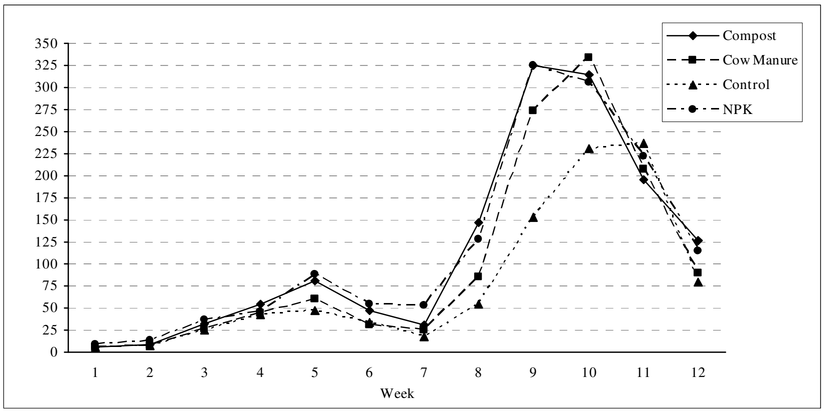
*Harvest Results*

The chillies were picked once a week for a period of 13 weeks. The first harvest was done, 10 weeks after transplanting.

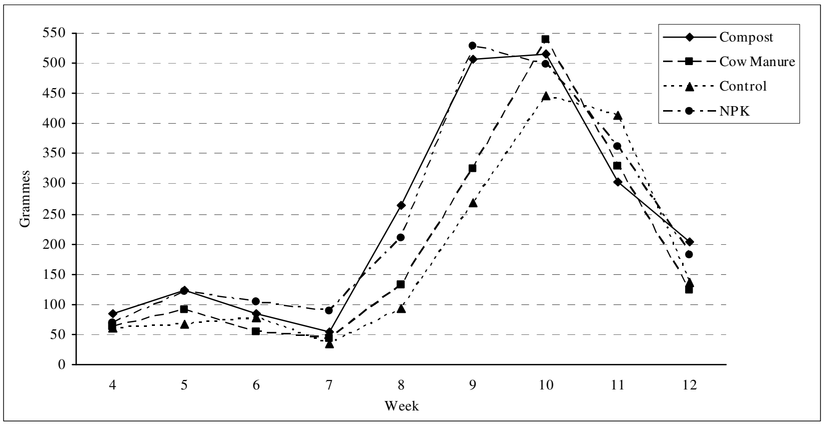
Although there were differences in yield between the treatments, they were not as clear-cut as in the tomato crop. In terms of the number of chillies picked over the 13 weeks, the differences were statistically significant (P.0.05) with the compost and NPK treatments performing better than the cow manure and control treatments. A similar trend was recorded for weight, but the differences were not statistically significant.

Graphs D4.4 and D4.5 show that there was a gradual increase in production until week five, when due to dry weather there was a two-week drop-off. After week seven production increased markedly to peak in the tenth week of picking. After week twelve the farmer judged the crop to have exhausted its production potential. Thus in week 13 the plants were picked clean and the crop removed.

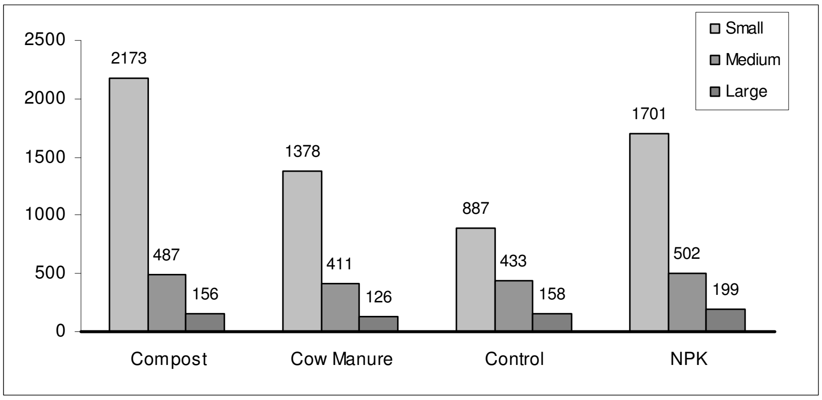
The farmer's opinion at the end of the cropping period was that the compost treatment had performed best followed by NPK, cow manure and control, in that order. This is backed up by the data.




*Graph D4.4 Number of chillies harvested each week, (plot average)*




*Graph D4.5 Weight of chillies harvested each week, (plot average)*




*Graph D4.6 Total number of peppers harvested in the different size categories, (plot average over a period of 13 weeks)*

## Cabbage

The spraying with neem and Bacillus thuringiensis successfully killed aphids and caterpillar larvae on the crop. At six weeks after transplanting the crop looked very healthy and clear differences could be seen between the treatments. However, towards the end of the cropping period the crop became re-infested with aphids that badly damaged the crop and resulted in a poor harvest. Again, the farmer noted that the compost treated beds dried out more quickly than the other beds. He also noted that there was more weed growth in the compost beds.

### *Pre Harvest Assessment*

Plants grown with fertilizer were variable in size and a large proportion of the transplants died off and had to be replaced. In spite of using the application rate and method recommended by the extension service, it appeared that the NPK application was too strong for the juvenile plants (Table D4.5). The survival rate of plants was best in the compost (99%) and cow manure (97%) treatments. In the NPK treatment as many as 11% of the plants failed, whilst in the control treatment 6% of plants failed. This difference was significant.

The compost treatment also produced the most uniform plants, followed by cow manure, control and NPK in that order. Upon visual inspection plants in the compost and NPK treatments had a darker green colour than those in the cow manure and control beds. At six weeks after transplanting, the control treatment stood out as being clearly smaller than the other treatments. Statistically this was highly significant. The size between the other three treatments was not very different.

*Table D4.5 Plant survival and diameter of cabbage heads 6 weeks after transplanting, based on the average measurement of 10 plants per plot (40 plants in total)*

| | **No of plants that were replaced** plot average | **Number of missing/unviable plants** (not counting the replaced ones) | **Failed plants** (from the first transplanting, plot average) | | **Head Diameter** (cm) |
|---|---|---|---|---|---|
| | | | No | % | |
| Compost | 0.8 a | 2 | 1.25 a | 1 | 53.1 a |
| Cow manure | 3.3 a b | 2 | 3.75 a b | 3 | 53.3 a |
| NPK | 16 c | 11 | 13 c | 11 | 50.8 a |
| Control | 4 b | 13 | 7.25 b | 6 | 39.6 b |
| | Significant at 5% LSD = 2.9 | | Significant at 5% LSD = 5.58 | | Significant at 5% LSD = 4.55 |

The plants in the compost and cow manure amended beds were more uniform than those in the NPK and control ones. The NPK treatment had particularly poor uniformity due to die-outs with subsequent plant replacement.

*Table D4.6 Uniformity of cabbage plants 4 weeks after transplanting (16 Oct 2000)*

| | **Block 1** | **2** | **3** | **4** | **Mean** |
|---|---|---|---|---|---|
| **Compost** | 3 | 4 | 4 | 4 | 3.75 |
| **Cow Man** | 2 | 3 | 3-4 | 3-4 | 3 |
| **NPK** | 1 | 2 | 1 | 1 | 1.25 |
| **Control** | 3 | 2 | 3-4 | 2-3 | 2.75 |
| **Mean** | 2.25 | 2.75 | 3 | 2.75 | |

*Harvest Results*

In the eighth week the cabbage plants were badly infested with aphids, which virtually ruined the crop. However, the crop was still harvested and the differences between treatments that had been clear on visible inspection prior to the attack were still showing even though the cabbage heads had become small and deformed. The crop was harvested over three times with four-day intervals. Both the compost and the cow manure treatments produced significantly more cabbage heads than the NPK and control treatments. Although the compost treatment produced more than the cow manure the difference was not statistically significant. In terms of weight the pattern was the same. Compost and cow manure produced a significantly higher yield than the NPK and control treatments. There were no significant differences between compost and cow manure treatments, nor between the NPK and control treatments.

The failure of the NPK treatment to produce a good crop of cabbage was likely to be due to the spot application method used which resulted in a too high a nutrient concentration near the root of the plant. The farmer was of the opinion that the crop would have performed better if the fertiliser application had been added at one month instead of two weeks after transplanting.

## Okra

*Pre Harvest Assessment*

The compost treatment did not do too well this time. This may be due to the fact that by this time too much compost had been supplied. The NPK treatment faired similarly. In contrast to previous crops, plants in the control treatment grew well resulting in a better performance in this treatment than in the compost (and NPK) treatments. The results indicated that emergence and take initial plant growth was slower in the compost amended beds (Table D4.7). A visual inspection indicated that there was not difference in weediness between treatments. Just like in the previous crops, the compost beds tended to dry out quicker than the other beds.

*Table D4.7 Emergence and early development of Okra seedlings, (plot average, 52 plants/plot)*

| | **Emergence 17 days after sowing** | | **Emergence 21 days after sowing** | | **Proportion of plants with only cotyledon leaves 21 days after sowing** | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| Compost | 39 | 75 | 49 | 93 | 21 a | 39 |
| Cow manure | 49 | 93 | 52 | 99 | 11 b | 20 |
| NPK | 38 | 72 | 49 | 95 | 22 a | 41 |
| Control | 45 | 86 | 50 | 95 | 14 b | 27 |

Significant at 10%
LSD = 6.93

In terms of plants surviving/plant emergence there was no statistically significant differences between treatments. The assessment of the number of plants that had only coteledon leaves at 21 days, did not reveal any statistically significant difference at 5%, but at a 10% level of analysis the difference was significant, with the NPK and compost treatments performing better than the cow manure and control treatments.

Upon visual inspection (on an overall plot level) five weeks after sowing, the cow manure and control treatments looked best. Plants grown in the compost beds looked worst, both in terms of size/bushiness and uniformity. The NPK treatment too faired poorer than the cow manure and control treatments. There was no clear difference between the control and cow manure treatments.

*Table D4.8 Uniformity of okra plants at 5 weeks after sowing, (1=uneven, 5=even)*

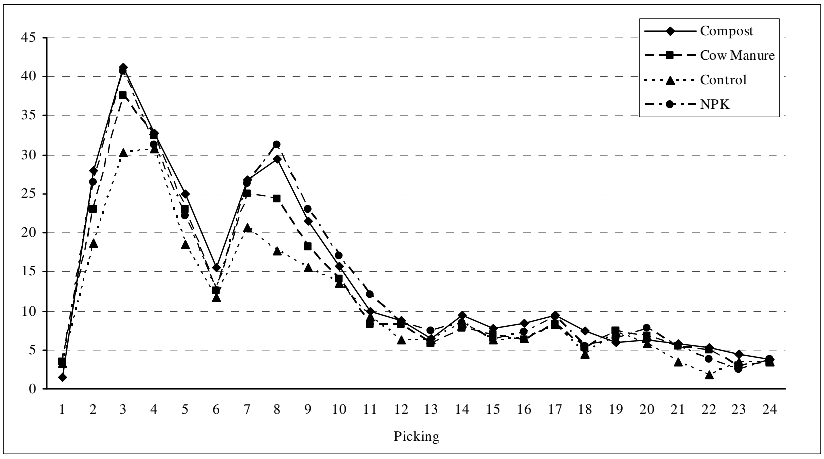
| | **Block 1** | **2** | **3** | **4** | **Mean** |
|---|---|---|---|---|---|
| **Compost** | 2 | 2 | 1 | 1 | 1.5 |
| **Cow Man** | 4 | 3 | 4 | 2 | 3.25 |
| **NPK** | 4 | 3 | 2 | 2 | 2.75 |
| **Control** | 2 | 3 | 1 | 1 | 1.75 |
| **Mean** | 3 | 2.75 | 2 | 1.5 | |

*Table D4.9 Ranking of best looking treatment, (not uniformity) (1=best, 4=worst)*

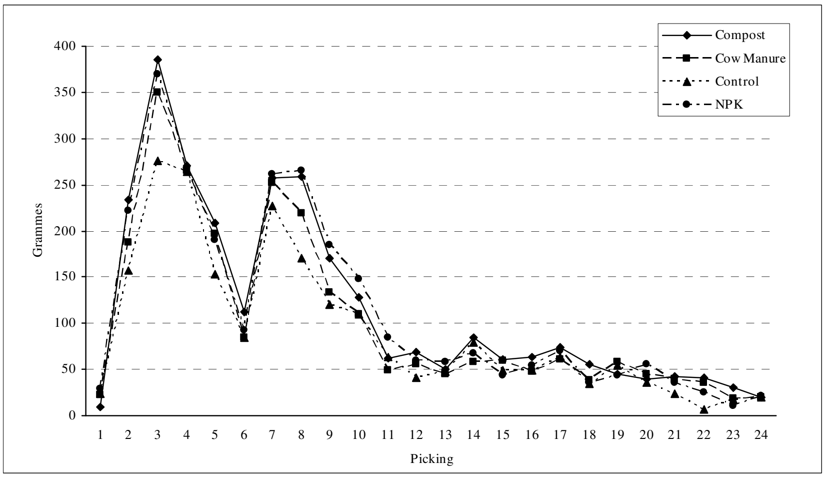
| | **Block 1** | **2** | **3** | **4** | **Mean** |
|---|---|---|---|---|---|
| **Compost** | 3 | 4 | 3 | 3 | 3.25 |
| **Cow Man** | 1.5 | 3 | 1 | 1 | 1.63 |
| **NPK** | 1.5 | 1 | 3 | 2 | 1.88 |
| **Control** | 4 | 2 | 2 | 3 | 2.75 |
| **Mean** | 2.5 | 2.5 | 2.25 | 2.25 | |

### *Harvest results*

The okra was harvested every four days during 11 weeks, which amounted to a total of 24 pickings. Having struggled with initial establishment, the plants in the compost amended beds produced a comparatively good crop in the end. There were no significant differences between the treatments in terms of the number of okras picked or the overall harvested weight. Nor were there any differences in the size distribution of okras produced from the different treatments (Graphs D4.7 – D4.9).

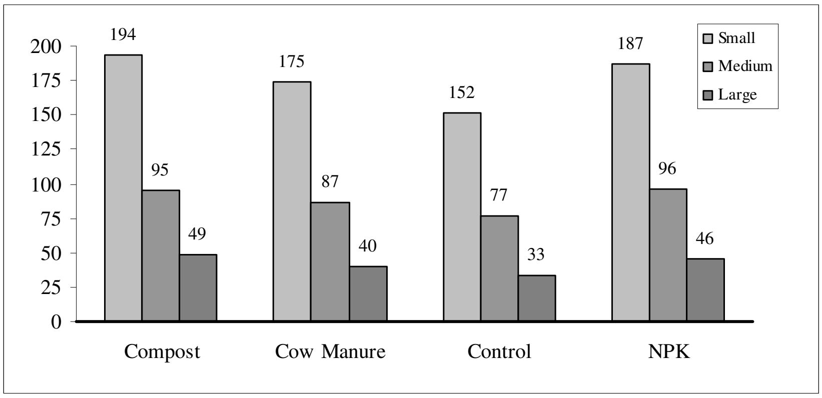



*Graph D4.7 Number of okras harvested at each picking, (plot average)*




*Graph D4.8 Weight of okras harvested at each picking, (plot average)*

There were no significant differences between treatments. At this point too much compost had probably been applied to the land, particularly in view of the fact that okra does not require very nutrient rich conditions.



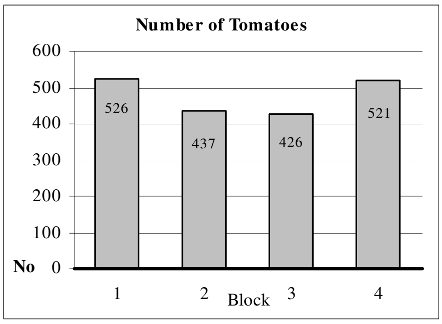

*Graph D4.9 Total number of okras harvested in the different size categories, (plot average)*

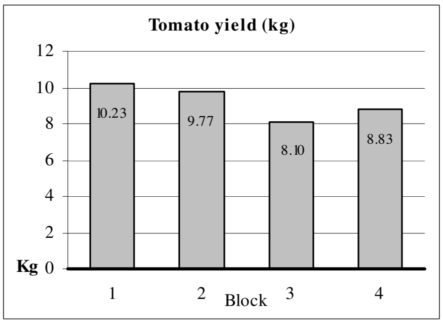
## Block effect

There was a significant block effect in all the crops except cabbage. Block 4, located at the upper right hand side (north-eastern) corner of the experimental area, produced the poorest results. In the first crop the performance in block 4 was comparable to the other blocks, but the difference became more marked with time, and in the final okra trial, the crop was so poor it could best be described as a failure. In the first, tomato crop block 2, also located at the top of the field (north western corner), produced the poorest results, but in subsequent crops this block produced comparable results to cops grown in other blocks. Block 1 was the block which consistently produced good results.

The poor performance in Block 3 in the okra crop could be ascribed to the fact that some goats accidentally got into the trial area and damaged the juvenile plants in this part of the field.

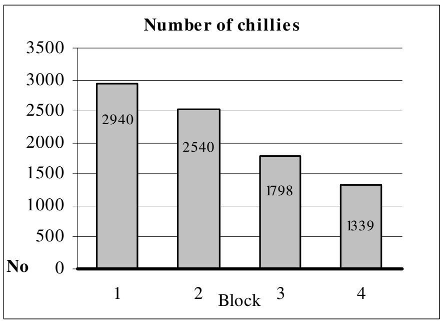
NPK treatment could have done poorly because the plots were located at the outer edges of each block, which means that they were in the poorest ends of B2 and B4 (which were the poor blocks).

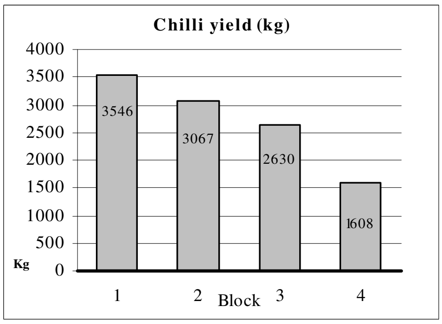



Significant at 5%

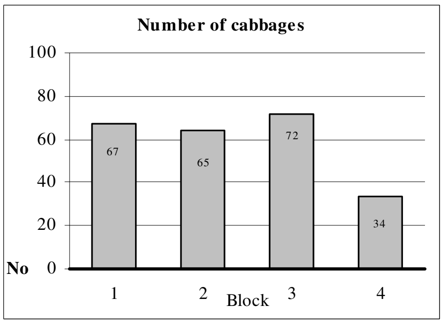
Not significant

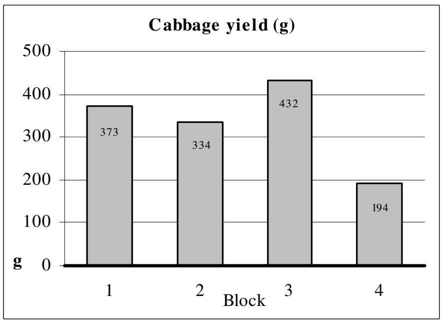



Significant at 5%

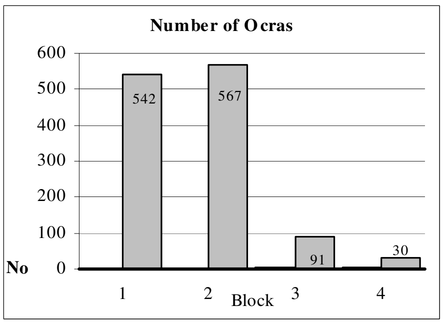
Significant at 5%

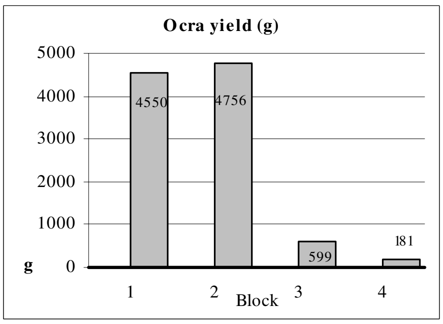



Not significant

Not significant




Significant at 5%

Significant at 5%

*Graphs D4.10 a-h Block effect in the different crops*

# APPENDIX E – RELATIVE COST OF DIFFERENT FERTILISER INPUTS

Two types of cost comparisons between compost, chicken manure and artificial fertiliser were made:

1. One comparing the cost of using the application rates generally used by farmers and/or recommended by the agricultural advisory service, in relation to two of the compost application rates used in the research (50t/ha and 25t/ha).
2. The other comparison made is that of the relative cost of the different fertility inputs in relation to the amounts of primary nutrients (N, P, K) they supply.

## Application Rates on which the cost comparisons are based

*Cost of using poultry manure*

Assuming a cost of transport of 30 000 cedis for 30 20 kg sacks, the cost of poultry manure to the farmers is 50 cedis per kg, or 50 000 cedis/ tonne.

With an application rate of 20-25 tonnes/ha the cost would be 1-1.25 million cedis per ha (£105-132). With a typical bed size of 10 square metres growers spend in the region of 1000 cedis per bed for each crop (£0.11).

*Cost of using artificial fertilisers*

Compound fertiliser is applied either in solution as a starter, or spot applied to the crop at 10-14 days after transplanting. Spot application of NPK 15:15:15 at 12 g/plant was the method and rate recommended by the extension service to the on-farm trial farmer and used in the on-farm trial. As such this is (the fertiliser and rate) used as an example here to compare input costs with compost for crops other than lettuce. In lettuce production it is common to apply the fertiliser in solution several times during the growing period, totalling 600 kg/ha.

When spot application is used, the rate of application to any given land area is dependent upon planting density, which in turn depends on the crop. For crops such as cabbage, pepper and tomato a plant spacing of approximately 40 cm (i.e. 6 plants per square metre) is common. Lettuces are planted much denser. For this crop 16 plants per square metre is typical. However, as spot application is less common on lettuces, the planting density has no bearing on the amount of fertiliser applied to a given land area. Based on a plant density of 6 plants per square metre, the application rates recommended by the agricultural services and the fertiliser prices at the time of the research[51], the cost of artificial fertilisation would be

[51] At the time of the research (March 2001) the cost of NPK 15:15:15 at the farm shop used by the majority of vegetable growers in Accra (AGLOW) was 3500 cedis for a 1 kg bag, 50 000 cedis for a 25 kg sack and 90 000 cedis for a 50 kg sack.

With a plant density of 6 plants per square metre and an application rate of 12g/plants the cost would be:

| | | | | | |
|---|---|---|---|---|---|
| 1 kg bag | ¢ 2.52 million per ha | (£265) | or | ¢ 2520 on a $10m^2$ bed | (£0.27) |
| 25 kg bag | ¢ 1.44 million per ha | (£152) | or | ¢ 1440 on a $10m^2$ bed | (£0.15) |
| 50 kg bag | ¢ 1.3 million per ha | (£137) | or | ¢ 1300 on a $10m^2$ bed | (£0.14) |

With an application rate of 600 kg/ha the cost would be:

| | | | | | |
|---|---|---|---|---|---|
| 1 kg bag | ¢ 2.1 million per ha | (£221) | or | ¢ 2100 on a $10m^2$ bed | (£0.22) |
| 25 kg bag | ¢ 1.2 million per ha | (£126) | or | ¢ 1200 on a $10m^2$ bed | (£0.13) |
| 50 kg bag | ¢ 1.08 million per ha | (£114) | or | ¢ 1080 on a $10m^2$ bed | (£0.11) |

The cost of fertiliser varies greatly depending on the quantity bought. Small scale vegetable producers tend to buy the fertiliser in smaller quantities, partly due to the initial outlay, partly due to lacking storage facilities, thus end up paying more. If fertiliser is bought in the smaller 1 kg bags, the cost of fertilisation is more than double that of chicken manure.

### *Cost of using municipal waste compost*

With an application rate of 50 tonnes/ha the cost would be:

| | | | |
|---|---|---|---|
| Compost bought in bagged form | ¢ 7.5 million per ha (£789) | or | ¢ 7500 on a 10 $m^2$ bed |
| Teshie compost bought in bulk | ¢ 2.5 million per ha (£263) | or | ¢ 2500 on a 10 $m^2$ bed |
| James Town compost bought in bulk | ¢ 3.35 million per ha (£353) | or | ¢ 3350 on a 10 $m^2$ bed |

With an application rate of 25 t/ha would cost would be:

| | | | |
|---|---|---|---|
| Compost bought in bagged form | ¢ 3.75 million/ha (£395) | or | ¢ 3700 on a 10 $m^2$ bed |
| Teshie compost bought in bulk | ¢ 1.25 million/ha (£132) | or | ¢ 1250 on a 10 $m^2$ bed |
| James Town compost bought in bulk | ¢ 1.675 million/ha (£176) | or | ¢ 1675 on a 10 $m^2$ bed |

Another way of comparing the relative cost of different fertility inputs is to look at the cost in relation to the amount of nutrients supplied. Based on the average nutrient values/contents of the compost and chicken manure samples analysed, the relative cost of supplying 100kg/ha of N, P and K respectively was calculated. The results of this calculation are displayed in Table E5.1. The inputs are listed in the order of cost for each nutrient from the least to the most expensive.

*Table E5.1 The cost of different soil fertility inputs in order to supply a given amount of nutrients*

| Rank | | | Cost cedis | Cost £ | Amount needed (t/ha) |
|---|---|---|---|---|---|
| **Cost of supplying 100 kg N / ha** | | | | | |
| Least expensive | 1 | Chicken manure | 193 500 | 20 | 3.87 |
| | 2 | JT compost in bulk | 623 100 | 66 | 9.3 |
| | 3 | NPK in 50 kg bag | 1 206 000 | 127 | 0.67 |
| | 4 | NPK in 25 kg bag | 1 340 000 | 141 | |
| | 5 | JT compost in sacks | 1 395 000 | 147 | |
| | 6 | Teshie compost in bulk | 1 850 000 | 195 | 37 |
| | 7 | NPK in 1 kg bags | 2 345 000 | 247 | |
| Most expensive | 8 | Teshie compost in sacks | 5 550 000 | 582 | |
| **Cost of supplying 100 kg P / ha** | | | | | |
| Least expensive | 1 | JT compost in bulk | 150 750 | 16 | 2.25 |
| | 2 | Chicken manure | 291 000 | 31 | 5.82 |
| | 3 | JT compost in sacks | 337 500 | 35 | |
| | 4 | Teshie compost in bulk | 1 200 000 | 126 | 24 |
| | 5 | NPK in 50 kg bag | 2 754 000 | 290 | 1.53 |
| | 6 | NPK in 25 kg bag | 3 060 000 | 322 | |
| | 7 | Teshie compost in sacks | 3 600 000 | 379 | |
| Most expensive | 8 | NPK in 1 kg bags | 5 355 000 | 564 | |
| **Cost of supplying 100 kg K / ha** | | | | | |
| Least expensive | 1 | Chicken manure | 292 500 | 31 | 5.85 |
| | 2 | Teshie compost in bulk | 380 000 | 40 | 7.6 |
| | 3 | Teshie compost in sacks | 1 140 000 | 120 | |
| | 4 | NPK in 50 kg bag | 1 458 000 | 153 | 0.81 |
| | 5 | NPK in 25 kg bag | 1 620 000 | 170 | |
| | 6 | JT compost in bulk | 2 030 000 | 214 | 30.3 |
| | 7 | NPK in 1 kg bags | 2 835 000 | 298 | |
| Most expensive | 8 | JT compost in sacks | 4 545 000 | 478 | |