FIELD-CROP ECOSYSTEMS, TRENDS AND MODELS TO IMPROVE MANAGEMENT OF RESOURCES IN MOCAMBIQUE'S AGRICULTURAL PRODUCTION SYSTEMS

Kemal Vaz

Institutionen för lantbruksteknik

Rapport 218
Report

Swedish University of Agricultural Sciences
Department of Agricultural Engineering

Uppsala 1997
ISSN 0283-0086
ISRN SLU-LT-R--218--SE

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Preface

This report consists of two general parts. The first part describes the problematic situation in the analysis of agricultural production systems, with a retrospective into historical phases in agriculture production and a prospective of what can constitute a new paradigm when looking at systems. In order to improve management of resources in agriculture production methodologies are proposed and briefly discussed.

In the second part, using data from a National Survey from 1994, done by the Ministry of Agriculture, an analysis of the rural families in Moçambique in terms of crop production is made. Different criteria to choose technological systems is discussed and options proposed. Finally, a model to describe farmer's behavior is proposed, which facilitates a better understanding as well as provide an interesting tool in order to improve farm production in this semi-subsistence sector of agriculture.

Acknowledgments

I am thankful to: Prof. Dr. José Negrão, Dr. Girma Gebrensebet and Prof. Nils Möller in their contribution in structuring my work and fruitful discussions. To the Ministry of Agriculture, Department of Statistics my appreciation for the possibility to use such an important data-base. To Lars Carlsson, for the long hours spent together in data processing and variables description, and to Prof. Ulf Olsson, in the contribution on understanding the design of national statistical surveys and analysis. To my colleagues, Alfredo Nhantumbo and Alfredo de Toro in their support on background material. To Prof. Rodrigues Pereira, for his early encouragement in pursuing these studies. To Merritt Becker for the helpful support in editing this document. To the Swedish International Development Agency for the financial support. To finish, I also like to include many other people which contribution was valuable in order to achieve this final report.

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Background

Due to various economical, technological and sociological factors in Moçambique, declined agricultural productivity is a serious problem. If this decline continues the natural resources' rate of deterioration will be unsustainable. In order to tackle the current problematic situation for the peasant farmer in Moçambique, it is necessary to improve the use of resources in their field-crop ecosystems.

First, an outlook on the world's trends in dealing with agricultural resources is presented, as well as methodologies to approach and analyze current crop-ecosystems. Second, using the 1994 National Agricultural survey, pertinent data is identified to describe and analyze different technological levels. The results so far indicate that different technologies are used by rural families mainly to achieve their subsistence levels. Agricultural commercial production does not seem to be affected by the technology used. The main reasons for these facts are explored in the following chapters.

1. Introduction

Searching for sustainable production systems in Moçambique is the main motivation for this work. In Moçambique, food security is critical when discussing sustainable systems. Besides low productivity as well as unfavorable climatic conditions and war in the past, low food production is often derived by not understanding the farmer's behavior and his goals within the existing system.

With stabilization of the country due to peace and economic reform, new socio-economic pressures from the national and international community will probably guide, in the short term, the vulnerable agricultural sector, in the "blind" increase of productivity (through a massive application of non-renewable resources and/or indiscriminate use of exogenous "culture"). This trend can be redirected if an explicit agricultural development policy that deals with this phenomena is available.

Traditional farming systems are unable to cope with changes such as increase in population and soil bio-ecological threshold values. However, traditional forms of agriculture are the result of adaptation by people to production conditions in their environment. Understanding the historical agricultural development and the decision-making process concerning the allocation of resources by the traditional farmer will enable a more effective introduction of new technologies.

1.1 Objectives

The main objectives of the current work are:

a) To describe the actual situation and the existing methods used in the identification and analysis of field-crop ecosystems.

b) To distinguish the technological situation and analyze potentially better models in terms of management of resources, adapted to social, economical and cultural conditions of farmers in Moçambique.

c) To provide a framework for future research in agricultural production systems.

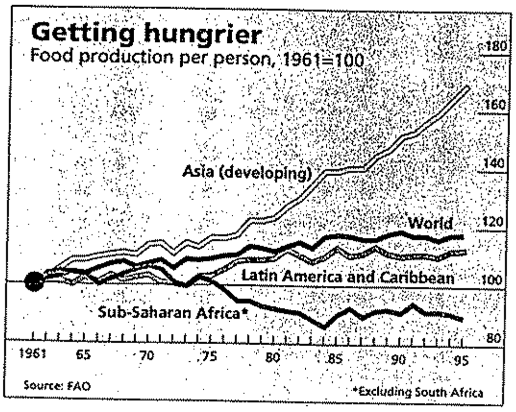
d) To develop recommendations to improve management of power units in the Moçambican situation.

2. THE PROBLEM SITUATION ON THE CONTINENT

2.1 Food Production

The basic problems facing African agriculture today are: how to increase output and trade levels by utilizing inputs that are external to the farm or country, and how to deal with the lack of capabilities for commanding access to inputs or developing technologies that can reduce cost, achieve sustainability, and enhance environment.

Figure 2.1- Trends in food production in developing countries , 1961-95 (source: The Economist 1)



Per capita food production in Africa between 1961 and 1995 actually dropped by 12%, ("The Economist 1 ; FAO, 1986) whereas it advanced in developing countries elsewhere, see figure 2.1 . This decline is partially self-induced. The present work will approach some of these internal facts which negatively affect farming production at the rural family level. However, the external part, is to be blamed on rich industrial countries, who proclaim and defend a free trade in manufactured goods and services in which they have a comparative advantage, but remain determinedly proteccionist about food, a sector in which African countries offer competitive products at attractive prices. Another factor in this arena is the periodic dumping on African markets of food surpluses (produced usually under subsidies) ruining prices for local farmers. Improving agricultural production levels is achieved by minimizing the negative effects of internal facts as well as external ones.

The access to land and the quality of the soil are very important in the process of developing of new agricultural systems. Holden (1993), cites the persistence in the slash-and-burn system in Northern Zambia instead of the adoption of modern technologies such as hybrid maize and fertilizer systems which are economically more favorable. This is an example of the viability of traditional production system due to the availability of sufficient woodland, that allow longer fallow periods for soil fertility regeneration.

African agriculture is practiced on highly fragile soils of low inherent fertility, where the biological processes of fertility maintenance, characteristic of the conservation model, constitute the main resource management strategy for increasing productivity (Okgibo, 1991). But a threshold has to be overcome, due to population pressure, that without external resources is difficult to attain and so is sustainability of the system.

In response to demands from increased population pressure the area of exploitation of resources that is concentrated on the home garden or that is used to feed the household or village, continues to expand, until it reaches the limit of the physical land availability. Access to land seems to not be a problem at least in many parts of Africa where the traditional systems are still allowed to capitalize on large quantities of biomass. It also seems that farm-households with expanding populations and labor forces can expect to obtain access to more land as they expand. This seems to be the general case at least in Moçambique (Table 2.1), in Swaziland (Low, 1982), and in Zambia (Holden, 1993), since larger farm-households have better claims to land than smaller ones, according to the traditional land tenure system. In this case the introduction of improved production systems can be hampered because the end of the moving frontier (explained in more detail on the Chapter "Agriculture History") is not reached at the individual household, village, or macro-urbanized town level. Also in

Mocambique, marketing, processing, storage and transport in the food system is handicapped. This also introduces a certain negative effect towards increasing yields through innovative technologies.

Table 2.1- Land Use with Household Size (source: author from Inq/94)

		Cropped area per household number of member classes											
		01-3			04-6			07-9			10 +		
		N° of House-holds	Farm area		N° of House-holds	Farm area		N° of House-holds	Farm area		N° of House-holds	Farm area	
	N° of obs.	SUM	SUM	average	SUM	SUM	average	SUM	SUM	average	SUM	SUM	average
Country	1 657	74 357	111 565	**1,50**	122 119	251 800	**2,06**	78 658	180 393	**2,29**	37 100	120 633	3,25
South	566	27 372	48 812	**1,78**	43 722	94 837	**2,17**	34 442	78 979	**2,29**	22 198	68 546	3,09
Center	560	17 124	17 266	**1,01**	44 131	79 584	**1,80**	29 356	64 212	**2,19**	11 942	41 731	3,49
North	531	29 863	45 485	**1,52**	34 265	77 379	**2,26**	14 858	37 202	**2,50**	2 960	10 356	3,50

Obs. in this Table only two provinces per geographical area were randomly chosen

Another issue in management of resources in poor countries is that the few resources available are not used in the best way - instead there may be a waste of resources - then the best way to manage them in order to achieve spectacular growth is to waste less of those we already have. Labor is an example; if Moçambique was using labor as well as it could, large emigrations of labor to RSA and other richer countries ought to raise the productivity of workers left behind (because each worker now has more capital, land and other resources to work with). But emigration does not seem to have this effect. On the other hand the continent's comparative advantage lies in its natural beauty and wildlife, its metals and minerals and its agriculture which are not being explored. It seems that capital and knowledge as well natural resources are being massively squandered in Moçambique as in many other countries.

2.2 Sustainable Systems

Sustainability arises out of different socio-economic circumstances and activities in developing and developed countries. While pollution and environmental degradation caused by deforestation, desertification, demographic pressures, soil erosion and water contamination result mainly from poverty in the developing countries; acid rain, atmospheric pollution, contaminated water, environmental mutagens and carcinogens as well as toxic waste are the result of wealth in the developed world. Furthermore, while the lack of capital and access to inputs and technologies are almost always blamed as the main reason for adverse environmental effects in developing countries, it is the excessive use of some otherwise appropriate technologies and the inappropriateness of some costly inputs that is causing concern in the developed world. Inappropriate technology use has caused environmental pollution, while in the absence of subsidies, costly inputs are increasingly resulting in uneconomical agricultural production systems.

Sustainability can only be achieved when all resources to be used in the production system are within the capabilities of the farmer, i.e. to own, hire, maintain, and manage with increasing efficiency, and to continuously achieve desirable levels of productivity with minimal or no adverse effects on the resource base, human life, or environment quality.

As a general guideline, development of sustainable agricultural production systems calls for the lowering of input levels in the high-input systems and for those of low input to be raised in a cost-effective manner. This involves a combination of elements of traditional production systems and their component technologies that make maximum use of internal biological inputs with affordable elements of the high-input system.

2.3 Economic Growth in Developing and Developed Countries

Most of the time the remedy for poverty is economic growth. In rich countries, this growth was and still is achieved at a certain cost: as congestion, pollution, and life stress.

Until the last 10 years, economics neglected the study of growth, and mainly concentrated in macro economic policy. Nowadays, human welfare has become the center of policy issues. This is not to say that economists have not thought about them. Smith (1776) was one of the originators of the building-blocks for understanding growth. He stated that the engine of growth was to be found in the division of labor, in the accumulation of capital and in technological progress. He emphasized the importance of a stable legal framework, within which the invisible hand of the market could function, and he explained how an open trading system would allow poorer countries to catch up with richer ones. David Ricardo in the early 19th century, formalized the notion of diminishing returns (Hill, 1990). He showed how additional investment in land tended to yield an ever lower return, implying that growth would eventually come to a halt.

In the 50s, Robert Solow and Trevor Swan laid the foundations for modern growth (Hill, 1990). Their models, also called 'neoclassical growth model', describe an economy of perfect competition, whose output grows in response to larger inputs of capital (i.e., physical assets of all kinds) and labor. This economy follows the law of diminishing returns: each new bit of capital, given a fixed labor supply, yields a slightly lower return than the one before. Two crucial implications are inherent in these models. First, as the stock of capital expands, growth slows, and eventually halts. To keep growing, the economy must benefit from continual infusions of technological progress. Yet this is a force that the model itself makes no attempt to explain. In the jargon, technological progress is, in the neoclassical theory, "exogenous". The second implication is that poorer countries should grow faster than rich ones. The reason is diminishing returns, i.e. since poor countries start with less capital, they should reap higher returns from each slice of new investment.

What happens in practice is a very different situation. Concerning the first implication, it is empirically proven through good long term data on rich countries that modern growth rates are well above their earlier long-run average. This appears to contradict the first implication, that growth will slow over time. It may be that an acceleration of technological progress accounts for this, but this would mean that the main driving force of growth lies beyond the scope of growth theory.

Concerning the second implication - are poor countries catching up? When growth rates for 118 poor countries between 1960 and 1985 were compared to their growth in the 1960 level, they showed that instead, poor countries have tended to grow more slowly (The Economist 2). Is there any chance for poor countries to catch-up? In this way this theoretical plausible model does not seem to fit the real situation.

After a pause of 30 years, along came "new growth theory", which among other things questioned the law of diminishing returns in the neoclassical model. If in fact, an extra bit of capital does not yield a lower return than its predecessor, growth can continue indefinitely, even without technological progress. A second strand of new growth theory seeks to put technological progress into the model, imposing a further divergence from the neoclassical model. A firm will not bother to innovate unless it thinks it can steal a march on the competition and, for a while, earn higher profits. But this account is inconsistent with the neoclassical model of perfect competition, which rules out any "abnormal" profits. So another assumption of imperfect competition is made, making the model more realistic. The attention is now shifted to the conditions under which firms will innovate more productively. In this way, technological progress has begun to occupy a central place in the economist's thinking about growth. All these new theories emphasize human capital, which in a way only differs from the neoclassical view in the subtle way labor is measured.

Both approaches lack the consideration of government policy or if they do, they do it largely off-stage. Connections between policy and growth are tenuous and indirect. So the important role of government in both models is frustratingly out of influence.

Conditional convergence (Romer, 1986), a term used by the new empirical growth economists, is based on empirical data and shows that absolute convergence does not hold. That is, most of the times in models, to study some factors, other factors are kept constant, which does not correspond to the real situation. So growth in poor countries depends on what determines the "conditional" nature of the catch-up process. Are slow-growing countries held back by government policies that can be changed easily and quickly? Or are more fundamental forces at work?

Evidence is showing that government choices are primary. Some conditions would be found very favorable to higher growth rates and convergence, like free-market policies, open economies rather than closed ones, high human capitals relative to physical ones, the importance of investments associated to good policies, political stability and so on. New growth-influencing variables keep adding up to the list. The emerging conclusion at least shared by the majority, is that poor countries can indeed catch up, and that their chances of doing so are maximized by macro-policies that give a greater role to competition and incentives. Additionally, encouraging education, opening the economy to foreign technologies, promoting trade and keeping taxes low, mattered a lot.

Economic opportunities available in today's developing countries are indeed unprecedented. Paradoxically, the gap between the richest countries and the poorest (wider now than at any time in history) is itself a measure of that apparent non-development. The enormous wealth of the world's rich countries is due to nothing more than a strong legal infra-structure associated with advanced technology and accumulated capital. In the last 20 years technology is more readily transferable across borders than ever before. What is up to us is deciding how to make them applicable locally. In Moçambique, after so many years of unstability finally, conditions seem fertile for development and growth. These conditions are essential, and any sort of development can not progress if they are not taken care of.

The most recent national economic indicators make us believe that the basic conditions for development are slowly being created. Moçambique's economy, a fast-growing economy in the sub-Saharan Africa (figures issued by the Harvard Institute for International Development) grew by 7,4% in the first six months of 1996, where agriculture proved a successful sector with growth of 9,4%. In the same period, inflation was 15,2% against annual inflation of 54% in 1995 and 71% in 1994.

3. Historical Development of Agricultural Practices

Definitions about agriculture abound, but explanations about why the practice started, why it is diffused so widely, why it was adopted and what is, in evolutionary terms, a fairly rapid rate are hard to come by. Most of the evidence points to a combination of population growth and environmental stress as the principle factors in agriculture adoption and intensification. Agriculture is essentially an energy conversion process - the conversion of solar energy through the photosynthetic process to food for humans and feed for animals. The conversion process may be enhanced by the use of different combinations of other resources. The way these resources have been used has marked important stages in the history of agriculture.

3.1 First Agricultural Revolution

In agricultural history there have been several technological breakthroughs, sometimes called agricultural revolutions (Blaxter, 1972). The first agricultural revolution occurred between about 12 BC and 7000 BC, involving several steps towards settled agriculture.

It became evident to the early farmers that competition from weeds was serious for the survival of cultivated plants, and tillage was necessary to create a seedbed and decrease competition. During this time, a socially profound and drastic change occurred - foraging towards sedentism.

Due to this, planned and implemented ecological imbalance that increases productivity per unit area, by introducing more energy into the system resulted. Whereas the transition from foraging to farming was initiated and sustained by a complex of energetic, nutritional, and social impulses, further evolution of agriculture can be seen primarily as a matter of clear energy imperatives.

As a particular food production system reaches its limits, the affected population can migrate, stay and stabilize or decline. Another alternative is to adopt a more productive subsistence arrangement. The last option may not initially be any more appealing or probable than the other solutions. When it comes, the shift requires higher energy inputs so that even with higher food production the net return ratio may decline - but the higher edible energy flux will support a larger population.

The area required for human subsistence (carrying capacity) varies a lot according to geographic location, and the system used to "harvest" the required food. Interesting data about carrying capacities can be seen in Stout et al. (1979) and Clark and Haswell (1970).

A millennia after the first agricultural revolution, grain yields in better agroecological regions varied from two to four times compared to the quantity of seeds sown, corresponding approximately to a productivity of 0.4 - 0.8 t per ha. (Hannerberg 1971; Blaxter, 1972). In the three field system (2 years of grain, 1 of rest) the yields on the average soils were not above this. On the large river plains of Asia and Europe, in the Nile valley of Northern Africa and from volcanic soils, yields were higher (1.0 - 1.5 t per ha). Yield estimations for the river valley of ancient Egypt were 2 t per ha (Clark and Haswell, 1970). Plant nutrients and water were the limiting factors in subhumid and humid areas and semiarid and arid areas respectively.

What happened in the African continent during this time in terms of agricultural development? Okigbo (1989), using the concept of Territorialism and the Moving Frontier Model from Turner (1962) approaches an interesting explanation. The 'territory' imperative has been known to operate in agricultural development in Africa as well as in many other parts of the world since pre-historic times. Territorialism operates in such a way that individual animals or a group of them live in a fixed geographical area, and are usually able to defend their territory against intruders. The evolution of territory minimizes friction and aggression. The moving frontier is defined as the temporary boundary of an expanding society at the edge of substantially new lands. It operated locally between pioneer farmers and hunter/gatherers or pastoralists and cultivators. Before Arabs and Europeans came to Africa, the moving frontiers had ended between a tropical seed-growing complex in Western Africa and hunter/gatherers in the savanna areas in about 2000 BC and in the eastern and southern savannas in about 1000 AD. The end of the moving frontier occurred between a cattle pastoral complex and cultivators in the western savanna areas at about 1000 AD (Alexander, 1977). The coming of Islam and colonialism caused severe changes in the consequences of the end of moving frontiers, since intrusion of pastoralists into areas occupied by cultivators and vice-versa were permitted and sometimes forced following the new establishment of the colonial powers. These disturbances are hard to overcome, as we still observe acute clashes between different groups, even after independence was obtained in most cases, more than 10-15 years ago. Political and anthropological problems originating in the past can still be hamper to sustainable development.

3.2 Second Agricultural Revolution

The Industrial Revolution and population growth in Europe were the main factors to initiate this Revolution. Salient features were the supply of nitrogen through leguminous crops, the turning effect of the steel moldboard plough, and crops grown in a time sequence in the same field, such as cereals and root crops that were grown in a sequence with a legume-grassland ley. England is considered the home of crop rotation agriculture, because of the Norfolk crop rotation system (Chambers and Mingay, 1970). During this time, animal power partially replaced human labour, fertilizers and lime were gradually added as inputs and field drainage further increased the mineralisation of the organic matter. Grain yields increased to 1.5-2.0 t per ha (Blaxter, 1972).

Contrary to many people's beliefs about sustainable agriculture and an ecologically balanced system, when retrospectively looking at this period, the system was not at all balanced. Soil cultivation, and the turning of the sod, contributed to the mineralization of the organic matter conserved during the sod years. This revealed a gradual decrease in soil organic matter with time (Njös, 1994), during which increases in food output came largely from expanding cultivated area.

In many African countries, this period represented one of the most tragic for the rural families. Colonial powers which formalized their scramble for Africa at the Conference of Berlin in 1884-85, introduced new rules into the traditional agricultural production systems. Forced and cheap labor was used in order to produce commercial crops in the interest of the dominating powers. Because labor could be acquired so cheap, the interest in technology introduction was not an objective unless product price competition in the world markets was a factor. New varieties were introduced, but the most negative effect probably was the rupture of the traditional habit in the production of the subsistence crops, generating an extreme problem in terms of food supply in rural areas. The decisions of the rural family in allocating resources have been taken within a twofold framework: the colonial state and the customary laws.

3.3 Third Agricultural Revolution

The third agricultural revolution of the western world (also called the Chemistry Revolution), began around 1940, and was characterized by tremendous rise in yields from chemical and other inputs, a strong decline in human labour and by the replacement of animal power with full mechanization.

The input of energy per area of land, as illustrated in figure 3.1, was increased many times by massive applications of fertilizers, pesticides, and mechanical power, as well as by increased drying, irrigation and drainage. The crop rotation of grain-rootcrops-grain-ley yielded to grain-grain or grass-grass. It was also the time of new theories of reductionism and gradualism from von Liebig, Darwin and Gregor Mendel, and of the incrementalism and rationalism of the neo-economists, Menger and Walras and Jerons.

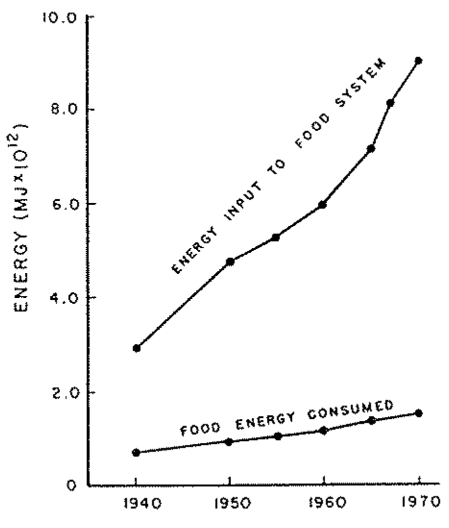


Figure 3.1- Energy used in the food system, 1940-70, compared to the heat content of food consumed (source: Stout, 1984)

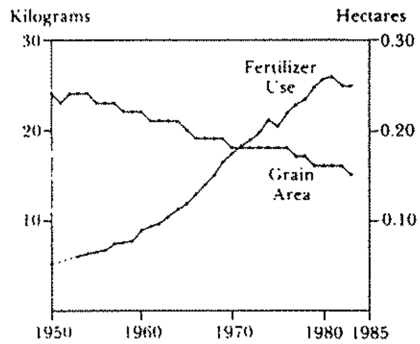


Figure 3.2- Substitution of grain area for fertilizer per person, 1950-83. (Source: Stout, 1984)

If mysticism, intuition and experience helped during the second revolution, the scientific method became available during this era. Economic theories to help the way people thought about agriculture, as well as specialized educational and research institutions to serve agriculture, also emerged during this phase.

Few can doubt the success of the application of what we might term the 'Liebigian paradigm' (based on the law of the minimum) on the growth of the agricultural production. However, the Chemical Revolution raised serious questions about environment, ecological balance and sustainability. The science of simplification is now showing some deficiencies in dealing with complexities.

During this time, an evident substitution of energy for land can be seen (figure 3.2). In the 50's when world population totaled 2.51 billion, the harvested area of cereals per person was 0.24 ha. As population growth outstripped cultivated area, the area per person dropped steadily to 0.15 ha by 1983. While the cropland per person decreased by one third, fertilizer consumption per person increased by a factor of five, climbing from just 5 kg in 1950 to 25 in 1983. On the contrary data available for Moçambique (last Agricultural Survey was in 1970) before Independence (Fagilde, 1987) indicate an average of 1,5 ha per household, and the more recent data for 1994 (Inq/94) almost 20 years later, shows a figure of 1,8 ha, with almost no use of chemical fertilizer and/or irrigation for the same unit and peasant sector. This might be an indication that land is still a flexible resource, and/or families can dedicate more time to agriculture than before.

It was also during this time that the European disengagement from Africa began. First in Ghana in 1957 and in the years to come, for the rest of the continent. After independence in 1975, Mocambique's capacity to feed itself may have been further damaged by an intellectual bias in the industrial countries (mostly of the Easthern block) against subsistence agriculture. Peasantry was mostly regarded with near-contempt, and leaders were urged to create an industrial base on the back of primary commodities. Peasants were herded off their scattered smallholdings into "Aldeias Comunais" (self help villages) and told to work together on large communal plots, sharing tractors, machinery, draught animal, ploughs, seeds, fertilizers and pesticides. The creation of large state-owned agriculture and trade enterprises with imported technology was another alternative which reduntly failed to succeed.

3.4 Fourth Agricultural Revolution or the Revolution to Come...

All the impressive successes in increasing physical yields, also meant that fewer farmers were able to produce more output, whilst due to surplus production, fewer people seemed to buy their produce. This meant the focus had to change from maximization of yield during the past phase, to optimization of return, i.e. from gross production to efficient production.

Interaction between the components and inputs and outputs became more important than dealing with single commodities which in turn allowed for agricultural economics and farm management to become disciplines for analysis and forecast. The present trends in agricultural development might also be expressed as "Biology Revolution", including developments within biotechnology, genetic engineering, mechanization, chemical inputs, advances in pest and disease control associated with information technology.

Furthermore, human concern towards sustainable systems and protection of the environment are forceful tools for a new type of agriculture, where non-renewable inputs might decrease as well as energy input per unit produced. Agricultural development is now facing three main paradoxes a) surplus production versus malnutrition; b) technological advances versus low income; and c) agricultural subsidies versus free trade. The crucial answer for the future is to reconcile these paradoxes bearing in mind an important problem - productivity versus environmental effects. A narrow obsession with increased productivity has obscured the fact that there has been a high cost to agricultural progress through the degradation of the rural environments, both biophysical and sociocultural.

To move from a production focus that essentially ignores people except as objective components, to one that recognizes people and their relationships with the environment as the central concern of agricultural development, requires a major shift in the worldview of farmers and of professionals who support them - a new paradigm.

Technological thinking, often characterized by a reductionist, mechanistic perspective, has to be complemented by an ecological, relational, systemic one (Capra, 1982) to deal with the complex issues of contemporary agriculture and rural development and to focus on the interrelationships between people and their natural and sociocultural environments.

In these perspectives, methods of inquiry are needed that can accommodate the totality of the issues being investigated - a holistic or systemic approach. We need to critically address the requisite for a new science of agriculture that embraces both "production enhancement" and "impact assessment" while transcending them both (Bawden, 1990). This is the essence of the paradigm for the new age. A paradigm that can accommodate complexity, uncertainty, and even chaos, both as aspects of the world itself and of the way we humans construe its meaning.

3.5 Technological Development: an Imperative in Agriculture?

Modern farming technology frightens many people, but life could be even more frightening without it. It might seem paradoxical (at least after the above exposition), but the only sustainable way in agricultural direction is the controlled massive use of technology. In the 1970s, when world food prices last reached a peak, many pundits argued that mass starvation was eminent because the world's population was growing so fast. Like Thomas Malthus, the 19th-century economist who first made the argument, they were proved wrong. They failed to take into account the "green revolution" in farm productivity. Farmers throughout the world began to apply pesticides and fertilizers to their crops. Irrigation allowed barren lands to bloom. Scientists devised more productive strains of cereals. This resulted in a steady increase in productivity per area; a long-run trend of falling food prices and a fall in the number of people classified by the United Nations as chronically undernourished. This has also introduced new ethics towards technological development which is changing people's behavior. So, how to debate the arguments that food from high-tech farms is bad for people's health, that intensive farming damages the environment and that it is bad for animal welfare?. Let's explore one point at a time.

The unhealthy question, a simple answer is that without modern farming technology more people would be starving and probably suffering from deadly illnesses. There is no doubt however, that some illnesses can be linked to modern farming. New ethics and most of all improving technology controls may reduce this negative effect.

In relation to contamination with pesticides or other farm chemicals the question is irrelevant given that existing regulations are fulfilled. There is no evidence that chemicals applied within these limits will harm human health. Being so difficult to account for in a short time, pesticides should be used only when absolutely necessary and not as a routine. The crucial point is not the use of resources but the way they are applied. More and more developed technologies allow techniques that just some years ago were science fiction. As Paracelsus observed, there are no poisons, only poisonous doses. I am not denying that modern agriculture technology has not caused environmental problems, what I am more interested in is how to minimize them. A full-scale switch to pre-green-revolutionary farming methods would not only reduce food supply but damage the environment even more than the green revolution itself. In order to compensate for lower output from each plot of land, there would need to be a dramatic expansion of the amount of land under cultivation. This would involve clearing many delicate ecosystems, such as mountainsides and forests. Even today according to IFPRI (International Food Policy Research Institute in DC), small farmers who clear land for agriculture or other self-sustaining activities are responsible for around two-thirds of the destruction of rainforests each year.

A better solution is not to fight modern farming technology but to smooth its rough edges. Governments in many rich countries are trying harder to enforce regulations about the run-off of fertilizers from farms. In many countries both water and chemicals are heavily subsidized. Making farmers pay the full cost for such imputs and using better tillage methods would cut their use, and hence limit environmental damage.

New technologies usually provide answers. For example, in the vast grain growing plains of America's mid-west, a agricultural vehicle is helping to reduce fertilizer run-off. The machine is loaded with a variety of fertilizers, which are sprayed from a multitude of pipes extending on either side. Traditionally many farmers apply fertilizers uniformly across a field. With this technology, a farmer starts by taking soil samples at regular intervals throughout his land -

with each position recorded to within a few centimeters using GPS (Global Positioning Satellites). The nutrients in each soil sample are analyzed to work out exactly how much fertilizer, and of what type, is required. The vehicle is then driven through the field, varying the mix of fertilizers as it moves. A computer in the cabin uses the satellites to figure out where the vehicle is, and calculates what mixture to apply.

By reducing the risk that too much fertilizer is applied, this method ensures that less will be washed off by rain and ensures a better targeting of fertilizer which eventually will boost yields, obviously an advantage to the farmer as well to the environment.

4. Identification of Agricultural Production Systems: Methods and Discussion.

An agricultural production system is a sub-system of the food system. Agriculture production includes all farming operations that occur starting from land clearing and developing, to operations such as tillage, fertilizing, pest control, harvesting, and farm-level storage, drying, processing, and marketing. The activities may be more or less complex according to regions and type of farmer considered. Some may not even cover all activities. This aspect is very important and great deal of attention should be dedicated in defining the system to be evaluated. At the systems level, an agricultural production system is location specific, and it is uniquely determined on the basis of interacting physiochemical, biological, technological, managerial, and socio-economic elements that satisfy specific objectives or goals. Due to limitation of existing data, the analysis here will only provide an insight up to the level of crop and animal production. Transport, storage, processing and part of the trading systems will not be included.

4.1 System Definition and General Goals

Distinctions can be made regarding the goal-related behavior of whole systems: those systems that have an imposed goal, which they then seek to achieve (purposive or goal-seeking systems) described as serving a purpose, and those systems which are able to set goals as well as seek them (purposeful or goal-setting systems). While goal-seeking systems (field-crop ecosystem) respond to any environment in different ways in order to achieve a particular outcome as a pre-determined goal; goal-setting systems on the other hand, are able to change their goals even in constant environmental conditions, as well as pursue the same goal in different environments by behaving differently.

There is considerable controversy surrounding the view that nature is indeed patterned around self-organizing ecosystems (Vayda and McCay, 1975; Simberloff, 1980; Moran, 1984). There is no empirical evidence to support the existence within natural communities of control mechanisms or information networks that enable them to maintain themselves as self-organizing, coherent systems (Engelberg and Boyarsky, 1979). However, the situation changes with the introduction of human beings as they are able to create self-organized systems. The internal combustion engine to vastly complex transport systems are examples of human-designed systems. Agriculture can be regarded in this context as the deliberate creation of organized systems.

Ontologically, we can say there are two fundamental opposite views about what nature is, one ontology holds that nature and environment are merely a loose affiliation of flora and fauna living in fairly unconnected ways with earth, water and air which surround them. In this reductionist view the whole is believed to be equal to the sum of the component parts. Therefore each fragment or part can be studied and or manipulated in isolation from any other without penalty.

The opposite belief is that all plants and animals in nature are inter-dependent and closely integrated with the earth, water and land around them. This is the ontology of holism. Nature is viewed as a whole and is intrinsically different from just the sum of its parts. Systems theory holds that the behavior of systems at one level in a hierarchy is influenced by the behavior of systems at other levels. However, the behavior of higher-order systems is not readily predictable by a study of its component subsystems or on the other hand, of its own suprasystem (Mislum, 1972; Checkland, 1981; Simon, 1982). Thus the whole is indeed different from, if not greater than, the sum of its parts (Bateson, 1972), with properties of its own which emerge as a result of its wholeness. This type of analysis creates some problems when it comes to quantification and modeling, and some authors ("soft" systems analysts) defend that systems are not bound to be modeled.

Field crop ecosystems exist only because someone wants them to. They are the product of the knowledge, skills, attitudes and values of those who design, create and operate them. In form and structure, these ecosystems represent interaction between people and the physical and biological resources available to them; in function they can represent interactions between people and people. Field-crop ecosystems are created to fulfill a purpose which is invariably associated with both individual and social need which in most cases, are concurrent. Systems exist in the mind of the beholder, disregarding their purpose. Purposefulness changes in conformity to each person's particular viewpoint of reality, which makes sense to him/her under any particular set of circumstances. This view, being unique to an individual, is called "construct" (Bannister and Fransella, 1971). This way at looking at systems is very important, for when we aim at improving the agricultural systems, success depends on being clear about, (i) what constitutes an improvement; (ii) which system is being improved (iii) which way one is viewing the system to be improved and (iv) who is doing the viewing.

4.2 Management Goals

Identification of goals is not an easy task when it comes time to analyze systems that exist to achieve a myriad of different goals. For example, sometimes the household is not interested in producing food to sell but to consume, so the introduction of yield increasing technologies in his/her agricultural system may not have the desired impact, not because the technology is wrong, nor even because the farmer is wrong. It is because we usually misunderstand his/her goals, that usually are based on very strong local foundation.

In its simplest form, any goal is merely a statement or sentiment about a future desired state (Kast and Rosenzweig, 1981). Perhaps, the primary goal of a farmer is economic security, Penny (1969) uses the awkward term "economic-mindedness". Norman (1979) suggests "...one of the prime tasks in agricultural development is to create conditions under which it is possible for the farmer to make choices that are economic." and Zandstra et al. (1981) define the cropping pattern as "...the arrangement of crops in time and space and their associated cultural techniques...{these} cover the choice of crop variety, times and methods of its establishment, fertilization, water management, crop protection and harvest". It seems simplistic to believe that such a pattern of activities reflect a single goal.

Bayliss-Smith (1982) has a more global suggestion "...it is more realistic to view the farmer as someone who attempts to balance... often conflicting goals to achieve a satisfactory level of income, security, leisure, etc. rather than trying (and inevitably failing) to maximize for any particular aim.". For example the smallholder on a farm in the tropics could have a spectrum of plants on her/his land at any time in order to meet a multitude of goals which will influence the way s/he does things. This situation is compounded by an overlay of goals of all other members of the farmer's household, who can either influence her/his goals indirectly, or conversely, direct involvement can influence the goals set for the farm. We can see then that rather than reflecting a single purpose, the form, function and dynamics of any field-crop ecosystem will fulfill a whole mosaic of purposes, and at the same time interact with other farm sub-systems. For this reason, where multiple purposes are shared or interacted, Bawden and Ison (1992) say that it makes sense to envisage the cropping enterprise as a system which itself has purposes, and postulate that field-crop ecosystems have organizational goals which represent more than the aggregation of the goals of the individuals who comprise the system.

After Kast and Rozenzweig (1981), and Bawden et al. (1984), management is presented as a "nested set" of three activities: strategic; allocative or co-ordinative; and operative, which in terms of field-crop ecosystems, we could make the following rationale: at the operations level, the farmer carries out those activities necessary to grow chosen crops; on the other extreme, the farmer as the strategic manager, plans for greater things. As a strategist the farmer considers new technologies and novel cropping plans and attempts to develop goals which align with the changing needs s/he perceives for himself and her/his household. Where operations must concentrate with the here and now, strategies deal with the future. So, where the operational manager works with relative degrees of certainty of the outcome, the strategist has to manage change and uncertainty. This involves differences in ways of learning and knowing as well as ways of taking action. Finally, it is as the allocative manager that the farmer makes decisions about resource use in order to convert grand visions into reality. Furthermore, the allocative manager designs and runs the budget and measures the performance of the system against expectations (Bawden and Ison, 1992). In summary, this is the behaviorists' approach.

For Ruthenberg (1971), with a different approach, a structural one describing the processes of the system, a farm is a system comprising subsystems of human activities. It serves to transform inputs into outputs and he distinguishes several kinds of activities:(i) activities which produce crops; (ii) activities which transform crops into livestock products; (iii) processing activities which transform crops or livestock products into factory products; (iv) procurement activities including investments and farm maintenance works (e.g. drainage); and (v) marketing activities.

Yet in another model, according to Dillon (1984), a purposeful farming system comprises five major ecosystems: i) a technical subsystem, whereby land, labour, capital, technology and knowledge are used to produce agricultural products; ii) a formal structural subsystem where labour and management work together; iii) a psychological or informal structural subsystem, or group relationships in the farm system; iv) a goals and values subsystem; v) a managerial subsystem concerned with planning, manipulating, and controlling the whole farm system.

Due to dissimilarities in modeling or the different ways field-crop ecosystems are construed (as managed ecosystems, cybernetic systems, purposeful, and organizational systems), the importance to carefully characterize any system is crucial otherwise it will be impossible to decide what constitutes an improvement.

In order to integrate the above approaches which characterize systems, Checkland (1981) in his soft systems thinking, discriminates between five classes of systems: i) natural systems - following the laws that characterize the universe; ii) designed physical systems - result of conscious human purposes; iii) designed abstract systems - result of human mind which cannot be directly observed; iv) human activity systems - comprising a number of activities which are linked together in some sort of set, as a result of some principle of coherence; v) transcendental systems - those systems that transcend human knowledge.

In relation to the contribution of goals, values, and culture to the purposeful systems one should be aware of not being beyond the boundaries of such a system. In other words, the purpose of those conducting research on cropping systems is very often to improve the productivity of field-crop ecosystems of which they are not a part. Research may not lead to improved field-crop ecosystems if assumptions about the purposefulness of farmers are made up.

In the neo-classical theories the goals usually relate to fairly concrete ends - they have an instrumental orientation (Gasson, 1973), implying that the farm is seen as a means of securing survival, obtaining security and perhaps, income. Gasson suggested three other orientations for goals: social, associated with satisfaction achieved through social relationships generated through joint activities on the farm; expressive, aimed at self-expression or personal fulfillment; and intrinsic, which values the operation of the farm as a pleasurable and satisfying activity in its own right. Bayliss-Smith (1982), addressed the connections between goals and motivation. And Maslow (1968), presented one of the most pervasive schemes on the psychological theories, in which each individual seeks to progress from the most basic, animalistic needs to those of self actualization, comprehending the following hierarchy: i) physiological needs; ii) safety needs; iii) affection needs; iv) esteem needs; v) self-actualization needs. Montgomery (1976), commenting on the work of Lasswell et al. (1976) concluded that "...the dominant values that serves as incentives to rural modernization seem to be wealth, well-being and skill (WBS)".

The pursuit of material wealth as a value whilst accompanying development, continues to cause controversy in debates about improving the system. Wealth is not only a relative term, but is a term that has many meanings, beyond the accumulation of capital assets, which is too frequently the basis of decisions about improvements. Because improvement could be seen in many different ways, Jamieson (1985) concluded "... only by studying both behavior and values in a specific context can one begin to understand why some people do certain things in a certain way at a certain time, why they choose not to do something else and what would be involved in motivating them to change their behavior (or to persuade other people to stop trying to change it)." An attractive model which integrates the socio-economic domain (as the desired Land of Plenty) with the cultural domain (as the Land of Righteousness) has been provided by Macy (1985). The socio-economic domain is characterized by three dimensions; social, economic and political. To these are added the culture or the "Land of Righteousness" characterized by a further three dimensions, moral, cultural, and spiritual, providing a six-dimension framework for examining the forces of any social environment whilst illustrating the nature of a particular set of "culturally prescribed goals".

The importance of cultural beliefs and what has been termed "indigenous knowledge", has often been undervalued in the quest of "progress". In this context, Lovelace (1984) gives a general comment "Rather than discouraging traditional beliefs, values and knowledge, it may be, in many cases, better to encourage their maintenance and the continued accumulation of information within the indigenous ideational framework."

In a future step of this research benefiting from the different theories it can be worth exploring the use of a constructivist conceptual model. This could generate a better tool for integrating agricultural knowledge for sustainable resource management. In this approach, system is in itself a construct with arbitrarily defined boundaries for discourse about complex phenomena to emphasize wholeness, inter-relationships and emergent properties. In this model the system is a coupled one, comprising a 'hard' ecosystem and a 'soft' platform which pay attention to human decision-making about this ecosystem.

Managing ecosystems is not only a question of biophysical information and technical intervention. Its management requires accommodation between human actors using the same natural environment usually with different purposes. They are independent in that each affects the desired outcomes of the others. Therefore, environmental management involves a collective agency or institution at a platform of decision-making involving the stakeholders. Thus, the "hard" ecosystem, which is seen to require unified management, cannot be managed except by the development of a "soft" platform for purposive action among diverse stakeholders.

4.3 Farmer's Behavior Model

It was the intention of the author to demonstrate that the development of sustainable agricultural production systems in Moçambique and elsewhere involves a wider scope of activities, and of design, analytical, and evaluation capabilities, than those that have been required in conventional agricultural research to date. It calls for a more holistic or systems approach and most of all, monitoring of performance over a longer period of time than has been the practice so far.

At this stage of my research, using the data from the Agricultural survey of 1994, borrowing from Low (1982), and benefiting from Chayanov (1966), Nakajima (1970), Becker (1965), and Holden (1993), an attempt is made to describe farm production in the rural areas of Moçambique. Understanding farmer's behavior as previously cited, is very crucial because this will allow a broader understanding about the best ways to introduce new technologies and most of all how they are, in any way a positive contribution in the achievement of the peasant's goals. Sometimes only by being able to understand a farmer's goals and how s/he behaves towards his/her ecosystem it is possible to succeed in the introduction or improvment of yield increasing technologies.

Analysing a semi-subsistence agricultural system using the same methods (like the internal rate of return), as the commercial agricultural system, can usually induce us to believe that those systems (semi-subsistence) are highly inefficient. It is important to note that yield-increasing inputs like hybrid seed, fertilizer or tractor are not always related to increased farm production but to the provision of cheaper household Z* goods or increased wage income which are difficult to quantify. (* Z goods are basic commodities which are not marketable and enter directly into the utility function, as a crop produced for subsistence). In Chapter 15 the model is discussed in more detail.

5. System's Prime Properties

5.1 Productivity - A Measure of System Efficiency.

The basic ecologists' concept of productivity relates to the relative efficiency by which energy is stored or assimilated. Odum (1969), has defined primary productivity as "... the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producer organisms in the form of organic substances which can be used as food materials." He further distinguished four steps of productivity.

In crop production, the focus of most research is in improving net community productivity, (improving the storage of organic matter in excess of that used by heterotrophic consumers) and enabling as much organic matter as possible to be stored in a form usable by humans. The "green revolution" is an example of this simplistic approach. Another approach, beyond maximizing the physical yields of crops, is that based on maximizing the economic potential of the cropping system, which tends to neglect the multiplicity of goals in the purposeful systems. Kingma (1985) has noted "the attempt to evaluate productivity change using only economic (exchange) efficiency is to address only part of the issue (for) productivity growth influences the social conditions of production and vice-versa".

In systems terms, productivity is the efficiency with which inputs are transformed into those outputs which reflect the system's purposes. Because systems productivity change in terms of energy conversion, crop yields, peasant labour, capital, etc. Rambo (1985), to make more sense in using a number of different measures to assess improvements of field-crop ecosystems, proposed that there are emergent properties associated with each of the following "partial" productivity factors: I) productivity per unit area; ii) productivity per man-hour; iii) productivity per unit energy. Energy evaluation has an important task in efficiency measurements. Bayliss-Smith developed a number of indices based on energy and incorporating other productivity factors. Using four such indices, he was able to compare and contrast seven diverse types of agroecosystems ranging from pre-industrial systems, semi-industrial and fully industrial systems with different market economies.

5.2 Stability - The Constancy of Productivity.

Stability as a concept of system performance is regarded as that property which measures the ability of a system to cope with short-term changes in the environment. Management strategies will be the perceptions about the likelihood of changes in the systems' future environmental conditions. The availability of resource inputs , and outlets for marketing the surplus are two aspects of the socio-economic environment which constitute areas of concern about the extent and frequency of change in productivity. But there is also the question of the extent and frequency of the changes in goals themselves and the values which they reflect, involving changes in ways of doing things. In summary, as Bawden and Ison (1992) say, "... managers reappraise values; set these as new goals; adopt new skills to master new activities; find new resources to achieve such goals; seek satisfaction from such change."

One example is the typical government strategy to subsidize farmers by intervening to affect the costs of system inputs and/or guaranteeing some sort of price for their system outputs, which might represent mechanisms for apparent stability. However this can lead to conditions of instability through insupportable distortions due to the continuous rise of economic cost of maintaining such a policy, where a conflict of values is often apparent between the needs of producers on the one hand and consumers on the other.

5.3 Sustainability - Enduring long-term change

To address this topic, one should definitely be aware of the different views on agricultural sustainability and their evolution. Douglass (1984) presented in his work that at least three major and conflicting views existed. The first addresses food sufficiency: field-crop ecosystems are instruments to feed the world, and preservation of the resource base or cultural values of agriculture are of secondary importance. The second view argues that agricultural sustainability is primarily an ecological question, advocating the agricultural system as a system which needlessly depletes, pollutes, or disrupts the ecological balances of natural systems. It is unsustainable and should be replaced by one which honors the longer term biophysical constraints of nature, and that the adoption of technologies that increase productivity often lead to environmental degradation. The third view of sustainability emphasizes on a broader focus embracing cultural and social aspects. This view attempts to capture the subtle and complex relationships which exist between people and their environment, and show how changes both affect these and can be intrinsic to them. They can provide a framework for the analysis of why technological innovations might not be adopted where their advantages seem to be obvious to an outside observer. The second and third views should not be seen as a hamper to the development of novel cropping patterns, but on the contrary, as providing a perspective for a "people-oriented" approach to the development of field-crop ecosystems in ways which are sustainable in terms of production, environment and community, and which respect peoples existing knowledge, skills, and values.

It is doubtful whether any prevailing agricultural production system can be claimed to have achieved absolute sustainability and to have managed continuous increase in productivity without some economic, social, and/or ecological cost to the farmer or community in the short or long term.

The observer may be able to distinguish whether sustainability is "good", "bad", "high", or "low". Sustainability may also relate to the distribution of tangible benefits, which provides the cue for Conway's (1987) fourth system of property equitability.

5.4 Equitability - A measure of Benefit Distribution

This topic, in a way, deals with a notion that was previously mentioned, concerning the multiplicity of goals and values in agroecosystems: what constitutes an improvement or benefit, and what is the meaning of equitable distribution of benefits. A change in a human activity system involving a number of participants, will inevitably bring a spectrum of outcomes which will be valued differently by different people or even the same people at different times (Bawden and Ison, 1992). New technologies will favor those who have the resources and skill to use them. This process of differential adoption of new technologies, forces the process of capital accumulation or intensification and the attendant pressures for land expansion.

As these pressures continue, they can lead to an accumulation of power by a rural elite, who can then accelerate the process through growing political influence. The nature of these dynamic changes can themselves be influenced by changes occurring in the overall economy. Thus as a country changes its state of economic development, so it will show different levels of inequality. To finalize this topic, Chaudri and Dasgupta (1985) have emphasized the multi-dimensional nature of this phenomenon, "... the incidence of inequality depends on both the rate of economic growth and in the way in which growth is achieved; but it may also be affected by political organization and the nature of the state, social customs such as caste, the legal system and in particular, laws governing the inheritance of agricultural land, and social and economic policies pursued by the government".

At a global level, the problem is how to share resources more equitably between the rich developed countries that have the economic and technological capabilities for tapping the world's resources and the developing countries that lack these as well as the trading system which highly favors manufactured products against very unfavorable prices on most raw materials or non-processed agricultural products.

Year	World price (dollars)		Amount of wheat to buy a barrel of oil (bushels)
	Bushel of wheat	Barrel of oil	
1950	1·91	1·71	0·9
1955	1·77	1·93	1·1
1960	1·58	1·50	1·0
1965	1·62	1·33	0·8
1970	1·50	1·30	0·9
1971	1·68	1·65	1·0
1972	1·90	1·90	1·0
1973	3·81	2·70	0·7
1974	4·90	9·76	2·0
1975	4·06	10·72	2·6
1976	3·62	11·51	3·2
1977	2·81	12·40	4·4
1978	3·48	12·70	3·6
1979	4·36	16·97	3·9
1980	4·70	28·67	6·1
1981	4·76	32·50	6·8
1982	4·36	33·47	7·7
1983	4·35	28·50	6·6

Table 5.1- Tradability between wheat and oil, 1950-83. (Source: Stout, 1990)

An example is the tradability relationship between wheat and oil, Table 5.1 . Analysis of the Table show that between 1950 and 1973 a bushel of wheat (27kg) could be traded for a barrel of oil. Since the oil price increase in 1973 this tendency changed to nearly 8 bushel for the same amount of oil. This can be interpreted as a massive redistribution of wealth from oil-importing countries to those that export petroleum. These price increases for oil relative to other agricultural commodities raise questions of sustainability of energy-intensive agricultural systems and place added emphasis on the need for reasonably priced renewable energy alternatives.

6. Managerial Economics and the Allocation of Resources of Agricultural Farms.

6.1 Labor and Technology and Renewable and Non-Renewable Energy

In the process of analyzing farms (commercial or subsistence) there are usually 5 steps to follow; one of the most important, being the establishment or identification of the objective(s) of the farm. Failure to do so in a correct way usually results in the complete rejection of an otherwise well-conceived and well-implemented plan. The next important step is the identification of the problematic situation requiring improvement. In the most simple case it could be problem(s) needing specific solution(s). The final step in the process, after all alternatives have been identified and evaluated, is the implementation of the best chosen alternative. This requires continuous monitoring to ensure that results are in conformity to the expectations. In this way, corrective action may take place when required.

The management of natural resources has to be rational and efficient and integrated in such a way as to minimize competition between agriculture, and the other sectors of activity as well as to reduce the adverse effects that they have on each other.

Natural resources for agricultural production consist of 1) physical resources, like climate soils and water; 2) biological resources like vegetation, animals and mankind; 3) energy resources like human, solar, wind, water, geothermal, biomass, and minerals; 4) human resources and institutions.

Leaving the problems of capital accumulation aside, and considering labour, fossil fuels and raw materials for manufacturing the means of production, we observe that labor is the only genuine renewable resource. And it is also the resource equally distributed amongst humans.

Fossil fuels, on the contrary, dissipate sooner or later in the production process, are not homogeneously distributed to different nations and most of all are exhaustible. Other raw materials are in principle inexhaustible as they do not dissipate during operation. However they may become scarce and again, raw material deposits are not equally distributed amongst nations.

If we express the cost of recoverable raw materials in terms of labor and energy necessary for their procurement, then the number of resources is brought down to three - labor, land, and exhaustible energy - which combined, will furnish a fourth one, the agricultural product. These resources may be combined in many different and efficient ways, depending on the circumstances and the goals (goals may be influenced by a multitude of factors). However it is worth noticing the intrinsical differences among these four entities. Labor and land are usually considered to be non-tradable as they cannot be sold over national borders (excluding slavery or near slavery labor systems). On the other hand, energy and agricultural products are tradable goods. This is very important for economic development as countries for example, poor in energy and natural resources will have to put more emphasis in some economic policies (in this case foreign exchange).

For commercial farms in general, the approach on the substitution of labor and energy can represent a good deal in evaluating technological innovation over time. Figure 6.1 shows the technical substitutability between added labor and energy for one production level of a farm product. The shape of the curve being convex to the origin implies that the two factors (labor and energy) are imperfectly substitutable and that the rate of substitution declines as energy is being substituted by labor or vice versa.

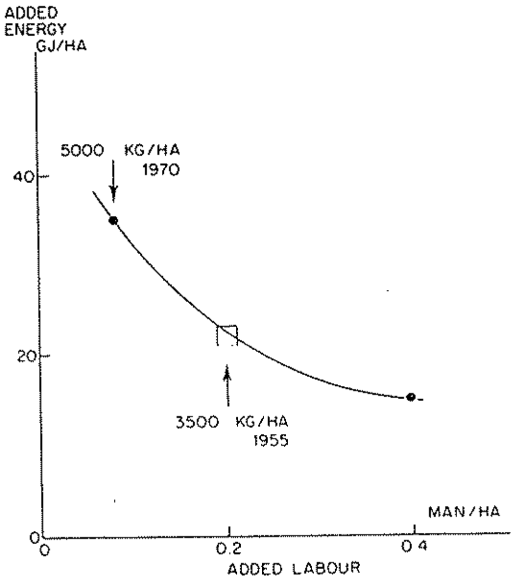


Figure 6.1- Substitution between added energy and labor for the cultivation of 5000 Kg of wheat per Ha in 1970, in Europe. (Source: De Wit, 1979)

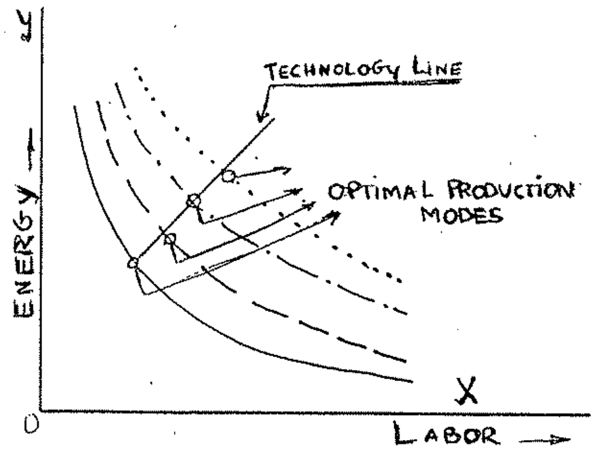


Figure 6.2- Increasing resource use efficiency, technology line as interception of optimal production modes

Technical improvement is given by the technology line in Figure 6.2 and is given when past data on labor added with energy is superimposed on the graph and compared to actual data used to build the curve. Labor and energy productivity can also be assessed when actual and past production per hectare are different.

Technological innovation would have been different in most developed countries had labor been cheaper and energy more expensive. Relative scarcity of energy and relative abundance of labor in the future could induce a different trend. One sensitive way governments have to affect technological innovation is to affect increasing taxes to energy employment and decreasing levies to labor employment.

Dealing with agricultural production systems in general and in line with the facts above, another approach could be to have a simpler division in terms of the resources used. A sustainable development of the agriculture production calls for an appropriate proportion (or mix) of inputs of renewable energies (Rn) and non-renewable energies (Nrn). When these two variables are put together in a graph a similar isoquant (in this case a link with biophysics and technology) will be obtained as in the figure 6.3 shows. If we use an energy method and assume that the energy embodied in each commodity or capital asset represents its true costs (Costanza, 1980), we may elaborate tables where different technologies' inputs are evaluated in terms of their mixed amounts of Rn and Nrn.

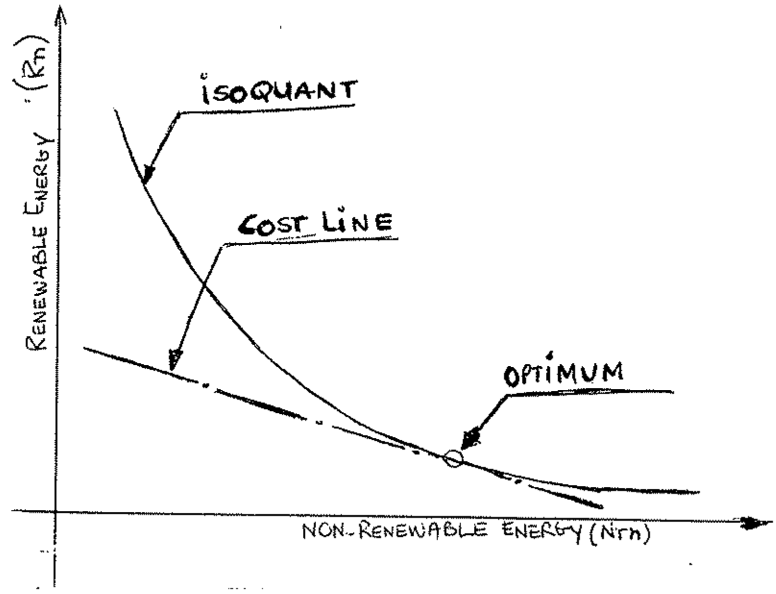


Figure 6.3- Searching the optimum, in this way the optimum can be obtained by the interception of the cost line with the isoquant

Following the law of diminishing returns we can easily accommodate ourselves that the relationship between Rn and Nrn can be represented by an hyperbola:

$$Y = a + (b / X) \qquad (6.1)$$

where Y is equal to Rn and X is equal to Nrn, and coefficients "a" and "b" are constants derived on the basis of observations of unit inputs per unit output for the alternative different technologies.

The important question is to find out the optimal point when trading Rn for Nrn. In conventional economics this would be established by the costs of resources. This would define a cost line with a certain slope. The tangent point between the isoquant and the cost line would define the optima, figure 6.3.

Cost equation:

$$C = P_{Rn} * (\text{Sum Rn}) + P_{Nrn} * (\text{Sum Nrn}) \qquad (6.2)$$

if we differentiate the cost equation and the isoquant equation we can find the optimal mix between resources.

However, one must be aware of the following: a) the definition of a unit price for all renewable resources P_{Rn} as well as for non-renewables P_{nm} ; b) the degree of aggregation in the total sum of input accounting; c) if a unit price is achieved how would it be influenced by environmental issues?; d) how to account for labor?; e) substitutability may hide non-sustainable situations, like fertilizer management.

6.2 Fertilizer Use Efficiency

Because mineral fertilizers make up a large and increasing proportion of total commercial energy use in agricultural production, and are so important in raising crop yields with the existing technology, we must examine how they can be used more efficiently. In general, the first 15-30 kg/ha of nitrogen fertilizer bring an increased yield of 10-15 kg/ha of grain per kg of nitrogen (Stout, 1990) after which the response slowly declines. One kg of corn contains approximately 15.6 MJ of energy; therefore, each kg of nitrogen must increase yields by 4.0 kg to return the amount of energy required to produce the nitrogen fertilizer. Often, 100 kg of corn contain as much energy as 25 kg of nitrogen. One farmer in the US can expect a 500-600 kg increase in yield with 25 kg of nitrogen. The sustainable approach would be to obtain maximum yield with minimum amount of fertilizer, as far as we keep soil fertility constant. The greatest fertilizer efficiency results from the first increments of added fertilizer, but additional increments usually results in a lower fertilizer efficiency but may still boost profits. And because farmers are paid by kg produced they will try to maximize production at the cost of extra fertilization.

The environmental pollution of high-yielding agriculture, is often associated with the law of diminishing returns which states that the relationship between the amount of a production factor and the yield level is not linear, but levels off so that more and more external inputs are needed to push up the yields to their potential level. This has not been true in experiments on yield increase and fertilizer use (approximately half the additional energy input supplied by the farmer to a cereal crop is in the nitrogenous fertilizer). Sometimes the Law of Diminishing Returns conceal the continuos use of more than proportional resources to acquire large increases in production. In Figures 6.4 to 6.6, efficiency of nitrogen fertilizer (given by the slope of the respective curves) is almost the same instead of showing a steady decrease, the ratio between yield and nitrogen use did not change systematically.

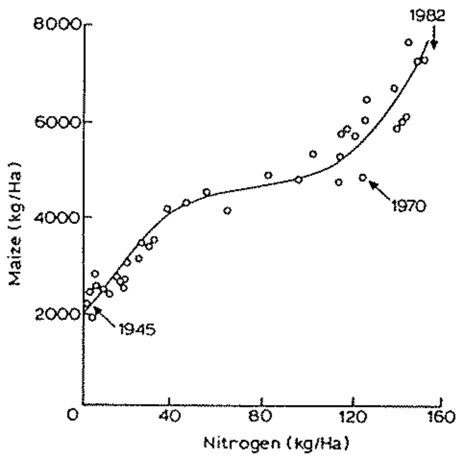


Figure 6.4- Maize yield with fertilizer application in USA, 1945-82 (source: Sinclair, 1990)

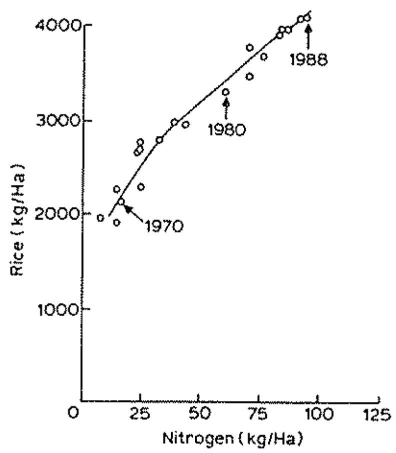


Figure 6.5- Rice yield with fertilizer application in Indonesia, 1968-88. (Source: FAO production yearbooks & fertilizer yearbooks)

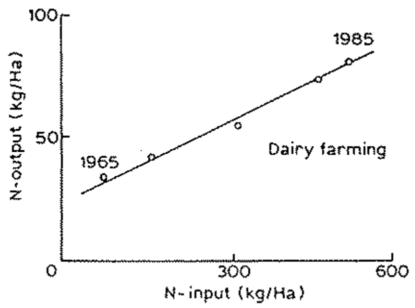


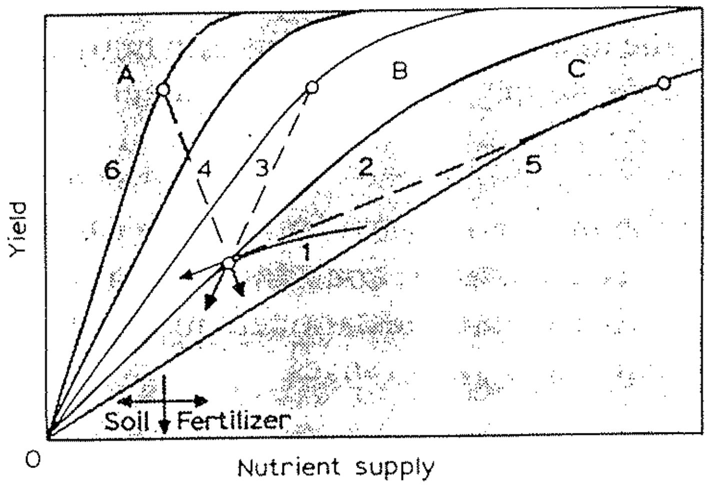
Figure 6.6- Application of fertilizer and concentrates (nitrogen) with production of milk and meat (nitrogen). (Source: De Wit, 1979)

When expressed in terms of energy use, there are even stronger indications of a systematic increase (Giles, 1975). This does not invalidate the law of diminishing returns, but means that the decrease of marginal returns to increase fertilizer use has been compensated by the beneficial effects of technological change. Better technology allowed increased use of fertilizer at the same efficiency.

Not much has been done in the field of resource use and technological change. Consequently, policy measures may be taken that, despite good intentions, contribute little to the efficient use of resources and the control of pollution, and may even be counter-productive.

Van der Paauw (1938), Figure 6.7, used these 3 functions to distinguish yield responses in 3 regions, A, B, and C, separated by the production functions of Mitscherlich (curve 4) and Von Liebig (curve 2).

Figure 6.7- Yield response laws to nutrients. 1 and 2 - Liebig's law of the minimum, more and more of one nutrient is applied while the availability of others remain constant; 1 and 3 Liebscher's law of the optimum, the production factor that is in minimum supply contributes more to production the closer other production factors are to their optimum; 1 and 4 - Mitscherlich's law of constant activity, implies that the absolute amount of nutrient needed to reach a certain fraction of the maximum yield is the same whether yields are high or low. (Source: De Wit, 1992)



In region C the yield increase is less than according to Liebig's law, curve 5 is an example. The broken line that joints points with the same relative yield (in % of maximum yield) in curves 1 and 5 intersects with the horizontal axis to the left of the origin. So, the need for nutrients that is in minimum supply increases both in relative and absolute terms under improved growing conditions. Therefore the efficiency of nutrient use or nutrient productivity is lower, thus making this dismal responses like soil-chemically and plant-physiologically unlikely.

In region A, responses are more favorable than according to the law of Mitscherlich, curve 6 is an example. The slope of the broken line joining the two points with the same relative yield in curves 1 and 6 is now reversed, so that the need for nutrient decreases both in relative and absolute values under improved growing conditions. An example of this benign response is that crops growing under otherwise better conditions can stand lower pH much better and therefore need less lime.

Under region B, the domain of the optimum law of Liebscher, the broken line intersects the horizontal axis to the right of the origin. Meaning that indeed the absolute need for a nutrient that is in minimum supply increases under improved conditions, the relative need decreases: more nutrient is needed when expressed per unit of area (kg/ha), but less when expressed per unit yield (kg/kg). The marginal return at a given nutrient application increases therefore with increasing maximum yield, but the increase is less than proportional.

In general, it is found that in experiments with more than one nutrient, most production functions by far are located in region B, sometimes over the border in region A, but never in region C (De Wit 1991, 1992).

Apart from using optional yield-increasing and yield-protecting factors, certain activities are conditional for agriculture at any yield level and require the input of labor, capital and energy. Their requirements are partly area-related (e.g. plowing, harrowing and sowing) and partly yield-related (e.g. transport and drying of harvested crops). Harvest activities occupy intermediate positions. All in all, at increasing levels of production the use of labor, capital, and energy increases per unit surface, but decreases per unit product.

For variable production factors the law of Liebscher has general validity, so that with increased yields their needs expressed per unit surface may increase, but expressed per unit product it decreases. Or the marginal productivity of resources that are limiting increases with improvement of growing conditions. Marginal productivities do not exist for fixed activities, but by definition their productivity increases with increasing yields.

6.2.1 The Non-Substitutability of some Factors in Agriculture

Considering two factors p_1 and p_2 and according to the law of constant activity of Mitscherlich as well as at law input levels, yield is proportional to the input of each of the production factors when varied on its own. Hence it is proportional to the product $p_1 * p_2$ and increases initially in quadratic fashion when both are varied concurrently. This increase levels off again at high inputs, as shown in Figure 6.8, where the yield response to both production factors is supposed to be identical. The combined response is therefore S-shaped and thus the more pronounced, the larger the number of production factors involved.

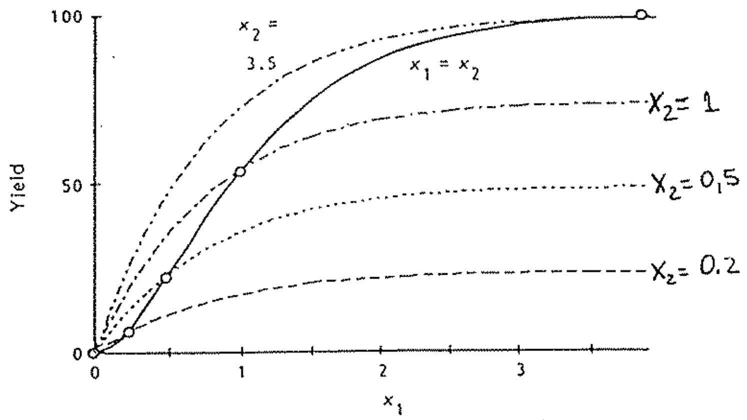


Figure 6.8- Returns to scale (x1 = x2), as constructed for a situation where the yield responses for two inputs are the same. (Source: De Witt, 1992)

According to Von Liebig (1855), one or the other production factor is limiting, depending on the ratio in which both are applied. Hence, the yield response to combined application remains linear until a limit, dictated by a third production factor, is reached. The optimum law of Liebscher (1895) assumes an intermediate position: at increased supply of two production factors the initial yield increase is less than quadratic but more than proportional. Hence, across the whole yield range, first there are increasing returns to scale which gradually change into decreasing returns to scale when the maximum yield is approached, and the S-shape is more pronounced the larger the number of production factors involved and the more the law of Liebscher approaches that of Mitscherlich(1924).

Many production factors have unique physiological functions: solar radiation cannot substitute for lack of water and nitrogen not for lack of phosphorous. Such lack of substitutability is reflected in the law of the minimum of Von Liebig (1855). However, according to the law of Liebscher (1895), there is always a possibility for partial substitution, as in figure 6.7, where in the yield range of 0 to 100 the same yield can be attained with less of the nutrient, when growing conditions are more favorable.

When seeking economic optimum (combination of inputs that maximizes output) one can find this in any basic economics literature:

Being, $Y = F(X_1, X_2, ...)$ the Production Function restricted to double differentiation and inputs and outputs being homogeneous.

$$W = p_y Y - (p_1 X_1 + p_2 X_2) \qquad (6.3)$$

W, the net value of transforming resources X into produce Y, the maximum is found by solving:

$$(d_Y / d X_1)\, p_y = p_1 \quad \text{and} \quad (d Y / d X_2)\, p_y = p_2$$

where p_y, p_1, and p_2 the prices of crop yield, and fertilizers respectively. As the position of the maximum and hence the fertilizer rates depend on the price ratios, there is no technical optimal of applying fertilizers.

Nitrogen (X_1) and phosphorous (X_2) in such equations are only suitable in the range where the same yield increase can be obtained by applying only P or only N.

Due to this the physical process in the soil is quite inhomogeneous. If phosphorous is applied, not only yield increases, but the nitrogen reserve in the soil decreases due to increased uptake in the harvested material. Similarly, if nitrogen is applied, the stock of phosphorous in the soil decreases. There are more changes, but this suffices to show that there is not only one homogeneous output (i.e. the yield), but also at least one inhomogeneous output (i.e. a change in soil fertility). Hence, simple mathematics to determine optimal fertilizer rates are not applicable. Also the results are not very meaningful, because situations where only one nutrient is applied are always unsustainable. The relationships between inputs and the yield are not simple because of the large number of complex and interdependent processes which take place during a crop cycle (from sowing to harvest) and because of the stochastic nature of the environmental variables, which affect crop growth, and the long duration of the growing season, production processes in agriculture are not steady-state ones for which it is possible to calculate, or measure a unique package of inputs. Similarly, optimal yields are only by coincidence sustainable, because agro-ecological sustainability is defined in natural science terms, and optimal yields are defined in economic terms, which sometimes do not represent the same.

If the reasonable demand of agro-ecological sustainability is imposed, yields can in general only be maintained by fertilizing (with organic or inorganic fert.) in such way that the uptake of one nutrient is matched by the uptake of others. Moreover, if yield is improved by, for instance, improved water supply, better varieties or better disease control, increased nutrient uptake is required. Consequently, agronomic production factors are more complementary than substitutable in sustainable agriculture. This does not imply that the law of Von Liebig holds and there is no positive returns to scale, but as seen, input combinations are only sustainable in a restricted range. So the important question is then, not about the marginal returns to increased fertilizer application under otherwise constant conditions, but what fertilizer rates are needed to realize a given target yield in such a way that the fertility of the soil is brought to or maintained at its corresponding equilibrium level.

Nevertheless, many substitution possibilities remain in sustainable agriculture, but much more so at the management level than at the agronomic level. Many activities that are conditional for agriculture at any level, like plowing and seedbed preparation, can be executed with much more labor and little capital and energy or the other way around. Weed control is always necessary, but can be done with ecological (i.e. dense planting) or mechanical means or using herbicides or even any combination of these. If a price increase, due to taxation in nitrogen is introduced, a more efficient application method may be developed, but the uptake that is necessary to achieve the target yield will remain the same.

In agriculture, one agronomic measure to improve growing conditions leads to others in a heuristic process of trial and error and based on limited and sometimes flawed knowledge of the production system. The analysis suggested that the law of the optimum of Liebscher has general validity, so that this heuristic process occurs in an environment where returns to scale of yield follow an S-shaped curve. When the increasing returns to aggregate supplies of two or more production factors are to be examined, one should systematically consider whether each resource is used in such a way that other resources are used most efficiently. The increase in production per unit area and the efficiency of resource use are closely interlinked. Due to controllability it is less complicated to identify the minimal production factors and activities to achieve target yield than to determine production functions that give yield as a function of all possible input combinations, disregarding their sustainability.

Looking again to eq. 6.3, farm business analysts, simplifying above mentioned complexities (in quantifying production functions), proposed that the value equation could be resolved into either of two possibilities: i) Regarding Y and hence p_y * Y as fixed, with the result that maximizing W became equivalent to minimize the second term of the eq. 6.3. Small-scale projects were presumed to fall into this category, in which the system was expected to meet specified standards at minimum cost. Since machinery is one of the production factors or resources used in crop production with a cost which should be minimized, it is necessary to emphasize at this stage how erroneous it would be to uncouple machinery cost from yield.

From the point of view of the cost of using a machine, cost decreases with utilization in the productive process. However there are critical time periods for crop growth and development, with the result that if certain operations like planting and harvesting are not carried out in time, there will be a reduction in yield. If the owner of a machine attempts to harvest too great an area, a stage is reached at which the crop gets over ripe before the machine can finish the job, resulting in loss of crop that eventually is greater than the reduction in the costs of the machine through utilization. The "timeliness factor", in such operations as planting, irrigating, spraying, and harvesting, has such an effect on yield that it is not possible to consider utilization independently of yield.

The trade-off between machine capacity and timeliness is one of the problems of machinery selection. When a farmer invests in a bigger machine he incurs bigger costs in owning that machine. However, with a bigger machine, the losses in yield as a result of not carrying out the critical operation at the correct time should decrease. Adding the two costs together produces a resultant cost which shows a minimum. This is the level of machine capacity for which the farmer should plan in order to minimize the total machinery costs of that operation.

ii) Regarding the package of resources ($p_1 X_1 + p_2 X_2 + ...$) as fixed, so that maximizing W is equivalent to maximizing p_y * Y and consequently Y. Large-scale investments such as irrigation and roads would fall into this category, where the optimization problem becomes one of constructing a maximum package of development within a fixed budget.

However, we should not forget that the productivity of the traditional fixed activities increases with increasing yields, while the marginal productivity of more variable yield-increasing and yield-protecting production factors remains high because of their complementarity. This implies that within a rather wide range, their input level is less independent on their costs and their reward is less dependent on their scarcity, than for independent production factors (Van Dijk and Verlaik, 1989). Accordingly, within a wide margin, relative prices have little influence on their optimal mix (De Veer et al., 1992).

6.3 The Frontier Of Minimum Costs Of Production

This is a concept to elucidate the link between technical and economic considerations. The relation between production and costs over the whole range from extensive to intensive farming, is schematically presented in Figure 6.9.

It has to be emphasized that a sustainable agricultural production system should also be based on sound economic principles and should not necessarily be a low-input production system. According to Holt (1988), the development of economically viable agricultural production systems should be based on research aimed at selecting one or more production systems from among several alternative systems, which evaluate the optimal combination of inputs, in such a way that the lowest cost of input per unit of output is achieved often at the point of maximum economic yield.

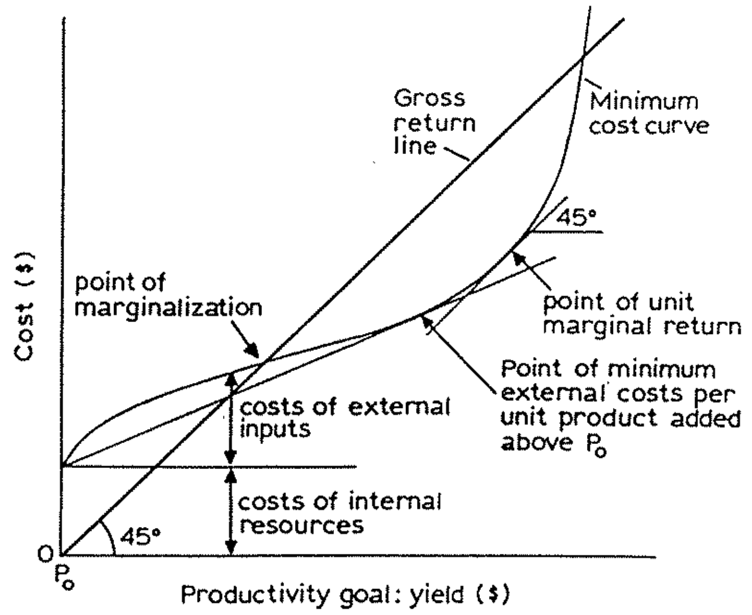


Figure 6.9- Minimum production cost dependent of productivity goals of farming systems. (Source: Holt, 1988, revised)

But if we better analyze figure 6.9 we come to a conflict between the highest efficiency in financial terms and the highest efficiency in resource use.

The production target, expressed in ECU/ha for a full rotation is given along the horizontal axis, with higher production targets representing more intensive production systems. The curve is the frontier of minimum production costs. Many possibilities exist to do worse, but none to do better. The curve represents the costs that have to be met to reach the production target in an agro-ecologically sustainable way.

Sustainability implies here that the quality and fertility of the soil, the damage level of pests, diseases and weeds, and the capital stock do not deteriorate systematically in the course of time and is therefore not restricted to a certain production level.

In this example amelioration level (bio)technology level is fixed, but all other costs, including those of capital goods, are considered variable. Further amelioration reduces the minimum costs to reach a certain target, and shifts the maximum attainable production to the right.

The 45 deg. line represents the gross production value when production target is attained. Other scenarios my develop like lines for gross returns "b" and "c", in this last case the farm would set a goal for minimum loss.

Net return is the difference between gross production value and costs of production and is by definition equal to the entrepreneurial reward plus the soil rent.

It is assumed that prices are independent of production target, to avoid unnecessary complexity; this implies that all labor is supposed to be hired on an hourly basis or that the farm size is adapted to the availability of labor in the farm household. Due to limited substitution possibilities at agronomic levels it is very difficult to determine such a frontier of minimum production costs across the whole range from extensive to intensive farming. The recommendation is initially attempting to look at production systems with a simple crop rotation as, only grain, or only maize and beans and for the actual level of mechanization.

Through figure 6.9 we can also see that:

I) The lowest costs per unit product are represented by the point of contact of the line through the origin and the frontier of minimum costs. This is also the point of highest ECU productivity.

ii) The increase in production and in the costs of production are the same at the point of contact of the minimum cost frontier and a line parallel to the gross production value. Here net return is at its maximum. This point is always to the right of the point of highest productivity if a range exists where net return is positive.

iii) The intersection of the line of gross production and the frontier represent the point below which the farming system does not pay.

One important issue emphasized here is that the point of highest efficiency in financial terms is not the point of highest efficiency of resource use. For some resources the later may require more extensive production targets and for others more intensive ones.

It seems that a greater part of EC farms still have a substantial gap between current production levels and the levels that could be reached at present amelioration level, and current production would be possible, with a much more efficient use of resources (WRR, 1992; O'Callaghan, 1994). Therefore, farms are not clustered around the point of maximum return, but scattered above the frontier of minimum costs, and if profitable, below the gross production value line. Possible reasons for this are: a) Attachment to the established way of running the farm; b) time needed to acquire and apply new knowledge; c) lack of knowledge of the production situation and alternatives; d) imperfectly functioning markets for credit and products; e) production resources not widely used in the region.

It is also important to note that with increase of production volume without increase in demands sooner or later leads to reduced prices of agricultural products. This reduction can be represented by a decrease in slope of the gross production value. An extreme point is reached where marginalization moves up and maximum return down till they all meet in the point of highest productivity, which remains in the same place as it is independent of agricultural products' price. An uneconomical situation is reached if product prices decrease still further. The highest productivity point may also be referred as the vanishing point of agriculture.

For a less developed region it is expected that the maximum return point is lower and the minimum production costs higher, where the gap is lower and the system is more vulnerable as the vanishing point is reached earlier the less endowed the region is.

7. Agricultural Production Systems' Evaluation Tools

In order to evaluate in a rational way, the benefits and costs of investing in energy-saving, yield-increasing or alternate energy technologies, methods of analysis are needed that account for the important variables.

7.1 Economic Analysis Enumeration

Some common types of economic analysis are break-even analysis, benefit-cost analysis, and analysis of payback period or present worth. In a break-even analysis, the break-even point occurs where two options are equal. This is applied most commonly to profit and loss. A benefit-cost analysis is used to determine whether the higher initial cost of an alternative may be justified by its lower operating costs. A payback period analysis is used to calculate the time to repay an investment. A short payback period is usually desirable, although in certain cases an investment having a longer payback period may result in a greater return over its lifetime. The purpose of an analysis of present worth is to determine the present worth of future expenditures or savings. It takes into account the time value of money.

However, monetary value does not reflect the energy value of a product or resource. E.g. in the US one dollar's worth of electricity contained less than half as much energy as a dollar's worth of gasoline.

7.2 Energy Analysis

Other sources of analysis are being investigated and sometimes used with success. Energy Analysis (EA) - defined as the determination of the energy sequestered in the process of making a good or service within the framework of an agreed set of conventions or applied the information so obtained (in IFIAS, 1974). They evolved mainly to fill the gaps that we encounter in economic analysis when it comes to quantify in economic terms the impact of many variables in the production process. Energy analysis (accounting) evolved as an alternative to monetary accounting for situations in which the energy value of inputs and outputs was the primary objective. This also known as the first-law of Thermodynamics analysis is mainly criticized in its generalized failure to identify energy waste or the effective use of fuels and resources (Tsatsaronis, 1989).

However, the main criticism to the energy analysis derive from different approaches to a number of issues. The most important being the selection and definition of the system boundary; the treatment of labor; and the treatment of land, capital and time. In other words, how is the energy value of an input determined? Suppose it is a fuel, such as gasoline, the most obvious energy value is the heat of combustion, or a bomb calorimeter value. But what about the energy required to drill, transport, and refine the petroleum? Should these be also included? If so, which elements should be included? The fuel used to run the drilling equipment? the heat required in the refinery? What about the energy required to manufacture the drilling equipment or even the gasoline used in the refinery employees' cars as they drive to work?

Clearly, standards should be established. One useful and simple pictorial boundary proposal when it comes to the evaluation of crop-ecosystems is depicted in Figure 7.1 which reduce energy values to a common denominator to provide an opportunity for analysis and comparison.

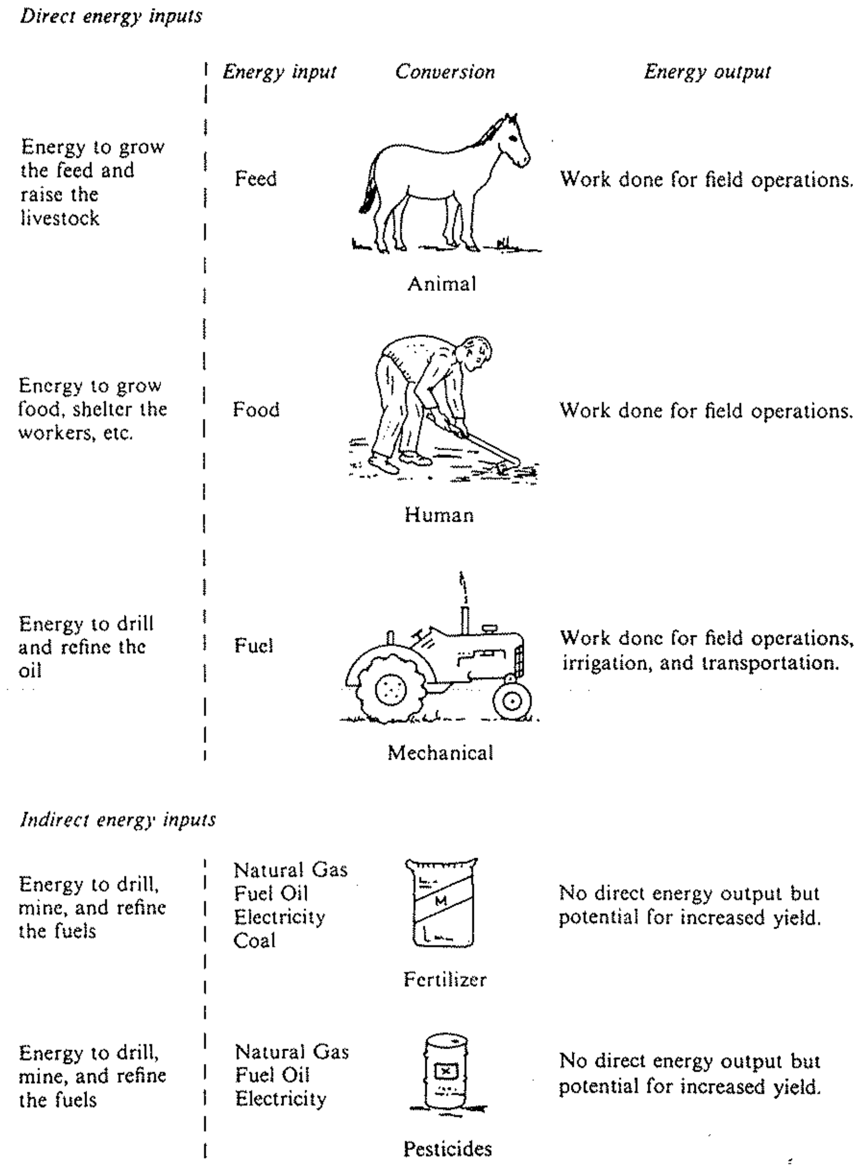


Figure 7.1- Energy-bearing inputs to agriculture are animal draft, human labor, power units, fertilizer, and pesticides. The energy values of inputs are evaluated at the level of the feed, food or fuel

required to operate the direct inputs, or manufacture the indirect inputs. (Source: Myers, 1983)

The input categories are animal draft, human labor, power units (i.e. tractors, combines, vehicles, and liquid-fueled irrigation pumps), fertilizer and pesticides. Animal draft, human labor , and power units are all direct energy inputs. Each requires some sort of fuel - either petroleum, gas, food, or feed - which is converted into useful work by the energy conversion device (i.e. animal, worker, or engine). The energy output is the energy available for useful work. Fertilizer and pesticides are indirect energy inputs. They do not produce useful work but they should be included in order to determine how much energy is consumed in the production process, because the energy required to manufacture these indirect inputs is quite substantial. For some crops, the manufactured energy invested in the fertilizer and pesticides applied to the fields is more than all other energy inputs combined. This associated to the fact that the majority of the energy used derives from non-renewables is in my opinion a decisive argument to start using some form of taxation to compensate for environmental pollution. Further on, one example of this type of energy analysis is used to analyze different crop production systems. Other types of analysis in this energy area are the exergy analysis and emergy analysis, which in a way try to overcome the main restrictions faced by the EA.

Exergy[1] analysis, is a strong tool when it comes to evaluate and understand the conversion processes of energy and other resources in society. This method is based on the connection to the physical environment, a main criticism to the other mentioned methods. Exergy represents the useful part of energy for a system in its environment, i.e. the maximum quantity of work that the system can execute. When energy and matter flow through a system they function as carriers of energy quality. So they are not consumed in the process, what is changed is the quality of the energy. An exergy analysis is the only way to unmask the high irreversibility in processes. Causes of these irreversibilities are located and quantified and the effects of inefficiencies in one component on the performance of other component is clearly illustrated.

Wall (1977) uses an interesting example to illustrate the method "...an ice-block and its environment in Greenland or in tropical Africa are quite different. This variation may be related to the economic value of the system. An ice-block is worthless in Greenland, but could be valuable in tropical Africa".

This system has its weak points also. One is concerning the definition and calculation of the Quality Indexes, which gives the approximate exergy content of a product. It is bound to be bias as it is relative to the environment where the exergy is calculated. The lack of data on organic compounds is another gap. But perhaps the most significant problem in applying the exergy concept in agricultural production systems is that it is based upon a specific reference environment. This is not the case in natural systems. One purposed way to overcome this problem would be to construct a hypothetical reference system whose properties are those that the actual system would acquire if it were to go to the equilibrium reversibly, delivering maximum work to a work reservoir (Morris & Szargut, 1986; Gallo & Milanez, 1990). However, the neglect of radiation in attempts to define general geophysics reference states (Arrendts, 1980) may be unacceptable for agricultural systems where radiation is fundamental. Photon energy is paramount in photosynthetic organisms because radiated heat exchanged with the environment is an important component of the energy budget for all animals.

Emergy Analysis is a measure of the work previously done. The core of this method is the transformity ("emergy per unit of energy). Emergy is the available energy of one kind previously used up directly and indirectly to generate another kind (Odum, 1988).

The amount of one commodity required to generate another can be expressed as the energy of one type required to transform the first commodity into that of another type. The solar energy required to generate something is the solar emergy.

[1]The term exergy has been accepted in science as denoting the most general attainable-work or free energy concept, embracing all others as special cases. Various terms have been used to denote exergy: available energy, availability, énergie utilisable, and technische Arbeitsfähigkeit. The term was derived by Rant (1956) with the objective of finding a word which had the correct etymology (ex meaning out and ergon meaning work) and would fit semantically with other thermodynamic terms, e.g. entropy, and enthalpy.

The "m" is to indicate that it is a measure of the "energy memory" of a product or process.The units of emergy are solar emjoules per joule (sej/J) or solar emjoules per gram (sej/g). The energy of one type necessary to produce or generate one unit of another type is defined as the Energy Transformation Ratio, see Figure 7.2 . The larger the ratio the larger the prior use of solar energy is in generating that flow. Thus the energy used in the transformation gives a measure of the quality of the energy both in the sense of what is invested in it as well as the effect it has in real systems.

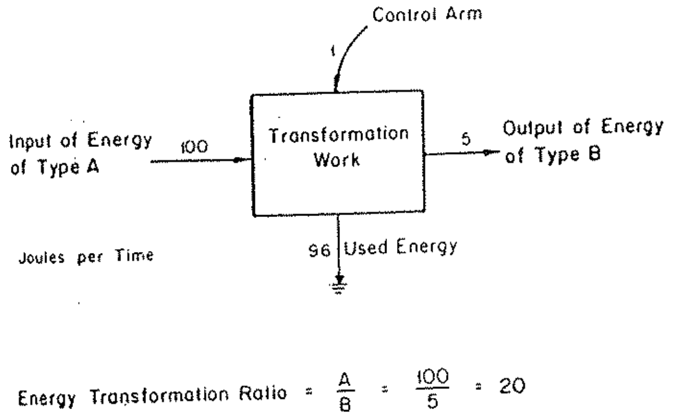


Figure 7.2- Energy Transformation Ratio (source: Odum, 1984)

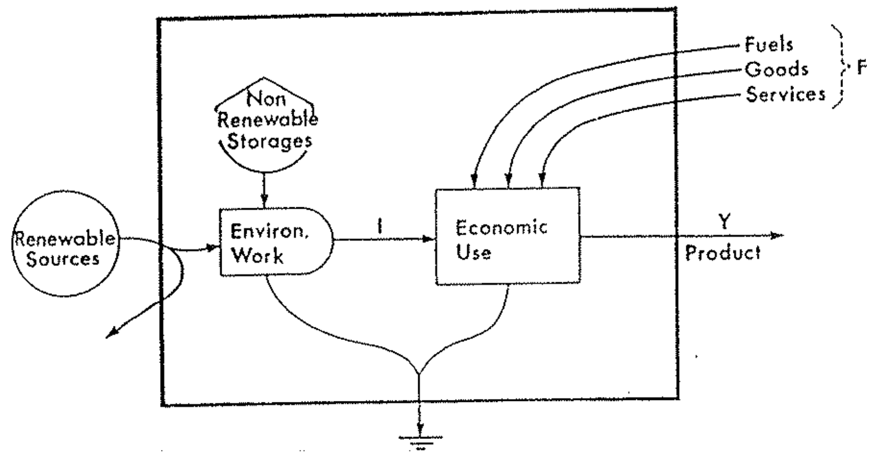


Figure 7.3- Net Emergy Yield Ratio (source: Doherty et al, 1991)

The embodied energy flow is obtained by the product of the actual energy flow and the energy transformation ratio from sunlight. The Net Emergy Yield Ratio is the emergy of an output divided by those inputs from the environment fed back into the economy, see Figure 7.3. This ratio indicates whether the process can compete in supplying a primary energy source for an economy. Recently the ratio for typical competitive sources of fuels has been about 5 to 1 (Doherty et al., 1991). Processes yielding less than this are not currently economic as primary emergy sources.

The emergy necessary to concentrate a material from its background level is measured as the emergy per unit mass, to evaluate we should multiply the data on material flows by the emergy per unit mass to obtain the emergy contribution (detailed methodology and application can be read through Doherty et al., 1991 and Odum, T., 1995).

7.3 Life Cycle Assessement Analysis

Lately this EA methodology was broadened to take into account resource requirements, environmental loading from water and air emissions, and waste production.

In 1985 with mandatory rules issued by Liquid Food Container Directive of the EEC, which charged companies with monitoring the energy and raw materials consumption and solid waste generation of their products, and when solid waste (and recycling) once more became a public issue in the late eighties, the Life Cycle (Inventory) Assessments (LCA) analysis emerged as a tool for analyzing environmental problems. Parallel to this, more quantitative life cycle inventories, a broader qualitative tradition, developed in Germany under the name Produkt-Linien-Analyse (PLA). PLA abstains completely from aggregation of the inventory data, which makes the results somewhat difficult in interpretation (Weidema, 1993). These methods are usually in broad use only in the food packaging and processing industry. In order to be able to draw appropriate conclusions aiming at an efficient reduction of environmental loading, it is necessary to widen the system boundaries and study the whole food production system (Kooijman, 1993)

LCA is a process used to evaluate the environmental burdens associated with product, process, or activity. The life cycle of a product is represented in Figure 7.4 . Raw materials are brought from nature into the technological system, where through agricultural processes they are transformed into products (and by-products). Transports occur between all steps in the life cycle and resources like raw materials, energy and land are used at all steps in the life cycle. Emissions to air and water as well as waste are generated at the different life cycle steps as well as after usage when the product leaves the technological system. The concept of minimal resource utilization and low environmental impact have only (to a limited extent) been applied to the food production system, where they are used in the packaging industry.

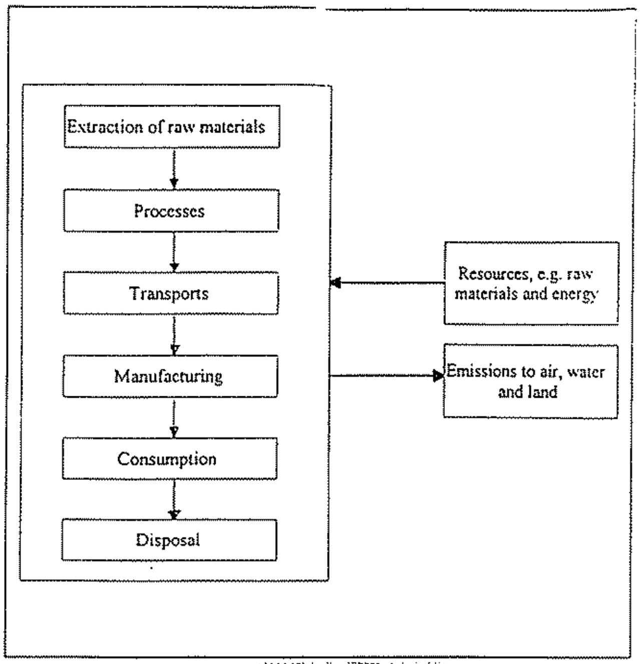


Figure 7.4- Main scheme of a product's life cycle. (Source: Steen, 1992)

Three main valuation systems for LCA have been described in detail by Bauman et al. (1992), who have applied them to milk packaging systems. They are in general a mix of science, political decisions, and subjective assessments. Due to the aggregation of the different environmental effects into a single index, the process becomes rather obscure if we do not have information about the assumptions behind the index.

The EPS (Environmental Priority Strategy in Product Design) system (Steen, 1992), developed by the Swedish Environmental Research Institute, Volvo and the Federation of

Swedish Industries, tries to put environmental and health effects into perspective.It is a "book-keeping" system using Excel to calculate the ELV (Environmental Load Values) of the different parts of the life cycle, which will be added to yield the TELV (Total Environmental Load Values) of a product, process or service. So the higher the ELV the worse it is.

The second valuation method, the EC (Effect Category) method consists of three different steps. First, the results from the LCA inventory are summarized in effect (or impact) categories in the same way as in Table 7.1. The effect-equivalent is divided by the total contribution to the studied effect category within the studied area. The result will be a dimensionless number accounting for the product's (or system's) contribution to a certain environmental problem. In the last step the effect categories are weighted by using of e.g. political goals. It is then possible to add the dimensionless figures from all the effected categories into a single number, corresponding to the environmental index.

Impact categories	Suggested endpoints
Global warming	*Global Warming Potentials, GWPs (CO_2-equivalents)
Ozone depletion	*Ozone Depletion Potentials, ODPs: (Chlorinated and brominated). *Nitrous oxide
Acidification	*H^+ (Acids and nitrogen compounds) *Loss of cations
Eutrophication	*Oxygen consumption (aquatic) *N (terrestrial)
Photo-oxidant formation	*NO_X *Photochemical Ozone Creation Potentials, POCPs (Volatile Organic Carbons, VOC, incl. CO)
Ecotoxicity	*Acute toxicity *Potential bioconcentration *Acute toxicity not degradable *Potential bioconcentration not degradable

Table 7.1- Suggested endpoints to evaluate effect or impact categories. (Source: Steen, 1992)

The ES (Ecological Scarcity) valuation method, developed by BUWAL, the Swiss Environmental Protection Agency, is defined as the relationship between the total existing environmental loading, F, and the maximum accepted or critical loading, F_k , within a geographical limited area: Ecological scarcity is given by the ratio, F/ F_k. The data generated from the inventory are weighed using a eco-factor and the scarcity, Eco-Factor = (1/ F_k)*(F/ F_k). (Bowmann et al., 1992). The eco-factor is multiplied with the loading (emissions and resources) and the resulting indices for the different loadings are summarized to an environmental index for the studied system: Environmental Index = Sum_i (eco-$factor_i$ * $loading_i$).

The valuation methods mentioned above are backed by dedicated software. Weidema, 1993, page 93, gives an extensive coverage of existing material and comments on their applicability in LCA.

In my opinion the above enumerated methods should be explored to evaluate agricultural production systems. It is highly recommended that more than one evaluating method are tried and compared before jumping to conclusions about the best system. Energy analysis coupled with life cycle analysis would seem likely to be most useful where conventional economic analysis is weakest. As discussed, methods of evaluation always present weaknesses, but it is our skill to use their potentials in the best way. This would suggest that energy analysis may be of greatest use as a long-term planning tool rather than as a guide for day-to-day decision making or as a tool for fairly general comparisons, rather than for analyzing specific systems.

It was not my intention to criticize any system or favor another. As I feel that its use can always bring to light issues that sometimes would not be evident to the conventional or biased analyst. The choice of evaluating methodology is therefore not fixed, but will depend upon the purpose of the analysis. It is also true, that some methodologies are not fully accepted by the scientific community, and some of them are even put to very strong negative criticism (Månsson & McGlade, 1992). To end this part on system's evaluation and sharing the same opinion as Patten, 1993 "...Empirically measurable energy in different forms, or other conservative quantities, can be (and should be) used as a tracer (or numeraire, common denominator, etc.) to unravel certain design features of ecosystems - similarly to the way currency flow can give certain, though not all, information about societal organization."

8 Food Production and Resource Use in Developing Countries

Relationships among labor, fossil fuel use, and food production are of great importance in developing countries. Almost without exception, governments in the Developing World emphasize the role of agriculture within their overall development strategy, with particular emphasis in increasing food production, rural incomes and employment opportunities. Although only about 7% of national budget is allocated to this sector, compared to 30 or 40% which is deemed necessary to meet the region's food security challenges (IFPRI, 1996 meeting in Johannesburg on the 25 of June 1996).

Today, African agriculture is facing a challenge for higher demand from a higher population, where for sub-Saharan Africa annual food production is expected to grow by only 3% a year, just slightly ahead of a 2.9% population growth (FAO, 1993). This is a problem of how to increase input levels by utilizing also inputs that are external to the farm. This situation of no-input agriculture is also prevalent in Moçambique as demonstrated by tables in chapter 10.

8.1 Shifting Agriculture and Carrying Capacity

In order to study and improve the economy of peasants in Moçambique, it is essential to understand how small farming systems operate in the region. The practice based on shifting o/and the slash-and-burn agriculture was once ubiquitous on every continent, except Australia, and in this century it has remained of major importance for the majority of families in Africa (Allan, 1965), Latin America (Waters, 1971), and Southeast Asia (Spencer, 1966). There are many fundamental similarities in all regions (Grigg, 1974; Okigbo, 1984). Nomadic pastoralism and shifting farming are two very dissimilar modes of traditional agriculture sharing the intermittent and extensive use of land. Shifting agriculture is a part of the evolutionary sequence running from foraging to incipient farming to permanent cropping, while pastoralism followed domestication of animals as an adaptation to arid regions or as a response to desiccation. In this stage more attention will be given to the cultivation of crops.

Shifting cultivation alternates variable but short cropping periods with variable but commonly fairly long periods of fallow. Ruthenberg (1980) propose the following definition:

$$R = (C * 100) / (C + F) \quad \text{eq. 8.1}$$

where C is the number of cropping years, and F is the number of fallow years. Shifting system has values of R bellow 33, a fallow system R is between 33 and 66 and permanent cultivation R is greater than 66. In the shifting system crops are grown in the ashes for a few years and then the soils are left to fallow for (at least theoretically) many years (8 to 12 years in tropical rain forests and 15 or more in drier areas). This system is only sustainable under low population density (2 to 4 persons per km^2 in Holden, 1992, or 30 to 40 in FAO, 1986). One person requires as much as 10 and as little as 2 ha of land in fallow and under the crops, with the actually cultivated area ranging from just 1/10 to 1 ha. However, shifting still persists as a non-sustainable practice in regions with higher population densities. The survey done in 1994 does not give a realistic picture about the periods land is left fallowing. However, if consecutive surveys are put together in the analysis, some clues about this could be derived, which will allow us to establish the boundaries of the farming systems - the time span.

The cultivation cycle starts with clearing the natural vegetation. The most labor-intensive phase of field preparation is felling of large trees (which might happen if fallow periods are long enough), trimming and pollarding of smaller trees, and slashing of younger growth. After a period of drying, the cut phytomass is burned. Fire clears away the slash litter, prepares the surface for planting, reduces the regrowth rate of forest species and attack rates of pests, and although most nitrogen is lost, mineral nutrients in the soil are recycled.

On the other hand, agriculture in Africa is considered to be one of the main causes of deforestation due exclusively to the slash-and-burn cultivation practiced by the 250 million peasants. From an energy efficiency view point, shifting cultivation is an extremely unproductive system as it capitalizes large quantities of biomass and, therefore, is a high input system (McGrath, 1987). But its present use is mainly attributed to the low external input system which from the peasants' economic perspective is very efficient (Boserup, 1975; Richards, 1984). Another reason which may be associated to Boserup's idea is that the consecutive timely presence of external resources in rural areas have not been guaranteed in the past, pushing the farmer into a situation of counting on their "own forces"- the use of their own and internal resources. This is one of the main reasons to study productive systems that could achieve the goals of the peasant agriculture in a more sustained way. It will be a failure to look at the problem from just one angle. The food chain has to be put in perspective, and every connected component analyzed.

There was an unfounded tendency in the past to explain the continuation of shifting cultivation and slash-and-burn cultivation systems in terms of peasants' non-rational and traditional-bound behavior. On the contrary, as shown in many works (Negrao, 1995; Holden, 1992; and Low, 1982) peasants are largely rational beings, with a very sensitive perception of their environment, opportunities and needs. This is one of the reasons to stress that if infrastructural work is performed and appropriate policies established, better results can be obtained from rural populations than have been experienced in the past.

A variety of edible, fiber, and medicinal species, dominated by grains (maize, rice, millet), roots (sweet potatoes, cassava, inhams, yams), and legumes (various beans and groundnuts), are grown in often unruly-looking gardenlike arrangements, typically with high degrees of interplanting and intercroping and staggered harvesting. Although two to five staples may provide most of the food energy, the number of cultivated crops is rarely less than a dozen species crowded in a small area, resembling the variety that prevailed in the original forest for the most humid tropics. In some instances we can also observe this sector highly involved in the production of cash crops, like copra, sugar, cotton and cashew nuts. This diversity is one way of risk minimization, and at the same time a way of pest management.

Profuse gardens are commonly fenced and/or a good deal of time must be spent guarding the crops against mammal and bird predation, furthermore manual weeding in order to keep the herbaceous and ligneous competitors in check, must be repeated as many as five to six times per harvest. Except for the once or twice a year harvests of grain crops, there is a continuous digging of roots and picking of seeds, leaves, and stems.

Total labor inputs vary between as little as 600 and as much as 3200 h/ha; men felling the trees and women carrying disproportionate shares of less labor-intensive but still taxing repetitive chores such as tilling, weeding and harvesting. Net energy returns cluster between 11 and 15 for small grains, and between 20 and 40 for most root crops, bananas, and also for good corn yields, see Table 8.1.

However no form of agriculture can be achieved by simple maximization of energy returns. Many other imperatives besides the energetic ratios of input-output are governing peoples desires. To illustrate, we sometimes have preference to corn which returns less energy than beans. Palatable factor, risk-consideration, nutrients craving, etc., should also be taken into account when recommending crops.

Energy-efficiency data should be analyzed very carefully since most of the time we do not quantify the quality of the products. For example, when comparing maize's energy efficiency, the oil used in its production is not edible as maize is not produced for burning. A better example is the production of computer chips. Their manufacture requires added energy but when thrown into the fire, their heat of combustion appears to be nearly zero. This zero energy efficiency does not mean they should not be produced - that depends of course on how much these chips are appreciated. Food prices are mostly based on the energy input to get it to the consumer, not on the energy content.

Agricultural system	Energy ratio
Hunting-gathering	7·8
iKung bushmen	
Herders	
Dodo tribe, Uganda	5·0
Shifting cultivators	
Congo	65
Tsembaga	20·3
Subsistence and shifting	
Rice, Dayak	16·5–18·2
Rice, Iban	14·2
Rice, Tanzania	23·4
Maize, Africa	37·7
Millet, Africa	36·2
Sweet potato, Africa	31·3
Cassava, Africa	22·9
Yams, Africa	22·9
Groundnut, Africa	12·8
Subsistence	
India (from Odum)	14·8
China (1935–37)	41·1
Corn, Mexico (axe and hoe)	30·6
(oxen)	14·15
Guatemala (axe and hoe)	13·6
(oxen)	3·95
Nigeria (axe and hoe)	10·5
Philippines (Carabao)	5·07
Wheat, India (bullock)	1·69
Rice, Philippines (Carabao)	5·51

Table 8.1- Energy efficiency ratios for various agricultural systems
(source: Leach 1976)

No form of extensive cultivation (at least historically) could produce enough food to lay the foundations for a high culture: incipient urbanization and emergence of states could be supported only by intensified modes of cropping. The development of modern civilization is more and more interdependent with the development of urban centers. To maintain an ever growing urban population, labor productivity of the rural population has to be much larger than that of subsistence. This is only possible if the urban sector supplies means of production - machines, fertilizers, biocides and information. Intensive use of draft animals is a key characteristic of intensive farming, although not a pre-condition; the diversification of implements and increasingly complex machines followed, as did the spread of fertilization, irrigation and multicropping.

The energy source for agriculture in Africa is mainly from humans since most operations are performed manually. Manual labor accounted for 81% of farm power used in crop production, as compared to 16% for animal draft and 3% from machines in 1980 (Grigg, 1985). These percentages are not very far off when compared to the Moçambican situation.

Sustainable agriculture production at reasonably high levels of productivity cannot be achieved in Sub-Saharan Africa unless a substantial proportion of the human energy used in all phases of production and post-harvest operations are replaced by alternative sources of energy and better soil management is introduced in the traditional systems. Similarly, considerable amounts of domestic energy, which currently comes from fuelwood, should be obtained from more diverse sources and not at the cost of deforestation.

Different strategies exist for a planned sustainable production system such as 1) expansion of area under cultivation, 2) increased production per unit of input; 3) genetic improvement of crops and farm animals; 4)mechanization and appropriate technology; 5) integrated management of pests weeds and diseases; 6) improvements in, and broadening the range of, post-harvest technologies; 7) better management and utilization of the forest and range resources; 8) improved pasture management; 9) better management and utilization of aquatic resources; and 10) use of non-conventional food production methods, especially in regard to opportunities offered by advances in bio-technology.

When trying to make improvements in the agricultural production system we should be very careful in the strategy to use. In the past most development projects were biased towards a specific topic in the plan, this is unsustainable. In agriculture many resources are complementary. For example, the use of hybrid maize is only explored to its potential yields when supplemented with fertilizers which again need the presence of pre-determined soil moisture. This requires infra-structure and simple appropriate systems not only to supply the external resources and extension services, but as well to facilitate trade, storage, and transport. Though my antagonism in delivering a beautiful stand alone "package".

One of the major constraints in agriculture production in Africa, especially sub-Saharan Africa, is the widespread of manual labor and drudgery. There is an imperative for higher forms of energy inputs and energy cost-efficacy. There is limited use of animal power, because of adverse environment and lack of tradition and, limited tractorization due to the high cost of acquisition and operation of the tractor and related implements. Associated with that there is the acute labor shortage at peak periods of clearing and planting, weeding and harvesting. As a result, timely operations are often not easily accomplished.

Fuelwood, the other major energy resource after oil, used for cooking, water heating, preserving food, lighting and heating, and social and ritual purposes, is another source that is becoming scarce, creating problems for women who are already burdened with other activities and also problems of nutritional status and health. Fuelwood is an important resource in the whole analysis of the peasant's agricultural system. This in the traditional habits, is usually taken for granted. For a long time mother nature have provided men with this precious resource. The cost in real terms have been incalculable - loss of land and fertility due to erosion, change of weather - that when put into the income function of producing fuel-wood give highly negative balances. Again, it is unfortunate that trough the survey very little can be said about the most important contributor into the food-chain - conservation and processing.

8.1 The Energy Constraint

The importance of higher levels of power use to world agriculture is threefold. In the first place they must be used if certain operations, such as deep plowing and land clearance, are to be performed effectively. Secondly, its greatest advantage is probably its ability to perform crucial operations, such as tillage, and planting in time. Timely tillage and planting are of key importance in semi-arid, and subtropical areas, where the total crop area depends on how much land can be prepared and planted in the brief period when the uncertain rains arrive. The third and most basic function of mechanizing the system is to replace human labor. Although important in most developed countries, where labor is expensive, this function is unlikely to be as important in most developing countries in the Sub-Saharan region. An approach towards a sustainable introduction of farm power technologies is in terms that mechanization should be used to complement rather than replace human power.

Mechanization, one way of solving the drudgery problem, is influenced by a number of features of the smallholder and the existing technological level used. The level of mechanization is dependent upon the availability of qualified human labor and the level of industrialization which reflects the existing farming system within each country.

It is important to note that the new or improved technologies to be adopted by developing countries must be appropriate and fully accepted, not only in terms of technical suitability, but particularly in terms of resources and aspirations of the recipients.

Fertilizer is the other important variable in the energy constraint. However to increase the use efficiency (productivity) of fertilizer yet other resources have to be considered into the production system. Irrigation is fundamental, even more in countries where rainfall is irregular and sometimes faltering. The other resource associated with fertilizer use is the seed. Improved and hybrid seeds give better responses to the use of fertilizer than local varieties.

9. The 1994 Agricultural Survey

The original title is *"Inquerito Agricola ao Sector Familiar, 1994"* (Inq/94). This survey as well as the one referring to 1992/93, have substantial value in identifying many critical variables that have been extrapolated since the last Agricultural Survey carried out in 1970. Most of the data published from 1970 to 1992 were never backed up with such an extensive data base as the ones now available. This survey (Inq/94) will give new light to the research on improving production conditions for the agriculture sector.

9.1 The Survey Design

Moçambique has 10 provinces, and 15 agroecological zones (see map of the country bellow). The survey for the agricultural campaign 93/94 (Inq/94), was carried out in 30 Districts (3 districts per province) from April to September, the inquiries were carried out after the main harvest and lasted around 4 weeks. The main objective of Inq/94 was to provide basic data on agricultural production during the agricultural season 1993/94 and also data on the conditions under which this production was achieved. Inq/94 was the second in a series of annual agricultural surveys that began with the agricultural year of 1992/93, and intended to be followed in the next years.

Theoretical and Actual Model of the Survey:

Theoretical sample size: 10 provinces * 3 districts * 8 villages * 12 households = 2.880. The actual number of families covered were 2.749.

In Table 9.1[1] we have a better picture of the real situation in terms of the households interviewed. According to this, of the 17.317.212 inhabitants (or 3.183.201 households) in the whole country 76% live in the rural area. The 30 districts where the survey was carried out represents around 26% of the rural population. Surveying around 91/92 households per district, gives us an actual sample (very close to the theoretical sample size - 2880) of 2.749 households, equivalent to 0,42% of the rural population existing in the 30 districts.

For this survey the Ministry's limitation in the design of the survey model was to get a sample with maximum possible data having in mind financial constraints as well as infrastructure constraints as these factors are decisive in defining the sample size. The first priority was to get correct information for the Country, and the second priority at the level of provinces. It is mentioned that for a good statistical analysis at the district level more money would be required; the survey 1994 retrieved average information for 96 households per district and the Ministry thinks this is a short sample for specific studies at the district level.

Sample selection was done in three stages: The first stage was a deterministic selection of the 30 districts, 3 in each of the 10 provinces, the districts were selected from the list of considered priority districts "Lista dos Distritos Prioritarios", according mainly to political/war situation reasoning. In later surveys this deterministic selection is to be avoided.

A list in Appendix 1 was created to extrapolate with a weighing system based on population per region all the values for Provinces and Country.

The final selection of the districts in each stratum was randomized in relation to population size in each district.

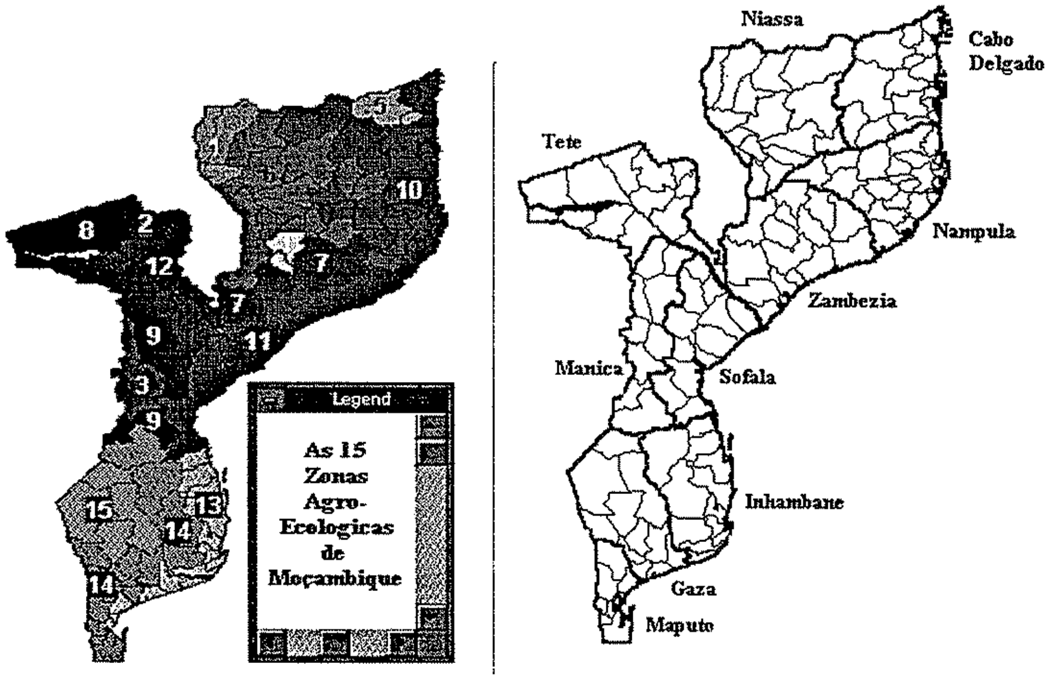
[1] Table 9.1 conflicts somewhat with the one bellow Table 9.2 based on the appendix 1. Population figures for the districts do not correspond. This originates a difference of 266944 rural inhabitants (13125193-12858249). It is not explained very much how the table bellow is originated. Table 9.1 is obtained by extrapolation of data (using weights from Table in Annex 1) from the Inq/94. If Table 9.2 was obtained from projections of the National Census Bureau, then we could make some inferences about the accuracy of the data acquired, but as nothing is mentioned I feel dubious. All the figures produced by the author are based on the Table 9.1.

This selection was sent to the provinces and in some cases it was necessary to change to the neighboring district, mainly due to the inaccessibility to the original district.

Table 9.1						1994
Mozambican Population & Households & Sample.						
Prov. / Distr. of	Sample		households	Total in prov./distr.		Members per
Survey 94	Household	Members	in sample	Households	Members	Household
01 Niassa	**243**		29 756	**168 132**	**825 385**	**4,91**
0101 Cuamba	76	362		5 794	27 599	4,76
0103 Lichinga	71	341		18 030	86 595	4,80
0111 Sanga	96	516		5 932	31 883	5,38
02 Cabo Delgado	**288**		52 190	**300 413**	**1 397 141**	**4,65**
0208 Montepuez	95	421		19 715	87 370	4,43
0209 Mueda	94	456		24 244	117 607	4,85
0212 Pemba	99	454		8 231	37 745	4,59
03 Nampula	**276**		86 910	**630 053**	**3 217 981**	**5,11**
0313 Monapo	96	496		45 581	235 503	5,17
0319 Nampula	91	450		20 110	99 430	4,94
0320 Ribaue	89	457		21 219	108 958	5,13
04 Zambezia	**286**		105 082	**642 752**	**3 363 082**	**5,23**
0404 Gurue	96	504		38 264	200 888	5,25
0410 Mocuba	93	470		28 912	146 116	5,05
0416 Nicoadala	97	519		37 906	202 818	5,35
05 Tete	**257**		68 139	**202 961**	**1 003 429**	**4,94**
0501 Angonia	97	419		28 919	124 920	4,32
0502 Cahora Bassa	84	479		11 771	67 124	5,70
0509 Moatize	76	401		27 449	144 831	5,28
06 Manica	**282**		40 919	**136 160**	**821 494**	**6,03**
0602 Gondola	96	558		19 809	115 137	5,81
0605 Mossurize	93	532		12 308	70 407	5,72
0607 Sussundenga	93	648		8 802	61 332	6,97
07 Sofala	**278**		61 636	**251 641**	**1 552 106**	**6,17**
0701 Buzi	96	593		35 497	219 269	6,18
0706 Dondo	98	664		10 153	68 790	6,78
0707 Gorongosa	84	484		15 986	92 108	5,76
08 Inhambane	**273**		80 354	**287 399**	**1 513 963**	**5,27**
0802 Homoine	83	396		21 872	104 355	4,77
0805 Massinga	95	514		42 533	230 126	5,41
0814 Maxixe	95	529		15 949	88 809	5,57
09 Gaza	**277**		77 470	**221 642**	**1 334 322**	**6,02**
0904 Chibuto	95	528		36 959	205 413	5,56
0906 Xai-Xai	86	581		17 277	116 722	6,76
0907 Chokwe	96	596		23 234	144 247	6,21
10 Maputo	**289**		50 264	**163 762**	**1 093 794**	**6,68**
1001 Boane	96	566		10 893	64 224	5,90
1003 Manhiça	97	767		21 766	172 105	7,91
1006 Moamba	96	542		17 605	99 393	5,65
11 Maputo Cidade				178 286	1 194 515	6,70
Total do Pais				3 183 201	17 317 212	5,44
Rural Country Total				2 464 571	13 125 193	5,33
30 districts Total	**2 749**	**15 243**	**652 720**			
Source: Modified from Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.						

Table 9.2 used for the weights associated with Annex 1

Province	**rural population 1994**	**N° of distr.**	**Agro. Ec. zones**
Niassa	675.128	4	1,6,10
Cabo Delgado	1.229.790	5	5,6,10
Nampula	2.462.083	11	6,7,10,11
Zambézia	2.959.743	13	4,6,7,11
Tete	817.426	4	2,8,12
Manica	603.259	4	3,9,12,14
Sofala	1.080.215	5	9,11,12
Inhambane	1.332.638	6	13,14
Gaza	1.073.103	5	13,14,15
Maputo	624.864	3	13,14
Total Rural Moçambique	**12.858.249**	**60**	**1..15**



Map of Moçambique.

. In the second stage 8 villages were selected* in each District with a probability proportional to the village total population. This total was obtained through a previous registration done during the preparation phase carried out in all villages of the district. Finally in the third and last stage a fixed number of 12 households per village were selected*.

* The selection of the Unit of Analysis, were carried out strictly according to the rules for a representative sample inside each district. That means that in each district each household had the same probability to be selected. The value of this probability of selection and the error were calculated.

Raw data available is stored in a data base created with SAS. The database consists mainly of 6 datasets, I94.AGR with a matrix 246 variables and 2749 observations, I94.PRO with 152*15878, I94.MAC with 76*5195, I94.MEM with 38*15243, I94.EXT with 38*1652 and I94.DIS with 11*156. The existing information concerns the questionnaire in the Appendix 3.

9.2 Main Contributions for the Present and Future Agricultural Surveys

Every study contains a certain margin of error. In general they are classified by random error, deriving that only one part, a sample of the population is studied; and systematic errors caused by deficiencies in the survey process.

The first one, the random error can be maintained under control if a careful sampling design is used. It is suggested that in the Ministry of Agriculture's Document of Statistics, a more detailed chapter explaining all the methodology in the sampling procedure should be demonstrated and made clear. For a common reader the issue may be of little importance but for research purposes, awareness of the quality of data and potential use in concluding arguments are of crucial importance. It is quite confusing the way which districts were selected. And still it seems, that for the Inq/94, districts were selected in a deterministic way, mainly based on the accessibility to the regions. If this was the case, care should be taken when extrapolations are made about the whole country. Because districts were selected through a list given as priority or any other reasons than random selection, the results obtained are bound to bias. This is one of the main reasons that in the tables produced by the author, only interviewed households are considered, and the weighting system was avoided. Whenever conclusions should be made, they are essentially based on percentile basis.

Concerning the systematic errors, there is little or almost nothing about the methodologies used: i)estimation of cultivated areas; ii)methodologies concerning production evaluation, (economic or biological production), consideration of losses, farmer's report, etc.,.

In these type of surveys researchers have to be aware of the main constraints, and the most important is the one related to vagueness and a considerable amount of incertitude in various collected variables which require or are based on the farmer's memory and their own biases. For example, area is very important in some kinds of analysis and sometimes it's accuracy is far from the real situation when it is based on the farmer's verbal and memory capacity. Farmer's in developing countries rarely are conscious of their accurate land possession area. The correlation between verbal area and the actual ones is frequently as low as 0,3-0,6 (Tanzania, 1988). In survey of 94 it was found difficult to compare averages for measured and inquired areas, because they have been adjusted by the surveyors before being entered into the database.

Another important comment is the harvested crops. Most of the time crops are harvested on a daily basis in some crops while in others may be during periods of necessity. When a crop is ripe it may only correspond to a fraction of what was really produced. To complicate matters worse, most of the time, more than one crop is planted in the same plot, so productivity of maize for example, have to be compounded with beans, cassava and perhaps four or more other crops.

This problem of an excess area mentioned by the farmer might be one of the reasons that productivities are very small in this sector of agriculture. Concerning this aspect, the author intends to use (in a later stage) the qualitative data existing in the database in terms of the proportions that crops seem to occupy in the plots interviewed. This is very subjective as it depends entirely on surveyor experiences and biases, but can at least come closer to the real situation in the areas occupied by the different crops. All areas given in subsequent tables should be looked upon carefully, as mostly they represent the actual area of the farm.

Concerning the agricultural production system of the peasant sector, it is important to understand the system and the resources available. Land is very important, when interpreting the data dealing with areas, it was difficult to distinguish between area cropped in association with area fallowed. It is difficult to establish how many years the soil is left without cultivation. This is very important as this shifting agriculture is suppose to use extensive areas of land.

An important issue that should always be part of a census is the answer to the crucial question: Are the results in terms of random design reasonable? Before the complete set of tables is produced, it is recommended that a few tables be prepared to check if the survey results are reasonable. They should include:

. Estimated total number of persons for each stratum. Add together the results to get a total for Moçambique.

. Estimated total of households and villages for each stratum. Add together the results to get the total for Moçambique.

The above is easy to get in Table 9.1, but what is missing are the figures from the National Bureau of Statistics to check if the two totals are reasonable. Based on the last population census 1981 these figures are produced every year based on this population census. If results produced by the survey are far from these projections (or any better projections produced by demographers), than something is wrong. It might be that this was done, but nothing is commented nor are figures given. As a researcher, these values are of some validity, as it can give a qualitative feeling about our analysis. I personally feel that on average the survey was exhaustive in many areas and superficial in others which is very understandable for the first inquires done in such a long time. In the analysis of data, precise comments are made whenever I felt the variables were not existent or would not describe in a sufficient basis the real situation. This should not in any way refute the high value of the survey not only for the research boards but as well for the whole community in understanding our rural populations.

10 Preliminary Identification of Data and Analysis

The database carrying the raw data of the Inq/94 was the main source for the following analysis. It was not easy to understand some of the existing variables, but in general the author found that the data always produced results consistent with each other, when using different datasets, or even different describing variables for the same outputs. Another aspect in this analysis, is the use of figures corresponding to the interviewed households and not extrapolations with the weight system usually used for outputs at the National level. The main reasons for these decisions was that first, the chosen districts were not done randomly, and second the interest was not to provide National Statistics, but to emphasize some household characteristics that may later give important tools in order to improve agriculture production. Some of the Tables are produced according to administrative division of the country, household size, or household development groups. The author is aware that the way data is output is very influential in enhancing some characteristics more than others, but due to the limitation of time and space only part of the data will be presented and analyzed.

10.1 Farm Size and Structure.

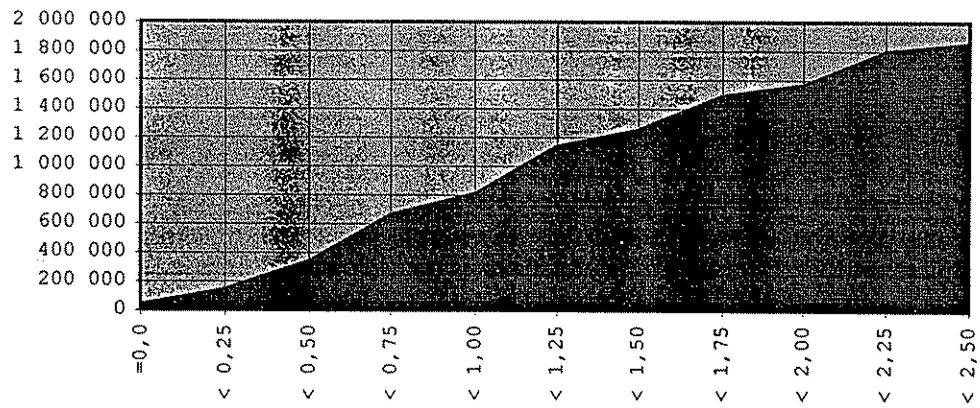
Variables to assess are: the size of the farms and representative percentages into the total number of holdings. Area classes are established and its relative percentage extrapolated in Table 10.1 (in next page). The figure that comes immediately to my eyes is the total amount of land cropped and in fallow which is around 4.488.000 hectares, contrasted with previous data, (Fagilde, 1987 citing Agri. Survey, 1970) the figure was 2.493.500 ha for the same sector of agriculture, and an extrapolated value of 3.000.000 ha in 1980 (Robinson, 1980). The direct implication is that from an average of 1,5 ha per household in 1970 we achieve a value of 1,82 ha per household in 1994; if this value is correct, it seems that the peasants farm area doubled in 24 years while the number of households increased by approximately 1,5. One reasoning is that after independence families had more access to land and probably could dedicate more time tending their farms than any other compulsory activities (Negrão, 1995) that were common practice during colonial times. The other important issue is that 56% of the rural households occupy 57% of the arable land with farm average area of 1,31 to 2,36 Ha; 10% of the households use around one third of the arable area. This trend (larger farms), if correctly representing the rural areas may create an illusion when it comes to the use of external resources like the use of draught animals as well as tractors. It will be shown that very often households have their farm area sparsely distributed (the plots are not necessarily contiguous) in many small plots with an average area of 0.9 to 1 Ha each.

Table 10.1						1994
Distribution of Households per total area of farm						
Classes of Area in Ha	Households x1000	%	Area in Class 1000 Ha	%	Avg. Area per Househ.	
Without land	42	2%	0	0%	0,00	
0,00 - 0,24	104	4%	14	0%	0,13	
0,25 - 0,49	195	8%	66	1%	0,34	
0,50 - 0,99	472	19%	303	7%	0,64	
1,00 - 1,99	756	31%	991	22%	1,31	
2,00 - 3,99	626	25%	1 604	36%	2,56	
4,00 - 9,99	257	10%	1 369	31%	5,33	
> 10	11	0%	141	3%	12,82	
Total	2 463	100%	4 488	100%	1,82	

Source: Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.

Observações:
- Of all households 14% have areas smaller than 0,5 ha and 10% have areas superior than 4 ha.
- Average area per household is 1,82 ha.
- "Area " includes cropped and fallow area.
- "Área in Class" is the area sum of interviewed household.

N° of Households with area smaller than X ha.



Source: Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.

Table 10.2 gives an idea of how much area was left to fallow during 1994. In shifting agriculture as mentioned below, the main resource is the soil fertility that is replenished by long periods of fallow (sometimes up to 15 years).

Due to unstability in the past, most of the land has been in production very recently so it might be premature to make conclusions about Table 10.2, however some indications could be traced. 83% of the households do not have land in fallow. Of the area in fallow (11%) 93% is fallowed by only 10% of the households (with larger farms). If we consider the value of around 5 million ha, the total area on average per household would be 2,05 ha. Again considering that each member of the family needs around 3 ha (some authors recommend 5 ha) we would calculate for the average Moçambican household 16 ha if shifting agriculture is used (which might seem contradictory with value in Table 10.2). There might be three possible explanations for this apparent contradiction, one is that due to war in the past years some land was not cultivated intensively or not cultivated at all. The other reason is because land in fallow is sometimes under traditional responsibility of the chief and not the household interviewed.

Table 10.2					**1994**
Fallowed Area in 1994					
Area Class		Households		Area in Class	Average Area
in Ha	x1000	%	1000 Ha	%	per Hh.
No Fallow Area	2038	83%	0	0%	0,00
0,00 - 0,24	102	4%	5	1%	0,05
0,25 - 0,49	25	1%	7	1%	0,27
0,50 - 0,99	52	2%	27	5%	0,53
1,00 - 1,99	125	5%	131	23%	1,05
2,00 - 3,99	91	4%	206	36%	2,27
4,00 - 9,99	25	1%	129	23%	5,21
Mais que 10	5	0%	60	11%	13,21
Fallow Area	2 463	100%	565	11%	0,23
Used for Agric. Production in 1994			4 488	89%	1,82
Total Area			5 053		2,05
Source:Modified from Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.					

From the data available it is still difficult to understand the idea about how many years corresponds to a whole production cycle, combining fallow and cropped years. The third aspect is that in the questionnaire there is some dubious questions (A10 and M13) that can shadow the real value of fallowed area. At least in the coastal belt (where population densities are high) due to intensive use of land for subsistence cropping and firewood, erosive problems originate in substantial soil-fertility losses.

In terms of gender it is important if the holding is female or male headed. In Moçambique, as in many African countries innovative technologies are most of the time the property of man as they, usually by tradition, have better claims to resources. In Table 10.3, male headed households consist of 81% of the rural households, and female ones the remaining 19%. The differences in land possession are more demarcated in the two extremes of the area classes. That means that there is more percentages of woman headed households with less land in the lower area classes as well as in the higher area classes. This Table shows that man-headed households have a better claim to the use of land. The author wants to remark again for some differences in Table 10.3 when compared to Table 10.8. Some values can differ because the last one was obtained by just using the households in the Inq/94, while Table 10.3 was obtained by the use of a weighting system.

Tabela 10.3a- Gender & Household Head & Area of Farm
Household distribution per area and sex of head.

	Total Households		Female headed		Male headed	
Area Ha	x 1000	%	x 1000	%	x 1000	%
Without land	42	2%	11	2%	31	2%
0,00 - 0,24	104	4%	37	8%	67	3%
0,25 - 0,49	195	8%	68	14%	127	6%
0,50 - 0,99	472	19%	123	26%	349	18%
1,00 - 1,99	756	31%	145	31%	611	31%
2,00 - 3,99	626	25%	65	14%	561	28%
4,00 - 9,99	257	10%	23	5%	234	12%
10,0 +	11	0%	1	0%	10	1%
Total	2 463	100%	473	100%	1 990	100%
Average Ha		1,82		1,18		2,00
Mediana (50%)		1,5		1,0		1,5

Source: Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.

Table 10.3b- Gender and Area of Farm

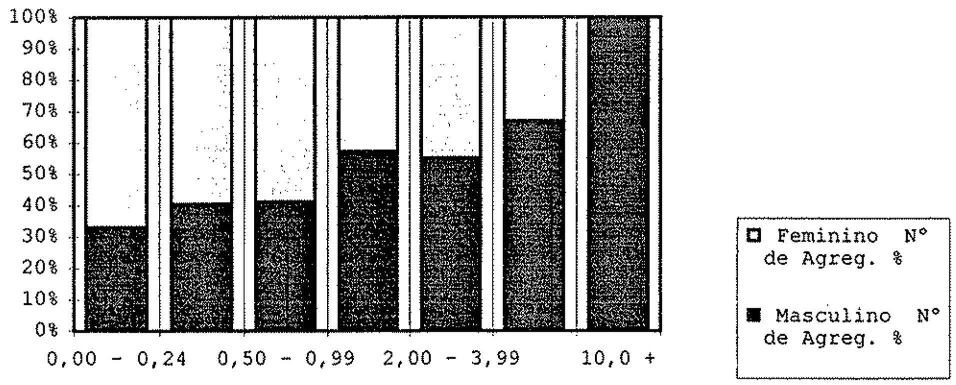


Table 10.4 gives an indication that larger households (with more members) also have access to more land. As mentioned before, the flexibility of land versus labor is by many authors assumed to be a fixed factor which does not seem to be the case for the whole country and not even for the South, Center and North areas of the Country. In this way we rarely obtain average areas greater than 4.5 Ha per household and this only happens for households with more than 10 members.

Table 10.5 'de Jure' work force is all members in active age, obtained when considering all members of the household with more than 16 years and less than 64. Some authors recommend the lower limit of 10 years of age and 60 for the upper limit, for the African situation. In this table, as expected, members in active age tend to increase with the household size (in some cases this criteria was changed but the average results do not change significantly).

Table 10.6 'de Facto' work force are only members of the household actually involved in their own farm activities using the same criteria as for Table 10.5 above. Tables 10.5 and 10.6 when put together give a strong indication about "off-farm" labor in the rural areas, and as well can provide explanations in labor migratory trends. The average rural family has 5,33 members (Table 9.1), with approximately 3,1 potential working units per household (calculated from Table 10.5) of which 2,5 work their own farms (calculated from Table 10.6). That means that for every two households one working person is not working on the household farm. This also can suggest the existence of wage employment opportunities, which may present advantages over remaining in the rural environment, where there is limited opportunity to

Table 10.4- Land Use with Household Size

		Cropped area per household number of member classes											
		01-3			04-6			07-9			10 +		
		Nº of House-holds	croparea		Nº of House-holds	croparea		Nº of House-holds	croparea		Nº of House-holds	croparea	
	Nº of obs.	SUM	SUM	average	SUM	SUM	average	SUM	SUM	average	SUM	SUM	average
ALL	**1 657**	**74 357**	**111 565**	**1,50**	**122 119**	**251 800**	**2,06**	**78 658**	**180 393**	**2,29**	**37 100**	**120 633**	**3,25**
ESTRUT													
Boane	96	3 064	4 442	**1,45**	3 177	3 914	**1,23**	2 837	3 775	**1,33**	1 816	2 273	**1,25**
Moamba	96	5 135	4 883	**0,95**	6 418	14 298	**2,23**	3 484	6 323	**1,81**	2 567	12 376	**4,82**
Manhica	97	2 468	3 061	**1,24**	4 937	10 672	**2,16**	6 956	12 660	**1,82**	7 405	17 502	**2,36**
Xai-Xai	86	2 813	5 039	**1,79**	6 429	15 889	**2,47**	4 420	13 882	**3,14**	3 616	13 569	**3,75**
Chockwe	96	3 388	5 349	**1,58**	9 923	19 875	**2,00**	7 019	17 651	**2,51**	2 904	6 210	**2,14**
Chibuto	95	10 504	26 038	**2,48**	12 838	30 189	**2,35**	9 726	24 688	**2,54**	3 890	16 616	**4,27**
South	**566**	**27 372**	**48 812**	**1,78**	**43 722**	**94 837**	**2,17**	**34 442**	**78 979**	**2,29**	**22 198**	**68 546**	**3,09**
Mossurize	93	2 912	1 908	**0,66**	5 691	11 702	**2,06**	2 382	4 587	**1,93**	1 323	4 628	**3,50**
Sussunden	93	1 609	3 290	**2,04**	3 218	8 733	**2,71**	1 798	7 144	**3,97**	2 177	13 974	**6,42**
Gondola	96	3 920	3 757	**0,96**	8 047	12 651	**1,57**	6 190	10 499	**1,70**	1 651	3 751	**2,27**
Buzi	96	4 067	3 335	**0,82**	17 009	29 718	**1,75**	10 723	26 860	**2,50**	3 698	9 891	**2,67**
Dondo	98	1 761	2 287	**1,30**	3 315	6 252	**1,89**	3 315	6 671	**2,01**	1 761	6 838	**3,88**
Gorongosa	84	2 855	2 689	**0,94**	6 851	10 528	**1,54**	4 948	8 451	**1,71**	1 332	2 649	**1,99**
Centro	**560**	**17 124**	**17 266**	**1,01**	**44 131**	**79 584**	**1,80**	**29 356**	**64 212**	**2,19**	**11 942**	**41 731**	**3,49**
Cuamba	76	2 135	3 361	**1,57**	2 440	4 205	**1,72**	991	1 715	**1,73**	229	839	**3,66**
Lichinga	71	6 349	6 437	**1,01**	8 126	13 848	**1,70**	2 539	4 767	**1,88**	1 016	4 444	**4,37**
Sanga	96	1 298	1 911	**1,47**	2 780	4 496	**1,62**	1 668	3 246	**1,95**	185	772	**4,17**
Pemba	99	2 910	3 677	**1,26**	4 157	7 317	**1,76**	1 081	1 810	**1,67**	83	125	**1,51**
Montepuez	95	7 886	15 741	**2,00**	8 509	22 911	**2,69**	2 905	8 002	**2,75**	415	1 868	**4,50**
Mueda	94	9 285	14 358	**1,55**	8 253	24 602	**2,98**	5 674	17 662	**3,11**	1 032	2 308	**2,24**
Norte	**531**	**29 863**	**45 485**	**1,52**	**34 265**	**77 379**	**2,26**	**14 858**	**37 202**	**2,50**	**2 960**	**10 356**	**3,50**

Table 10.5

Table 10.5- 'de Jure' Work Force versus Household Size (source: author from Inq/94)

		de Jure' work force - total number of members in working age (16 to 64 years old)											
		01-3			04-6			07-9			10 +		
		Nº of House-holds	de Jure		Nº of House-holds	de Jure		Nº of House-holds	de Jure		Nº of House-holds	de Jure	
	Nº of obs.	SUM	SUM	average	SUM	SUM	average	SUM	SUM	average	SUM	SUM	average
ALL	1 657	74 359	122 955	1,65	122 118	322 263	2,64	78 656	295 775	3,76	37 100	228 689	6,16
ESTRUT													
Boane	96	3 064	2 837	0,93	3 177	8 737	2,75	2 837	12 709	4,48	1 816	9 531	5,25
Moamba	96	5 135	7 702	1,50	6 418	16 871	2,63	3 484	12 653	3,63	2 567	15 221	5,93
Manhica	97	2 468	4 488	1,82	4 937	15 707	3,18	6 956	32 087	4,61	7 405	47 794	6,45
Xai-Xai	86	2 813	4 018	1,43	6 429	18 483	2,87	4 420	22 501	5,09	3 616	30 336	8,39
Chockwe	96	3 388	6 535	1,93	9 923	29 285	2,95	7 019	29 527	4,21	2 904	20 088	6,92
Chibuto	95	10 504	16 340	1,56	12 838	42 794	3,33	9 726	38 126	3,92	3 890	27 622	7,10
South	**566**	**27 372**	**41 920**	**1,53**	**43 722**	**131 877**	**3,02**	**34 442**	**147 603**	**4,29**	**22 198**	**150 592**	**6,78**
Mossurize	93	2 912	4 764	1,64	5 691	13 896	2,44	2 382	8 470	3,56	1 323	8 073	6,10
Sussunden	93	1 609	3 029	1,88	3 218	8 234	2,56	1 798	7 004	3,90	2 177	13 724	6,30
Gondola	96	3 920	7 222	1,84	8 047	20 634	2,56	6 190	21 253	3,43	1 651	9 904	6,00
Buzi	96	4 067	5 916	1,45	17 009	43 632	2,57	10 723	35 867	3,34	3 698	18 118	4,90
Dondo	98	1 761	3 522	2,00	3 315	8 288	2,50	3 315	12 225	3,69	1 761	8 806	5,00
Gorongosa	84	2 855	5 138	1,80	6 851	16 176	2,36	4 948	16 937	3,42	1 332	6 851	5,14
Centro	**560**	**17 124**	**29 591**	**1,73**	**44 131**	**110 860**	**2,51**	**29 356**	**101 756**	**3,47**	**11 942**	**65 476**	**5,48**
Cuamba	76	2 135	4 269	2,00	2 440	5 261	2,16	991	2 897	2,92	229	1 449	6,33
Lichinga	71	6 349	9 396	1,48	8 126	18 030	2,22	2 539	9 904	3,90	1 016	4 063	4,00
Sanga	96	1 298	1 915	1,48	2 780	6 920	2,49	1 668	5 005	3,00	185	741	4,01
Pemba	99	2 910	4 573	1,57	4 157	9 062	2,18	1 081	2 910	2,69	83	166	2,00
Montepuez	95	7 886	14 527	1,84	8 509	21 168	2,49	2 905	10 999	3,79	415	2 075	5,00
Mueda	94	9 285	16 764	1,81	8 253	19 085	2,31	5 674	14 701	2,59	1 032	4 127	4,00
Norte	**531**	**29 863**	**51 444**	**1,72**	**34 265**	**79 526**	**2,32**	**14 858**	**46 416**	**3,12**	**2 960**	**12 621**	**4,26**

Table 10.6

Table 10.6 'de Facto' Work Force versus Household Size													
		de Facto' work force - only working members envolved in the household farm production											
		01-3			04-6			07-9			10 +		
	N° of obs.	N° of House-holds SUM	de Facto SUM	de Facto average	N° of House-holds SUM	de Facto SUM	de Facto average	N° of House-holds SUM	de Facto SUM	de Facto average	N° of House-holds SUM	de Facto SUM	de Facto average
ALL	**1 657**	**74 359**	**108 284**	**1,46**	**122 118**	**269 172**	**2,20**	**78 656**	**233 621**	**2,97**	**37 100**	**173 306**	**4,67**
districts													
Boane	96	3 064	2 042	**0,67**	3 177	6 127	**1,93**	2 837	6 581	**2,32**	1 816	5 900	**3,25**
Moamba	96	5 135	5 868	**1,14**	6 418	11 186	**1,74**	3 484	9 352	**2,68**	2 567	10 636	**4,14**
Manhica	97	2 468	3 590	**1,45**	4 937	10 546	**2,14**	6 956	21 317	**3,06**	7 405	30 965	**4,18**
Xai-Xai	86	2 813	3 817	**1,36**	6 429	15 268	**2,37**	4 420	16 675	**3,77**	3 616	24 309	**6,72**
Chockwe	96	3 388	5 809	**1,71**	9 923	21 298	**2,15**	7 019	22 266	**3,17**	2 904	13 553	**4,67**
Chibuto	95	10 504	15 562	**1,48**	12 838	36 959	**2,88**	9 726	33 846	**3,48**	3 890	24 120	**6,20**
South	**566**	**27 372**	**36 688**	**1,34**	**43 722**	**101 384**	**2,32**	**34 442**	**110 037**	**3,19**	**22 198**	**109 483**	**4,93**
Mossurize	93	2 912	3 309	**1,14**	5 691	11 646	**2,05**	2 382	7 014	**2,94**	1 323	6 485	**4,90**
Sussunden	93	1 609	2 839	**1,76**	3 218	7 193	**2,24**	1 798	6 152	**3,42**	2 177	11 547	**5,30**
Gondola	96	3 920	5 984	**1,53**	8 047	17 951	**2,23**	6 190	16 920	**2,73**	1 651	8 254	**5,00**
Buzi	96	4 067	4 437	**1,09**	17 009	37 346	**2,20**	10 723	32 169	**3,00**	3 698	14 790	**4,00**
Dondo	98	1 761	2 383	**1,35**	3 315	5 594	**1,69**	3 315	6 734	**2,03**	1 761	5 594	**3,18**
Gorongosa	84	2 855	3 616	**1,27**	6 851	13 702	**2,00**	4 948	12 750	**2,58**	1 332	5 329	**4,00**
Center	**560**	**17 124**	**22 568**	**1,32**	**44 131**	**93 432**	**2,12**	**29 356**	**81 739**	**2,78**	**11 942**	**51 999**	**4,35**
Cuamba	76	2 135	3 736	**1,75**	2 440	4 727	**1,94**	991	2 516	**2,54**	229	1 067	**4,66**
Lichinga	71	6 349	9 142	**1,44**	8 126	16 760	**2,06**	2 539	9 650	**3,80**	1 016	4 063	**4,00**
Sanga	96	1 298	1 915	**1,48**	2 780	6 611	**2,38**	1 668	4 758	**2,85**	185	741	**4,01**
Pemba	99	2 910	4 240	**1,46**	4 157	8 231	**1,98**	1 081	2 328	**2,15**	83	166	**2,00**
Montepuez	95	7 886	13 489	**1,71**	8 509	19 715	**2,32**	2 905	8 924	**3,07**	415	1 660	**4,00**
Mueda	94	9 285	16 506	**1,78**	8 253	18 312	**2,22**	5 674	13 669	**2,41**	1 032	4 127	**4,00**
North	**531**	**29 863**	**49 028**	**1,64**	**34 265**	**74 356**	**2,17**	**14 858**	**41 845**	**2,82**	**2 960**	**11 824**	**3,99**

acquire the means for members' goals (marriage, higher returns over labor). A regional analysis, would also indicate that in the South, the off-farm wage opportunity seems to be better than in other regions, as almost one member per family is working or seeking work elsewhere. This varies accordingly with the presence of other employment markets (as the proximity of the capital, industrial area and richer countries like South Africa and Swaziland).

As in any other society, as soon as a member of the family achieves self-subsistence s/he looks to create a new household. In rural Moçambique this trend, I assume, would not be very different. Robertson, 1976 notes that the existence of wage employment opportunities "would tend to undermine the 3 generation household in the long run by offering young men the early opportunity of establishing their own homesteads". This offers some justification in the attempt to identify development cycle stages by adopting household demographic data. Chayanov 1966, was perhaps the first economist to recognize the relationship between farm production and the changes in peasant household structure over its development cycle. He recognized that: "Since the labor family's basic stimulus to economic activity is the necessity to satisfy the demands of its consumers, and its work hands are the chief means for this, we ought first of all to expect the family's volume of economic activity to quantitatively correspond more or less to the basic elements in family composition."

In Table 10.7, Domestic Development Cycle involves more than just the arrangements of numbers and consumer producer ratios. The classification is based on household size which includes all members. Three size groups are isolated: those with 1 to 6, 7 to 10 and 11 or more persons (including those working off-farm). All households in the later category are assumed to be in the Consolidation phase (Group 3). The smallest households with 6 members or less are presumed to be in the Establishment phase if the household head is less than 50 years of age and if any children under 10 years of age are present. They are also assumed to be in this Group 1 even if there are no children but, in this case, the household head is less than 40 years of age. All other households with 6 members or less are assumed to be in the Decline phase (Group 4).

Table 10.7- Domestic Development Groups / criteria for classification and basic characteristics
(source: modified from Fortes,)

		Establish.	Expans.	Consol.	Fission	Decline	Female H
		Group1	Group2	Group3	Group4	Group5	Group6
Classification Criteria:							
Household Size		1 - 6 a)	7 - 10'	11+	7 - 10'	1 - 6'	any
		1 - 3 b)			other	other	
					than	than	
Age of Head		< 50 a)	< 50 a)		those	those	
		< 40 b)	< 55 b)		in	in	
					group2	group1	
Children <10 years		> 0 a)					
		none b)					
child/population ratio			> .24 a)				
			> .49 b)				

Households with 7 to 10 persons are assumed to be in the Expansion Phase (Group 2) if the household head is less than 50 years old and 25% of the household members are children under 16 years old. Households can be also in Group 2 if the same number of members are found but the head is less than 55 years old and 50% or more of the members are children under 16. All other households with 7 to 10 members are assumed to be in the Fission phase (Group 4). Group 6 or Female headed households form a separate category. The selection of the criteria for classification of the groups is influential in the obtained mean values, but this selection is aimed at farm-households with the same population sizes being split according to age and consumer/producer ratio.

Households of the same size but at different stages in their development cycle may be expected to exhibit different production characteristics. A summary of the mean values of the basic characteristics for each group are given in Table 10.8.

Thus we have households in the establishment (G 1) and decline (G 5) stages with approximately the same average members (from 4,26 to 4). However, households in establishment have younger heads and a slightly higher consumer/producer ratio than do households of the same size in the decline phase, and probably with a relatively better wage earning potential than their counterpart in an household in decline, where wage earning

Table 10.8- Basic Characteristics per Domestic Development Group
(source: author from Inq/94)

	Establish. Group1	Expansion Group 2	Consolid. Group 3	Fission Group 4	Decline Group 5	Female H Group 6	Rural 94
BASIC CHARACTERISTICS							
B1 Household (Hhold) size	4,26	7,93	12,2	8,1	4	4,5	5,54
B2 Age of head	32,8	39,2	51,7	54,2	56,5	45,8	45,3
B3 Cons/Producer ratio	1,75	2,38	1,72	1,72	1,64	1,89	1,79
B4 No. of Hholds	796	298	151	335	655	514	2749
B5 No of Landless Hholds	14	7	4	6	18	19	68
B6 Hholds w. Farm Land	782	291	147	329	637	495	2681
B7 % of B4 Hholds	29%	11%	5%	12%	24%	19%	100%
B8 Average Area of Farm (ha)	1,71	2,03	3,49	2,53	2,01	1,32	1,94
B9 Total Number of Plots	1473	592	342	708	1250	830	5195
B10 Number of Members	3391	2364	1837	2714	2631	2306	15243
B11 Active Population	1938	993	1068	1578	1604	1220	8516
B12 Total Area of Farm Ha	1336,32	592,17	513,34	833,02	1278,46	651,96	5205,27

potential of its old members would be decreased.

So we would expect these two groups to have different production characteristics even though they are of the same size; the household in establishment using more labor on off-farm employment and less labor on subsistence production, but buying the deficit in food in the market. Instead, the household in decline is expected to produce its own food consumption requirements. The same characteristics can be found between the expansion and fission stages. While households in the consolidation phase have, by definition, the largest average population, the average consumer/producer ratio and age of the head lies, as we would expect, between those of the expanding and contracting groups on either side. Clearly also, as households move through their development stages their consumption priorities will change. The rationale behind this is very simple. Households at the establishment stage will be able to easily meet basic food needs, will place relatively small priority on child care and, being in a growth phase, will be concerned about accumulating capital for the future. Households in the expansion stage will need to concentrate more on consumption needs and child care and will still wish to accumulate for the future but, with food, clothing and school expenses to meet, may be less able to do so. Households in the fission and decline stages will have reduced current consumption requirements to meet and, being in the decline phase, will not put much interest in accumulating capital for the future. Since the opportunity wage costs of the members of these households will be relatively low, they can be expected to place a smaller value on their time and take more leisure. Female headed households may usually fit between the fission and decline categories or sometimes may resemble group 1 in some characteristics. In overall the results may resemble the typical pattern of accumulation and decumulation which is emphasized in the literature.

Resource advantages of farm-households in the consolidation phase (G3) are quite marked. Compared with other groups, farm-households in this group have more crop land together with more equipment, animals, and farm workers to cultivate their farms. They also have more wage earners to provide cash income. These resource advantages result in group 3, cultivating the largest area, growing the most maize and probably being the most extensive adopter of new technologies, like improved mechanization, hybrid maize and fertilizer. But the highest area of cash crops and the next biggest adoption of improved seed are accredited to group 1, which tend to have fewer resource advantages than any of the other groups. Group 1 households will likely have very strong desires to accumulate for the future and the need for extra cash to do so will be relatively high.

Table 10.8 also shows how the rural community is divided. The greater group is in the establishment phase (29%), followed by the group in decline (24%) and the female headed households (19%), which together represent 71,5% of the rural area. Further refinements on the established criteria to define the different development groups should be made if evidence is found. One important factor that can have a strong influence on these proportions might be that the return and movement of families and individuals (refugees and internally displaced people) to their original territories was not finished, by 1994. Contrary to expectations, households in decline (group 5) represent a significant proportion of the population and Group 3 in consolidation takes up only 5.5%.

10.2 Tenure Arrangements

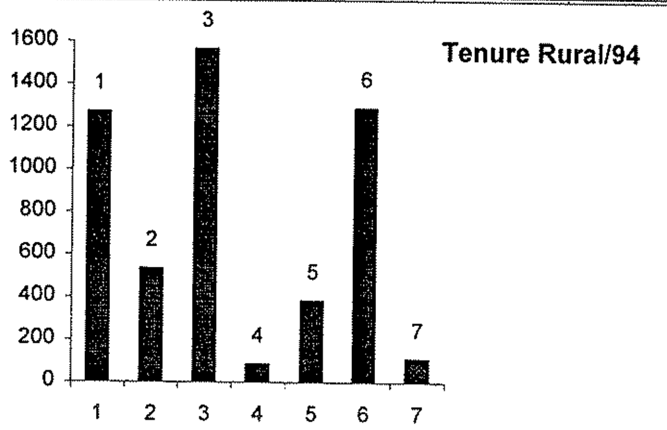
Land's role in Moçambique is (or can be) regarded as the basis of a social security system and is one of the most important when compared to all other economic ones. Any development program in the rural areas which enhances the value of the rural base and discourages permanent migration, will do little in terms of oscillating migration while income earning potential is greater in wage employment than farming. Owner occupancy, tenancies with varying degrees of security and rental arrangements, and communal ownership which grants usufrutory (land use) rights have differential effects on the farmer's willingness to invest in his/hers farming system. Credit facilities for resource acquisition or other type of subsidies are generally associated to area of land and tenure possessed by the farmer. Smallholder land itself can further limit the mechanization feasibility; namely topography, drainage, natural vegetation, and accessibility and size effects. The overall effect is to reduce the scope for sophisticated farm power systems more suited to large contiguous machinery-oriented holdings.

This survey, as demonstrated in Table 10.9, recognizes different levels of tenure arrangements, 1-allocated by traditional authorities, 2- allocated by formal authorities, 3- rented, 4- borrowed, 5- simply by occupation, 6- bought with land title, 7- inherited, 8-other. For the point of view of analysis, to consider all the different alternatives would be rather cumbersome. It would be much better to have less divisions as for example alternative 1 and 2, and inside each some of the suggested points.

Around 30% of the area is under use by occupation, 25% of the land is used through inheritance, and 24% by traditional habits. Households in the village seem to have access to land as they need it. With the start of land concessions by the state to the private sector, conflicts may soon become aggravated by an ever increasing population. This will be aggravated because as seen above, we have a large proportion of the area outside either the Traditional concessions or Governmental. Soon land will be a scarce resource (end of the moving frontier model) leaving two alternatives to the peasant sector: increase the use efficiency of resources by a decreased number of farmers and an increase of landless labor.

The fact that traditional tenure (or any other type of non-official land use) do not afford security of title, may be one reason for the decreased incentive in investing in the land which at the same time is aggravated by their unavailability of collateral credit. In the last 20 years, Moçambique is faced with the task of establishment of land tenure law reforms. Up until now an official document on land tenure has not been approved and this has tragic impact on agricultural production.

Table 10.9 Land Tenure per Domestic Development Group (source: Author from Inq/94)							
	Establish. Group1	Expansion Group2	Consolid. Group3	Fission Group4	Decline Group5	Female H Group6	Rural 94
1 Land under Traditional Tenure	260,07	131,97	134,23	224	322,04	194,31	1266,62
2 Land under Govern. Tenure	96,31	47,06	92,58	70,31	130,22	92,06	528,53
3 Land Use by Ocupation	435,57	158,91	110,61	270,27	427,89	157,44	1560,69
4 Land with Title	19,25	11,32	14,55	12,72	18,67	4,53	81,04
5 Rent & Borrowed Land	134,43	42,53	29,36	55,62	75,93	41,77	379,64
6 Land Inherited	357,31	192,88	114,76	172,6	287,61	157,7	1282,86
7 Land under Other forms of Tenu	33,38	7,5	17,25	27,5	16,09	4,15	105,87
							5205,25



10.3 Population and Labor

Small farm systems are by definition labour-intensive and family-oriented. One important factor to check is the percentage of the economically active population involved in the smallholder sector. This can be seen in tables of consumer/producer ratios which distinguish family sizes and active people. In Table 10.8 this distribution is patent, 56% of the members are in the active age. Group 2, in expansion, has the least proportional amount of members in active age (42%).

Domestic Development Groups were extended to many other resources and output produced to check if there's any differences in resource management accordingly to each of the six domestic development groups defined.

On the effects of technology over labor it is also worth to note that not only the lack of opportunities for technological improvement in cropping encourage migration, but increased migration, caused by improved wage alternatives and better conditions, is likely to reduce the potential of technological improvements to increase yields at the farm level, where less hands are available to apply it effectively and those that remain have less incentive to spend the necessary time with it.

10.4 Semi-subsistence Farming

On average, a 2-3 hectare holding generally devotes 60-70 per cent of its area to household food crops, mainly cereals crops (at yields of around 1 t/ha, a family of six would need about 1.6 hectares cereal equivalent to sustain itself) and livestock production area typified by low and unreliable yields, unimproved species, low use of fertilizer or animal fodder, and limited pest and disease control. The more intensive smallholder systems involve dryland intercroping, or irrigated relaying cropping. This sector of agriculture is very complex when it comes to analysis.

Table 10.10 "More Popular Crop" shows the same trend in terms of frequency encountered per crop as well as area dedicated to it. Maize is the most popular with 78% of the household practicing it in 39% of the total area. The five most popular crops (Maize, cassava, nhemba beans, sorghum and rice) are cultivated in 77% of the peasant's farmed area. Productivity as mentioned before is somewhat low. This requires a more detailed analysis that is difficult to achieve only relying in the quantitative data of Inq/94.

Table 10.10
More Popular Crops.

Crop	Households x1000	Households %	1000 ha	Total area by crop %	Area per household ha	*Average area by all households in ha*
Maize	1 923	78%	1 737	39%	0,90	*0,70*
Cassava	1 383	56%	786	18%	0,57	*0,32*
Nhemba Beans	722	29%	209	5%	0,29	*0,08*
Sorghum	701	28%	339	8%	0,48	*0,14*
Rice	644	26%	302	7%	0,47	*0,12*
Groundnuts	516	21%	179	4%	0,35	*0,07*
Other beans	469	19%	110	2%	0,24	*0,04*
Cotton	188	8%	180	4%	0,95	*0,07*
Sweet potato	182	7%	31	<1%	0,17	*0,01*
Mant. beans	167	7%	52	1%	0,31	*0,02*
Sugar cane	89	4%	23	<1%	0,25	*<0,01*
Millet	62	2%	19	<1%	0,32	*<0,01*
Gergelim	43	2%	9	<1%	0,22	*<0,01*
Banana	43	2%	14	<1%	0,33	*<0,01*
Tomato	32	1%	2	<1%	0,07	*<0,01*
Kale	32	1%	3	<1%	0,11	*<0,01*
Pumpkin	23	1%	5	<1%	0,21	*<0,01*
Onion	16	1%	3	<1%	0,16	*<0,01*
Sunflower	14	1%	2	<1%	0,16	*<0,01*
Other land use	-	-	482	11%	-	-
N° of households	2 464 571			Total Area	4 489 403	ha

Source: Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.

From Table 10.11, more realistic values are obtained in the column Production/Producer, which only considers households that have the crop. Still low, these figures are a strong indication that much is to be done in terms of yield increase potentials.

Table 10.11 — 1994

Household practiced Crops, Crop production and productivities

Crop	Household 1000	Household %	Crop Production 1000 ton	Production p/producer kg	*Average production in Mozambique 93/94. Kg/ano.* *p/household*	*per capita*
Maize	1 780	72%	788	443	*320*	*63*
Fresh Cassava	965	39%	510	528	*207*	*41*
Sorghum	636	26%	158	248	*64*	*13*
Nhemba Beans	597	24%	69	116	*28*	*6*
Rice	563	23%	135	240	*55*	*11*
Mango	535	22%	196	366	*79*	*16*
Groundnut	458	19%	39	85	*16*	*3*
Banana	363	15%	69	190	*28*	*6*
Coconut [in units]	347	14%	462	1 330	*187*	*37*
Cashew nuts	344	14%	49	142	*20*	*4*
Other beans	339	14%	19	55	*8*	*2*
Orange	212	9%	44	209	*18*	*4*
Couve	188	8%	29	153	*12*	*2*
Cotton	185	8%	115	622	47	9
Tomato	153	6%	22	145	*9*	*2*
Sugar Cane	152	6%	62	409	*25*	*5*
Manteiga Beans	132	5%	15	114	*6*	*1*
Sweet Potato	108	4%	17	154	*7*	*1*
Lemon	93	4%	9	92	*3*	*<1*
Onion	84	3%	31	370	*13*	*3*
Lettuce	58	2%	7	128	*3*	*1*
Millet	45	2%	4	96	*2*	*<1*
Gergelim	42	2%	2	40	*<1*	*<1*
Pumpkin	21	<1%	3	162	*1*	*0*
Sunflower	20	<1%	3	125	*1*	*<1*
Pineaple	5	<1%	0	40	*<1*	*<1*
N° of Households	2 464 571					

Tabela B 16b

Total Production per crop and per household.

Cultura	Tot.Prod. 1000 ton	*Average Production 93/94.* *kg per year per ...* *...household*	*...capita*	*kg per month per ...* *...household*	*...capita*
Cereals	1 086	*440*	*87*	*36,7*	*7,3*
Tubers	526	*214*	*42*	*17,8*	*3,5*
Fruit	318	*129*	*25*	*10,7*	*2,1*
Legumes	142	*58*	*11*	*4,8*	*1,0*
Vegetables	93	*38*	*7*	*3,1*	*0,6*
Coconut [in units]	462	*187*	*37*	*15,6*	*3,1*
Sugar Cane	62	*25*	*5*	*2,1*	*0,4*
Cashew Nut	49	*20*	*4*	*1,7*	*0,3*
Cotton	115	*47*	*9*	*3,9*	*0,8*

Fonte: Inquerito Agrícola ao Sector Familiar, MINAG, Moçambique 1994.

The author is creating a work-sheet that will in the future facilitate the calculations of production in terms of biomass, nutrient values, energy content, and energy inputted in the farming system, in order to be able to compare different technological systems in different regions of the country. Using the valuation methods described above I hope to resolve at least partly, the problems associated with mixing and simple cropping systems, as well as the inclusion of all factors that conventionally are difficult to translate in a common denominator.

10.5 Low and Variable Incomes

All the foregoing features and low produce prices combined contribute to low and uncertain disposable incomes for the smallholder. The level of income (if there is any), leaves little room for any form of new technology, much of which remains expensive and inherently risky. But again, we should be careful in understanding the farmer's objectives. They may not seek to become a commercial farmer at all; may be most of the times, their objectives are to feed their family and maximize their time for other activities that would either give better returns to labor or more time for leisure activities.

10.6 Institutional Support

Concerning this point, the main constraints to improved productivity are the limited input supply, marketing, credit, extension, and training. Not so long ago more emphasis was given to the state or more progressive farmers; a more flexible approach to satisfy the constraints should be envisaged in order to improve the situation of the smallholder farmer.

At the institutional level, project proposals should be carefully checked to make sure that the introduction of new technologies answer these critical aspects: a) is there any interest for the new technology? Do new technology achieve farmer's goals? b) can the farmer afford it? c) is it possible to guarantee replacements, maintenance and operation backup? d) is there any capacity to consume/transport/market/process the surplus production?

Much of the development projects failed in the region because they neither covered all the above topics nor have they done it in an appropriate way. One common mistake is the use of wrong assumptions and the other is the absolute and sometimes paternalistic willingness to help.

For the first aspect, a remedy could be more research, using different methods in order to investigate and identify the productions systems' constraints. For the second, a change of attitude is required, a "pay-for-it" instead of "giving away" resources' policy may be more sustainable.

Again, a fundamental tool in introducing new technologies is the credit system, which is non-existing or if it exists it performs poorly. This, instead of resource subsidizing could affect productivity in a more sustainable way. In some countries, a basic service package, featured through medium-term credit provisions and training schemes have been devised with some success. It is fictitious to approach the problematic situation of introducing new technologies without dealing at the same time with the factors above described. And this require a sound management of the input-output involved resources.

This chapter has in my opinion, an important task in promoting development in rural areas. Activating and reinforcing the institutions that could absorb the surplus from the producer at an advantageous price, or at least at the pre-agreed price, would encourage the rural families into becoming self-subsistent and if desired, into commercial farmers.

11 Farm Mechanization And Related Benefits

In economic terms, mechanization usually involves injecting extra energy (or capital) into the farming system mainly with the primary objective of increasing labor's capacity to do work defined in terms of quantity and/or quality of output per worker. In general, mechanization is a "labour-augmenting" technology increasing output per worker rather than output per unit of land. The potential benefits are reduced drudgery, increased returns and reduced costs with additional benefits on the prestige associated with ownership of a higher energy system. These benefits have been greater where labour is scarce (and therefore expensive) and/or land is plentiful.

Leach (1976), referring to this, used a simple example citing that the price of one barrel of oil at $1.5 which is the equivalent of having one human 'energy slave' working for 4000 hours for a dollar (4000 MJ/dollar); this, he says is the major reason behind the West's mechanization of agriculture. This characteristic of mechanization has important implications for its role and impact in the small-holder system, where for the most part, land, capital, information, and management are limited and labour is generally abundant. Mechanized agriculture is usually energy and capital intensive. Energy costs and availability of capital determines the potential levels of mechanization in a society.

11.1 Trends in Developed and Developing Countries

There is a close relationship in Table 11.1 between commercial energy input and cereal output per agricultural worker in nearly all regions. In terms of arable land per farm worker the trend is different. In all developed regions, this area increased between 1972 and 1982 as workers left agriculture for other occupations.

Table 11.1- Commercial energy use & cereal output per Ha & per agricultural worker (source: FAO, 1982)

Region	*Arable area per agricultural worker (ha)*		*Cereal yield (t/ha)*		*Cereal production per agricultural worker (t)*		*Energy per hectare of arable land (kgoe)*		*Energy per tonne of cereal (kgoe)*		*Energy per agricultural worker (kgoe)*	
	1972	*1982*	*1972*	*1982*	*1972*	*1982*	*1972*	*1982*	*1972*	*1982*	*1972*	*1982*
North America	64·5	92·0	3·4	3·7	219·3	340·3	293	280	86·3	75·7	18 929	25 744
Western Europe	4·6	6·1	3·2	3·8	14·7	23·3	535	716	167·2	188·3	2 453	4 387
Oceania	75·4	99·7	1·2	1·3	90·5	129·6	84	78	70·3	60·1	6 361	7 786
Other developed countries	1·5	2·1	2·5	2·6	3·8	5·4	321	858	128·5	330·1	491	1 789
Developed market economies	10·3	14·4	3·1	3·4	32·0	48·8	333	389	107·3	114·3	3 433	5 581
Eastern Europe, USSR	6·0	7·7	1·8	1·8	10·8	13·8	142	203	78·8	112·9	851	1 557
Total developed countries	7·9	10·6	2·5	2·7	19·8	28·5	253	312	101·2	115·6	2 006	3 294
Africa	1·6	1·4	0·8	0·9	1·2	1·3	13	18	15·8	20·3	20	26
Latin America	4·1	4·5	1·5	2·0	6·1	9·0	48	64	31·7	31·8	194	286
Far East	1·0	0·9	1·4	1·8	1·5	1·7	34	77	24·3	42·7	33	72
Near East	2·6	2·4	1·2	1·5	3·2	3·6	46	120	38·7	80·3	123	285
Other developing countries	0·8	0·7	1·9	2·1	1·5	1·4	34	49	18·1	23·5	27	33
Developing market economies	1·5	1·4	1·3	1·6	1·9	2·3	34	66	26·3	41·0	51	95
Asian centrally planned economies	0·4	0·4	2·2	3·3	0·9	1·3	103	278	46·9	84·3	40	106
Total developing countries	1·0	1·0	1·5	2·0	1·6	2·1	45	96	29·7	48·1	47	99
Total	1·8	1·8	1·9	2·3	3·4	4·0	143	195	75·1	84·9	252	344

In developing countries, the area per worker decreased in all regions except Latin America because rural population increased faster than new land entered production and non-farm employment opportunities. In the same table we can see many different trends in the input of energy and the output. For example the Asian centrally planed economies achieved high yields per ha through a combination of high labor inputs and high levels of energy input per ha, particularly in the form of fertilizer, which accounted for almost 80% of the commercial energy used for agricultural production in this region in 1982.

In developed countries, one of the most interesting trends has been increased efficiency in the use of agricultural energy in both North America and Oceania, where yields have increased, while energy per hectare and energy per tone of cereal have decreased. However, in other developed countries both energy per hectare and per tone of cereal has continued to increase. Technological development has allowed incredible increases in resource input with an acceptable productivity.

In developing countries three main groups can be identified. The first group consists of the countries with limited land, limited capital resources and abundant labor, such as those in the Far East Asian centrally planned economies. Here, emphasis in agricultural development has been on increasing yields through extended use of mineral fertilizers in continued use of no-commercial forms of energy and labor intensive methods of production. Agricultural development has been emphasized within the overall development effort and both commercial energy use in agriculture as well as agriculture's share of total commercial energy has increased significantly. As a result, per capita food production has also been increasing in these regions.

A second group of countries are those with relatively abundant land and labor resources, but increasingly limited capital. Moçambique and many other Sub-Saharan and Latin America countries fall into this category. In these countries, farm machinery and irrigation, which have a high initial investment and require several years for cost recovery, have accounted for about half of the commercial energy used in agriculture. However, between 1972 and 1982, the emphasis changed toward a greater use of mineral fertilizer, which has the great advantage to allow quick cost recovery. The rate of agricultural development grew at about the same rate as the economy as a whole.

The third group is the countries with relatively limited land resources but large capital resources. This comprises the countries in the Near East. Under these conditions, investments in agricultural development were significant, although less than in the other types of developmental sectors, with the main increases occurring in farm machinery and mineral fertilizer.

This shows that trends in general are very much related to the resources each region has more access to. In Africa, the application of energy-intensive forms of agricultural production has been lower than in any other regions and the result of this agricultural transition is not yet clear. However the decline in per caput food and agricultural production during the past decade requires careful and particular attention.

12 Criteria for Selecting the Technology Systems

12.1 Energy Requirements

Because of energy requirements soil tillage and weed control are the main limiting factors in the production process of most crops. Energy used for ploughing varies between about 20 MJ (working depth 8 cm) to about 200 MJ per ha (depth of 20 cm) on clay soil (Klaij, 1983). For the temperate zone and motorized situations, Perdock and Van de Werken (1983), mentioned 145 - 575 MJ per ha. This energy (Astrand & Rodahl, 1977) can be supplied by humans at 0.075 kW (0.1 hp or 1.07 kcal/min) during 2-3 continuing hours, animals at 0.5 kW per ox during 5-6 continuing hours, and by tractors, furnishing power almost non-stop, with 50% of their engine power as tractive (at the draw-bar), and about 80% at the PTO (power-take-off). For detailed information see Tables 12.1, 12.2, 12.3 and 12.4 where different authors give some figures for energy expenditure in agricultural operations.

Table 12.1- Oxygen consumption & heart rate according to work levels (source: Astrand & Rodahl, 1977)

In terms of oxygen uptake (liters/min)	
Light work	Up to 0·5
Moderate work	0·5–1·0
Heavy work	1·0–1·5
Very heavy work	1·5–2·0
Extremely heavy work	More than 2·0
In terms of heart rate responses (beats/min)	
Light work	Up to 90
Moderate work	90–100
Heavy work	100–130
Very heavy work	130–150
Extremely heavy work	150–170

Table 12.2- Energy expenditures of a 55 kg reference woman during 24 hours during different activities (source: FAO & WHO, 1974)

Distribution of activity	*Light activity*		*Moderately active*		*Very active*		*Exceptionally active*	
	(kcal)	*(MJ)*	*(kcal)*	*(MJ)*	*(kcal)*	*(MJ)*	*(kcal)*	*(MJ)*
At rest (8 h)	420	1·8	420	1·8	420	1·8	420	1·8
At work (8 h)	800	3·3	1 000	4·2	1 400	5·9	1 800	7·5
Non-occupational activities (8 h)	580–980	2·4–4·1	580–980	2·4–4·1	580–980	2·4–4·1	580–980	2·4–4·1
Range of energy expenditure (24 h)	1 800–2 200	7·5–9·2	2 000–2 400	8·4–10·1	2 400–2 700	10·1–11·8	2 800–3 200	11·7–13·4
Mean (24 h)	2 000	8·4	2 200	9·2	2 600	10·9	3 000	12·5
Mean (per kg of body weight)	36	0·15	40	0·17	47	0·20	55	0·23

Table 12.3- Energy expenditures of a 65 kg reference man during 24 hours during different activities (source: FAO & WHO, 1974)

Distribution of activity	*Light activity*		*Moderately active*		*Very active*		*Exceptionally active*	
	(kcal)	*(MJ)*	*(kcal)*	*(MJ)*	*(kcal)*	*(MJ)*	*(kcal)*	*(MJ)*
At rest (8 h)	500	2·1	500	2·1	500	2·1	500	2·1
At work (8 h)	1 100	4·6	1 400	5·8	1 900	8·0	2 400	10·0
Non-occupational activities (8 h)	700–1 500	3·0–6·3	700–1 500	3·0–6·3	700–1 500	3·0–6·3	700–1 500	3·0–6·3
Range of energy expenditure (24 h)	2 300–3 100	9·7–13·0	2 600–3 400	10·9–14·2	3 100–3 900	13·0–16·3	3 600–4 400	15·1–18·4
Mean (24 h)	2 700	11·3	3 000	12·5	3 500	14·6	4 000	16·7
Mean (per kg of body weight)	42	0·17	46	0·19	54	0·23	62	0·26

Worldwide, there are 200-400 million draught animals, which cultivate about 300 million hectares or 28% of the World's arable soils (Giles, 1975). This means on average one animal per hectare compared to 0.25 before 1940 in Zeeland, The Netherlands, (Phernambucq, 1984). For instance, traditional cereal yields of 0.8 t/ha can be increased to about 2.5 t/ha for an increase in power input of 0.35 kW/ha (Giles, 1975). In terms of power sources, this surplus amount of 0.35 kW could be obtained with the aggregation of 4-5 men per hectare using traditional hand tools and digging at around 8 cm deep, or alternatively the use of a pair of oxen (500 kg each) pulling 100 kg of force (10-20% of their own weight), enough to plough one furrow at around 10 cm deep and representing 3-4 hectares of work for the same time available in the manual system.

Table 12.4- Energy expenditure of agricultural tasks (sources: Passmore & Durnin, 1955; Astrand & Rodahl, 1977; Duff, 1978)

Activity	Country	kcal/min	Activity	Country	kcal/min
Soil preparation			*Post-harvest*		
Plowing	Russia	6·9	Binding wheat	Hungary	7·3
Plowing	Russia	5·4	Thrashing rye	Russia	5·0
Clearing shrubs	Gambia	7·1	Thrashing rye	Russia	4·5
Ridging (deep-digging)	Gambia	9·5	Binding oats	Russia	3·3
Hoeing	Gambia	5·8	Binding oats	Russia	4·1
Bush-clearing	Nigeria	6·1	Binding rye	Russia	4·2
Hoeing	Nigeria	4·4	Binding rye	Russia	4·7
Average		6·5	Threshing	Italy	6·0
			Threshing	Italy	5·1
Seeding or planting			Threshing	Italy	5·8
Planting groundnuts	Gambia	3·7	Threshing	Italy	3·8
Transplanting	Philippines	3·2	Threshing	Italy	3·5
			Threshing	Philippines	4·8
Average		3·5	Average		4·8
Weeding			*Pesticide application*		
Weeding rake	Russia	3·3	Herbicide application	Philippines	6·9
Weeding	Gambia	5·3			
Hoeing	Gambia	5·8	*Tractor driving*		
Hoeing	Nigeria	4·4	Plowing	Germany	4·2
Weeding	Philippines	6·1	Plowing	Germany	4·2
Average		5·0	Average		4·2
Harvest			*Animal driving*		
Mowing wheat	Hungary	7·7	Horse plowing	Germany	5·9
Mowing barley	Hungary	7·0	Horse plowing	Germany	5·1
Setting up stocks	Hungary	6·6			
Preparing stocks	Italy	5·5	Average		5·5
Preparing stocks	Italy	4·8			
Mowing with a scythe	Italy	6·8	*Other*		
Loading stocks onto carts	Italy	5·6	Standing		2·0
Grass cutting	Nigeria	4·3	Sitting		1·8
Cutting and stacking	Philippines	4·9			
Average		5·9			

On the other hand, tractors on average can pull half of their weight. For a 50 kW tractor with about 25 kW at the drawbar, handling about 80 hectares for the same unit of time. See Table 12.5, Figure 12.1, Figure 12.2.

Table 12.5- Work potential of alternative farm power sources (source: Giles, 1975)

	Man (1 man)	Animal (1 pair of oxen)	Tractor (50 kW, 67 HP)
Weight, kg	55	750–1000	2500–3000
Pull, kgf	–	100	1500–2000
Speed, m/s (m/h)	–	1 (3.6)	1.7 (6.1)
Power, kW (HP)	0.07 (0.09)	1 (1.3)	25–34 (35–46)
Power requirements for mouldboard ploughing, kg/cm²		0.7	
Work capacity:			
implement size, cm, depth × width		10 × 14	20 × 100
work rate,[a] ha/h		0.04	0.45
work rate, h/ha	75–125	25	2.2
work day length, h	5	5–6	8–16
daily output, ha/day	0.07–0.04	0.20–0.24	3.6–7.2

[a] Assuming 70 per cent field efficiency.

Figure 12.1- Capacity of man, animal and tractor in soil tillage (source: Segler, 1994)

	energy		ploughing				
stage	power[1] kW/furrow	cost[2] DM/kWh	furrow depth cm	furrow width cm	speed km/h	field productivity m²/h	comparison
B1	0.07	50	7	9	1.0	100	0.2
B2	2 × 0.4	12	14	20	2.5	500	1.0
B3	5.0	0.1	25	32	3.0	920	1.8
B4	8.0	0.1	30	34	3.6	1220	2.4
B5	16.0	0.1	30	34	6.5	2200	4.4

1) 1 kW = 1,341 horsepower
2) wages 0.30 Deutsch Mark p hour

Using power as a criteria for selecting mechanization, as seen above, attention should first be paid to how productivity is considered. Some of the tables shown only consider the area cultivated, but to be more accurate, working depth and quality of work should be involved. Also the analysis of Figure 12.2 suggests that with an increased amount of kW/ha, yields increase and more food per worker is produced.

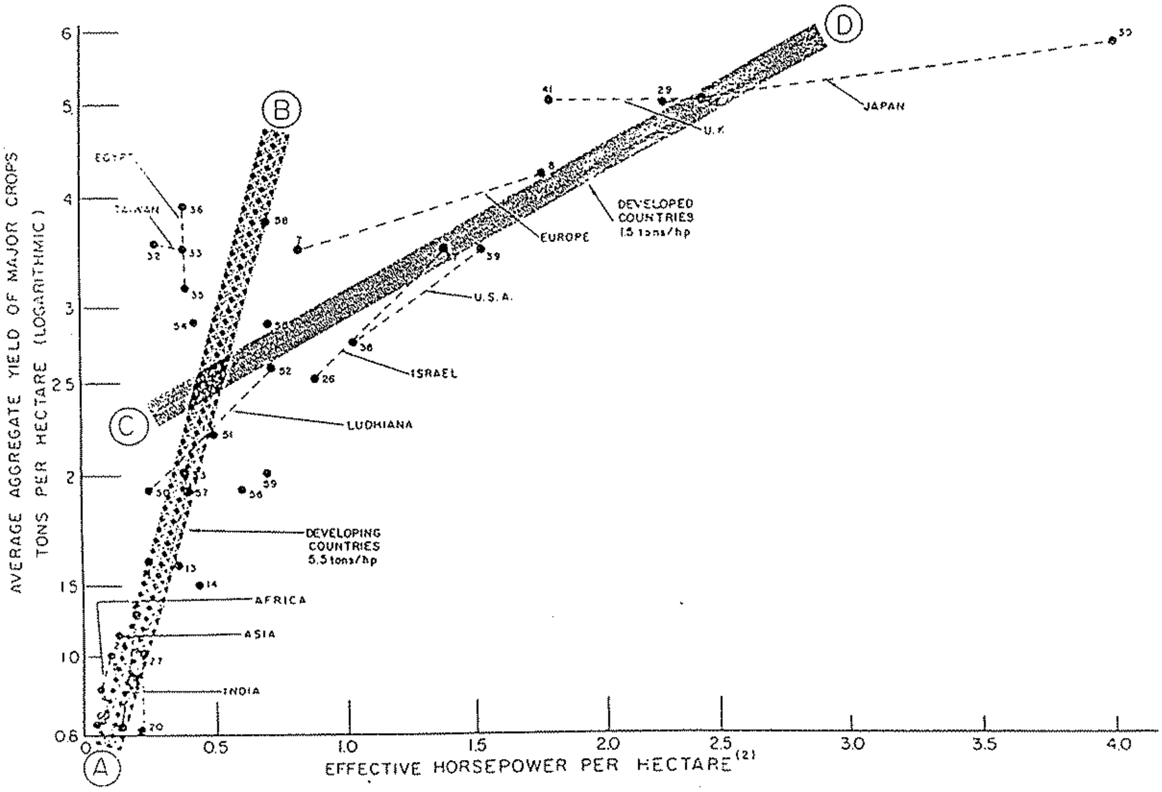


Figure 12.2- Crop yields associated with power, 1964-71 (source: Giles, 1975)

From 0 to 0.35 kW/ha yields increase at a rate of 3.9 t/kW, while from a yield bigger than 2.5 t/ha yields increase at a slower rate of 1.6 t/kW. The small farmer consumes about 0.1 kW/ha of mainly renewable energy; the UK farmer about 1.7 kW/ha of mainly non-renewable energy (Crossley and Kilgour, 1983). The energy ratio (energy out/energy in), decreases with an increase of motorization rate in agriculture, Leach, 1976, got the following results of 10.5 and 2.4 when calculating the energy ratios for cereals (this ratios can vary considerably when considering other crops) on the Nigerian smallholding and the UK farmer respectively. A level, of 'energy out to energy in', should be established per crop as a criteria for sustainable development.

Another important aspect as a selection tool, in terms of management of production systems, is the study of energy budgets in production cycles, even though the consideration of environmental degradation is not quantified in most of the studies, some conclusions can be summarized through the analysis of these budgets. Interesting work from White 1981, on production budgets, compared 3 popular systems for growing winter wheat: in Table 12.6 Conventional system 1, which includes moldboard ploughing followed by tine cultivation for seed bed preparation, and application of 150 kg/ha of N, 50 kg/ha of P_2O_5, 50 kg/ha of K_2O; conventional system 2, which composes a similar cultivation system, with an excess of 25 kg/ha of N and the same of the other fertilizers, in relation to system 1, and a direct-drilling system also using 175 kg/ha of N and the same quantities of the remaining fertilizers.

Table 12.6- Primary energy inputs for winter wheat GJ/Ha per year (source: White, 1981)

Item	Conventional system		Direct drilled system
	1	2	
Fertilisers			
Nitrogen	10.95	12.77	12.77
Phosphate	0.70	0.70	0.70
Potash	0.40	0.40	0.40
Seed	0.72	0.72	0.72
Herbicides	0.14	0.14	0.28
Fuel			
for cultivations	1.85	1.85	0.21
for combine harvester	0.62	0.62	0.62
Cultivation equipment	0.70	0.70	0.63
Tractor	0.49	0.49	0.17
Combine harvester	1.59	1.59	1.59
Drying plant	0.55	0.55	0.55
Grain drying (fuel, electricity)	2.44	2.44	2.44
Total	21.15	22.97	21.08

From Table 12.6 we conclude that fertilizers account for about half of the total energy used in the production of a crop (the other half being consumed through machinery), and most of this energy comes in the form of nitrogenous fertilizer. The comparison of these two extreme tillage methods prove that energy saving in tillage is insignificant in relation to other energy inputs. However accounts for extra soil compaction which are difficult to evaluate in systems 1 and 2 and residual effects of the larger amounts of pesticides applied in system 3 may, in the future, suggest which alternative to choose.

In a more recent work on the same subject, Bonny 1993, who studied the tendencies of energy used to produce wheat during 30 years in the Paris Basin, reported data included in Table 12.7. The message he revealed can be important in terms of three aspects; firstly about the progressing increase on tractor power associated with a decrease of time spent per hectare; second, the interpretation of energy ratios for the different periods.

Table12.7- Trends for direct & indirect energy to produce 1 Tonne of wheat, 1955-60 and 1990 (source: Bonny, 1993)

Inputs consumption	Quantity ha⁻¹	Unit energy coefficient	Energy per ha (GJ ha⁻¹)
(1) Wheat 1955–60 – Yield 4.5 t ha⁻¹. Energy intensity 3.85 MJ t⁻¹			
Seed	150 kg replaced every 4 years	6.3 MJ kg⁻¹	0.2
N fertiliser	70 kg	96.3 MJ kg⁻¹	6.7
P fertiliser	100 kg	16.7 MJ kg⁻¹	1.7
K fertiliser	100 kg	8.4 KJ kg⁻¹	0.8
Herbicides	1 application (1 kg active ingredient)	209 MJ kg⁻¹	0.2
Tractor 30 ch.	20–25 h work	approx. 125 l diesel oil at 40.2 MJ litre⁻¹ + lubricants + tyres	5.7
Combine harvester	1.5–3 h work		
Overheads on machines and buildings			1.9
Total			17.3
(2) Wheat 1980 – Yield 6.5 t ha⁻¹: Energy intensity 3.56 MJ t⁻¹			
Seed	150 kg	7.5 MJ kg⁻¹	1.1
N fertiliser	160 kg	75.3 MJ kg⁻¹	12.0
P fertiliser	70 kg	13.8 MJ kg⁻¹	1.0
K fertiliser	70 kg	8.4 MJ kg⁻¹	0.6
Pesticides	5 kg	209 MJ kg⁻¹	1.0
Tractor 100 ch.	9 h work →95 l diesel	approx. 112 l of diesel at 40.2 MJ l⁻¹ + lubricants + tyres	5.2
Combine harvester	0.7 h work → 17 l diesel		
Overheads on machinery and buildings			2.3
Total			23.2
(3) Wheat 1990, various management systems			
(a) Intensive wheat – Yield 8.5 t ha⁻¹: Energy intensity 2.68 MJ t⁻¹			
Seed	220 kg	7.5 MJ kg⁻¹	1.7
N fertiliser	191 kg	58.6 MJ kg⁻¹	11.2
P fertiliser	90 kg	10.5 MJ kg⁻¹	1.0
K fertiliser	90 kg	8.4 MJ kg⁻¹	0.7
Pesticides	8–9 applications 6.4 kg AI	209 MJ kg⁻¹	1.3
Tractor	8 h work → 83.6 l diesel	100.6 l diesel + lubricants + tyres	4.6
Combine harvester	0.7 h work → 17 l diesel		
Overheads on machinery and buildings			2.3
Totals			22.8
(b) Rotational wheat system – Yield 7.5 t ha⁻¹: Energy intensity 2.72 MJ t⁻¹			
Seed	150 kg	7.5 MJ kg⁻¹	1.1
N fertiliser	170 kg	58.6 MJ kg⁻¹	10.0
P fertiliser	90 kg	10.5 MJ kg⁻¹	1.0
K fertiliser	90 kg	8.4 MJ kg⁻¹	0.7
Pesticides	5 applications 4.9 kg AI	209 MJ kg⁻¹	1.0
Tractor	7.25 h work → 76 l diesel	93 l diesel + lubricants + tyres	4.3
Combine harvester	0.7 h work → 17 l diesel		
Overheads on machinery and buildings			2.3
Totals			20.4
(c) Extensive wheat – Yield 6.5 t ha⁻¹: Energy intensity 2.68 MJ t⁻¹			
Seed	100 kg	7.5 MJ kg⁻¹	0.8
N fertiliser	140 kg	58.6 MJ kg⁻¹	8.2
P fertiliser	90 kg	10.5 MJ kg⁻¹	1.0
K fertiliser	90 kg	8.4 MJ kg⁻¹	0.7
Pesticides	2 applications 2.65 kg AI	209 MJ kg⁻¹	0.5
Tractor	6.50 h work → 69 l diesel	86 l diesel + lubricants + tyres	4.0
Combine harvester	0.7 h work → 17 l diesel		
Overheads on machinery and buildings			2.3
Totals			17.5

The remarking point is, even though a double amount of nitrogen and more applications of chemicals were used, there was a reduction of 30% of energy used. However this improvement of 3.85 MJ/t in the period 1955-60 to 2.68 MJ/t in 1990 was mainly due to technical improvements in the methods of nitrogen fertilizer manufactured. Figure 12.3 can better elucidate the improvement in fertilizer production. The third aspect is the comparison of the three different management systems, intensive, rotational, and extensive and the conclusion that there is a close relationship between the yield of grain and the quantities of nitrogen fertilizer applied, however a detailed look on the 3 systems would point that the extensive system is more sustainable, assuming productivity (yield per ha) is not a limiting criteria.

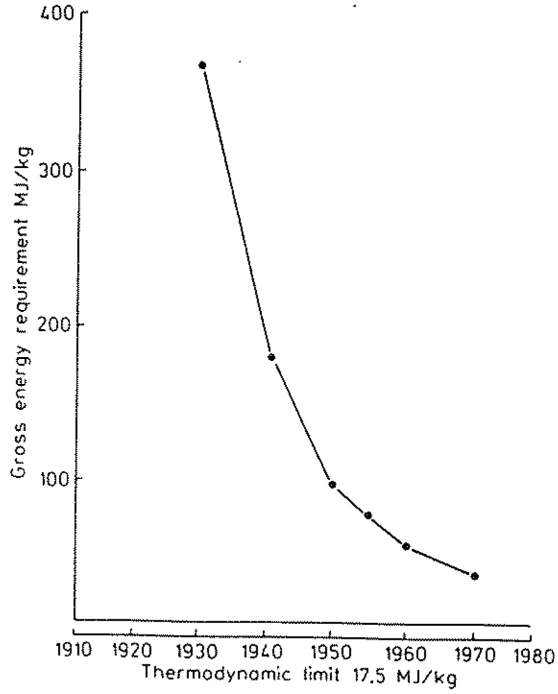


Figure 12.3- Improvement in gross energy requirement of ammonia production through time (source: Stanhill, 1984)

Because machinery and fertilizer represent the gross user of total energy in modern agriculture, it should be given special attention when doing an analysis. The lack in standard analysis is usually the valuation of the negative effects of this and other less energy embodied resources. There is a tendency in the substitution of cheaper resources, instead of expensive ones, this is natural when these resources are substitutable (like manual labor and mechanized power up to a certain level) but not sustainable when resources are not substitutable (like a compounded fertilizer) as it is common in agriculture, resources are complementary: they need each other to achieve greater productivity. Contrary, labor and land are the most used resources in the rural areas in Moçambique. It is difficult to envisage how the labor market will develop. But from other country's experiences, technology introduction will increase production per area and per person and will liberate man-power from farming that would be needed by employment generated from agriculture and other sectors of the industry and services. So less people will be farmers, and agricultural land will be explored by a decreasing number of people in increasingly larger farms. This process requires careful decisions and right policies.

12.2 Work Rate and Capacity

Peak power requirements are in general more important than averages. The size and nature of the task, and the time available, together determine peak power requirements. Where time is limited (which is the case in most agricultural operations), the rate of work of alternative systems of mechanization, as determined by their power characteristics, will be an important factor in selecting mechanization.

The most critical operations should be selected and analyzed in terms of availability of time to do that operation and the time actually consumed by the chosen technological system. Manual systems will take on average twenty days per hectare for seedbed preparation, whereas an ox team takes four to five days, and a tractor about two hours of field time. In case it is impossible to switch to higher power sources, there are still opportunities for productivity improvement, by introducing or modifying hand tools, using relative advanced devices such as seeders, knapsack and ULV sprayers, and improve on transportation tools. In the rural peasant situation, development and introduction of intermediate technologies would be advantageous. Data available indicate that some problems exist. Not only during production of the crop, where a great lack in the use of external resources is found but as well in heavy losses of crops along the food chain.

Where machinery is one of the resources used in crop production, with a cost which should be minimized, it is necessary to emphasize not to separate machinery costs from yield. From the point of view of machine costs, the cost decreases with utilization; i.e., the more hours and the longer the season during which the machine is used, the lower the cost per hour. However, as mentioned above, there are critical periods for crop growth and development, resulting in certain operations, like planting and harvesting not being completed in time, which further contributes to yield reduction. If the owner of a machine attempts to harvest too great an area, a stage is reached at which the crop gets over ripe before the machine can harvest it. This results in the loss of the crop which is greater than the reduction in the costs of using a "bigger" machine. The "timeliness factor", in such operations as planting, irrigating, spraying, and harvesting, has such an effect on yield that it is not possible to consider utilization independently of yield.

The trade-off between machine capacity and "timeliness" is one of the problems of machinery selection. When a farmer invests in a bigger machine he incurs bigger costs in owning that machine. However, with a bigger machine, the losses in yield as a result of not carrying out the critical operation at the correct time should decrease. Adding the two costs together produces a resultant cost which shows a minimum. This is the level of machine capacity which the farmer should plan in order to minimize the total machinery costs.

12.3 Costs

It might not be appropriate to have a cost comparison as a selecting criteria of mechanization systems, because of the tendency of following the numbers from cost-effectiveness and worthwhileness of the system, without checking first if the technology system is within the farmer's cash flow capability. Another problem is the variation on the definition of costs according to the purpose of the analysis. The mechanizing farmer (if I could use the term without any prejudice) will be more interested with market financial prices, as these are what he pays for in equipment or services. The government, however, will be more interested in economic prices which reflect the scarcity value, before taxes and subsidies, of the mechanization inputs (and sometimes outputs) to the economy.

A sound mechanization policy would seek to bring the two price bases together. Viewed in economic terms, it is not surprising that for developing countries in general, adjusting for subsidies, taxes, shadow values of labour, fodder crops, and foreign exchange, tractors appear the most expensive and labour the cheapest method of working. This is why during busy periods when labour is scarce, particularly on larger farms, the use of oxen power may become attractive. However, there may be differential benefits between systems arising from quicker or more effective operations. Where power is the constraint, and cost per usable kW is the criteria, there is little that beats the conventional tractor if right environment is available.

12.4 Institutional Support

Institutional support plays a key role in selecting the appropriate technological system. Given the complete absence or low level of institutional support in many smallholder situations, the most appropriate mechanization system is that one which is most reliable and self-sufficient.

Generally the more capital-intensive and the less indigenous the technology, the greater are the demands for support services.

In terms of subsidies, I can confess it is really a difficult matter. On average it did not give positive results in Moçambican past experience. In general, sustainable systems should be seen as one that don't require subsidies for their continuos existence. In case it is justified and I think they are at this moment, they should address to the system in a way not to distort it, and its best application would be in terms of establishing a solid credit system (may be with special interest rates for different agricultural activities) and most of all subsidies must be used in improving infrastructure in order to facilitate the flow (storage, transport, trading) of farmer's surplus.

12.5 Social and Economical Impact

The effect of mechanization on labour employment, and related issues such as rural income levels and distribution, are extensively debated. Improving hand or animal systems is generally considered to have a gentle and mainly beneficial effect on employment and other socio-economic parameters (Eicher, Zalla, Kocher and Winch, 1970; Yudelman, Butler and Banerji, 1971; Bartsch, 1977).

The available evidence suggests that where mechanization facilitates an expansion in the cultivated area, cropping intensities rise, new crop mixtures are increased, there is more use of other improved inputs, and overall employment level is increased. This is often the case in many smallholder situations operating at low power input levels.

The crucial debate is to find the point where mechanization begins to substitute for labour, particularly permanently hired labour. Extensive mechanization is usually associated with labour (and animal) displacement (Abercombie, 1973; McInerney and Donaldson, 1975). In some societies this is not a negative effect, as they are absorbed by other economical activities, some of them even originate from increasing agriculture production. The effect on labour employment has varied between types of worker, family and permanently labour inputs which have tended to decrease whilst in some cases this has been partially offset by increases in casual labour requirements.

Another important question is the gender issue. The impact of technology on woman, which some authors argue that, far from their being beneficiaries, the role of women can deteriorate as a result of farm mechanization. Men are often quicker and sometimes eager to associate themselves with machinery, leaving the unmechanized and most tedious jobs to women.

Evaluating the effects of technology introduction in this semi-subsistence sector is not always simple and sometimes may generate erroneous conclusions if objectives are not defined. Sometimes development is only seen as an increase in yields per family or per area. This might not happen always unless our objective is to transform the farmer into a commercial one. Farmers in many cases do cultivate their land in order to guarantee social security and access to it, and to feed their family, and improved technology may be used with the prime objective of generating extra time to be used in other activities like off-farm wage employment.

In relation to the agrarian structure, particularly on the farm size and tenure systems, as the level of sophistication of mechanization increases the smallest farmers find they are not big enough to adopt the new output-increasing (and possibly cost-saving) technology. As has been the trend in developing societies some small farmers are squeezed out by competition (fall of produce prices) due to increased output generated on the larger, more successful farms. Unviable small farms are eventually amalgamated into larger holdings and their occupants become landless laborers. In some instances, land owners (landlords, and/or the state) may dispossess, compensate, or reallocate their tenants in order to achieve economies of scale in machinery operation (Yudelman et al, 1971; McInerney and Donaldson, 1975). If the above mentioned conditions are satisfied, tractorization projects are economically profitable to the nation as a whole and more financially profitable to the participant mechanizing farmer (Era, 1979; Dalto, 1976; McInerney and Donaldson, 1975). The studies, however vacillate between whether labour savings should be measured as an economic cost or a benefit, or if the outcome of the analysis is particularly sensitive in this assumption. The long term social and economic implications depend on whether displaced farm labour can find a gainful employment elsewhere. In many Third World countries and Moçambique in particular, this have been difficult so far.

13 Options to Mechanization Systems: Advantages and Disadvantages.

To better understand the options available in the mechanization systems we have to go back a little and try to analyze the transitions or shifts into higher energy input agriculture. There will be a natural tendency to postpone the switch as long as a particular society could subsist within a less intensive arrangement. Intensification advances in several fairly universal stages from long forest fallow (with just one or two crops followed by a regeneration of 15-20 years), to bush fallow (a crop or two followed by a year off), to regular annual cropping (with reduced fallow), and finally, to multicropping (often irrigated) with two or three grain, seed, or forage crops, or up to five or six vegetable crops planted in rapid succession.

Each of these successive steps recovers more of the site's potential photosynthesis as food and supports more people per hectare of arable land as it demands higher energy inputs, first for forest clearing, planting, and digging and eventually for seasonal plowing, harrowing, seeding, weeding, construction of terraced fields, wells, and dams, and irrigation and drainage of the fields. These activities require further energy investment for making or buying, operating, and planning more sophisticated tools and implements.

Mechanization in agricultural systems is often characterized by human, animal, and machine-powered technology on the basis of sophistication, capacity to do work, costs, and in some cases, precision and effectiveness.

13.1 The Best System

At present levels of productivity, it is debatable whether the average smallholder should give priority either to yield-increasing inputs, such as improved seeds and fertilizers, or to mechanization. In practice the two are often inseparable, as the use of improved inputs provide the potential and justification for more farm power and at the same time more farm power may be necessary before the potential of new yield-improving inputs can be realized.

In terms of the question 'Human, Animal, Machine?', I think they should coexist and be applied in situations depending on where they are more appropriate. From a policy point of view, this requires a careful assessment of mechanization needs, an appraisal of available technology, and the formulation of policy measures which would encourage the development and selection of the mechanization appropriate to the pre-defined development objectives or the so called "selective mechanization".

Given the role of mechanization in the process of getting agriculture moving, and its important social ramifications, mechanization policy becomes an important aspect of agricultural planning. In an attempt to remove smallholder power constraints, while avoiding the wasteful and undesirable effects of over mechanization, particularly labour displacement, many governments have embarked on a programme of "selective mechanization".

For a given farming system, selective mechanization would attempt to exploit the potential benefits of mechanization as previously enumerated; including opportunities for the increase of cultivated area, the timeliness of operations, cropping intensity (multicropping), the quality of work, and labour employment. In conclusion this approach may incorporate all three technology types; for example oxen for land preparation, manual harvesting, and engine power for water-lifting and electricity for trashing.

The main disadvantages of manual systems is the long and arduous work, and low level of productivity in terms of output per worker. However, much scope exists in terms of increasing labour productivity, just by improving or introducing hand tools and man-powered machines, due to the fact that most traditional implements are rudimentary or primitive. Considerable improvements in smallholder performance can be achieved mainly by the use of improved inputs (other than mechanization) which increase yields per hectare, such as improved and appropriate seed, fertilizer, pest control, and irrigation, and these can be facilitated by modest increases in power inputs. In Moçambique, where manual systems still represent an important proportion in the agriculture sector, another way to improvements in production is the amelioration, and introduction of tools made locally with the creation of artisans networks.

In some areas, work animals are a common feature for transport and farm work, especially in places where animal husbandry is a tradition, where tsetse fly is not a problem and farms are relatively larger than in the manual system (usually above the 3 ha), where population pressure is low, and land is available for grazing and/or fodder production. This system's main attributes are relative low-cost, low-energy, self-supporting, reproducible, and potentially comprehensive system of appropriate mechanization. Gaza, Manica and Inhambane were the Provinces where the use of animal traction was more popular.

Ruminants were the most successful symbiotic draft animals, mostly because they do not compete with man for food, being able to digest all sorts of roughage and poor pasture, extracting energy from cellulose and properly managing nitrogen through the rumen's flora. They are a form for overcoming power constraints without labour displacement and provide a basis for informal contract hire.

The main disadvantages could be the lack of animal husbandry skills, and the cost of animals and equipment are usually out of reach for the smallholder. Animals should be fed properly and continuously in order to avoid limitation of power, and propensity to disease during the year. Feeding costs can be high in case of limited land. Work animals require organized institutional support, particularly regarding the supply of suitable animals and equipment, as well as veterinary services, credit, and training.

Animal draught power is often seen as the most "appropriate" mechanization package for smallholders, but we have to remember that this alternative is only feasible where the above mentioned conditions are verified and should not be seen as the compulsory transitional step from manual technology into machine powered technology.

Farm size and income largely preclude the average smallholder from acquiring machine-powered technology solely for use on his own farm. Machine power, usually associated with internal-combustion engines for their mobility and versatility, cannot be scaled down to the level where it is technically or financially suited to the smallholder farmer. Stationary power units driving processing machines, have a particularly important role, as do tractors for land preparation and transport, but their potential is in terms of multi-farm use through co-operatives, private contractors, or the not-so good Moçambican experience of state hire schemes.

High-power, high-capacity, tractor based systems theoretically offer the greatest achievement of the previously enumerated mechanization benefits, particularly those resulting from improved timeliness, new cropping patterns, and an extension of the cropping area. The disadvantages are the relatively expensive acquisition price, the complexity of operation, and maintenance, and the fact that tractors tend to require a high (largely non-renewable) energy input, and often represent a high non-local dependence on foreign exchange technology. Engine-powered systems becoming more and more powerful and heavy with time, have been particularly criticized for their undesirable social and environmental impact, especially the displacement of labour in conditions of general underemployment and the heavy input of resources and soil-compacting in agricultural systems. The use of high-tech alternatives in the present situation for the household sector is completely out of the question. The reasoning behind, is that when somebody invests in high technology, they also have to pay it back and to do so, external resources must be used and have to be explored to their maximum productivity.

14 Mocambican Technology Systems and Space for Technological Improvements.

14.1 Means of Production in Rural Families

The predominant form of smallholder technology is based on manual labour, with the hand hoe as a basic tool. In the specific case of Moçambique in Table 14.2, we can see the distribution of means of production according to development groups of the technology used. It can be seen that Group 3, 4, and 5 show a great interest in the use of other forms of technology.

Table 14.2 Agricultural Implements per Domestic Development Group							
	Establish.	Expansion	Consolid.	Fission	Decline	Female H	Rural 94
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	
Distrib. of Tools per Hhold							
Total Hholds in Group	817	339	226	413	762	548	3105
No. of Hh. with Manual Tools	761	292	148	331	646	481	2659
No. of Tools Owned	6055	2989	3478	4581	6389	2710	26202
Average Manual Tools per Hh.	7,96	10,24	23,5	13,84	9,89	5,63	9,85
No. of Hh. Owning Animal Plows	17	17	37	48	67	27	213
No. of Animal Tools Owned	30	25	78	71	94	35	333
Average Animal Tools Owned	1,76	1,47	2,11	1,48	1,4	1,3	1,56
No. of Hh. Using Tractor Power	39	30	41	34	49	40	233
No. of Hh. Renting Tractor	38	27	38	33	46	30	212
No. of Tractors Rented	53	29	56	59	59	44	300
Average Tractors Rent per Hh.	1,39	1,07	1,47	1,79	1,28	1,47	1,42

In this Table 14.2 we can already expect that the most used technology would be manual power. However there is a great household tendency to own manual tools even though they are using either animal traction or tractor (this tendency may be observed by the total number of households in group obtained in the first row of the above Table). In order to control for this mix of technologies the author introduced a control variable "PowCons3" or "PowConst".

14.2 Technology Use and Productivity Area per Household

In Table 14.3, three types of technology use were enhanced. 78% of the households using just manual power (JMP) , 11% of the households using animal traction and 9% of households using tractor power. It was also separated by another group (though small at the moment), which represents a group that we can call 'labor for hire' involving 2% of the households, as they do not hold any land, but live in the rural area and are involved in farming activities.

Table 14.3- Technology Use per Domestic Development Group							
	Establish.	Expansion	Consolid.	Fission	Decline	Female H	Rural 94
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	
Technology Use							
T1 Hholds in the group	796	297	151	335	655	513	2747
T2 Hholds w. Just Manual Power (JM	715	240	77	238	512	427	2209
T3Hholds w. JMP owning land	701	234	73	232	494	409	2143
T4 Hholds Owning Animals for Tracti	12	9	17	28	23	15	104
T5 Hholds using Animal Traction (AT)	42	27	33	63	92	46	303
T6 Hholds Using Tractor	39	30	41	34	51	40	235
T7 Area in the Group	1336,32	592,17	513,34	833,02	1278,46	651,96	5205,26
T8 Area Under Just Manual Power	1126,83	431,39	245,61	517,01	947,77	469,9	3738,5
T9 Average Area per Hh. using JMP	1,61	1,84	3,36	2,23	1,92	1,15	1,74
T10 Area under Animal Traction	121,36	75,64	127,37	202,94	194,21	101,45	822,97
T11 Average Area per Hh. using A T	2,89	2,8	3,86	3,22	2,11	2,21	2,72
T12 Area under Tractor	88,13	85,14	140,36	113,07	136,48	80,61	643,79
T13 Average Area per Hh. using Trac	2,26	2,84	3,42	3,33	2,68	2,02	2,74

Under the category "Animal Traction" a sub-group was also formed. Households that own their draught animals. It is expected to show some productivity differences from the group that own animals and the ones that rent them.

The trends in the groups' willingness to use the different technologies are as follows: households in establishment, female headed and in expansion are the groups showing respectively higher rates in manual power use (values above average) in their farm activities. While groups 3, 4 and 5 show less interest in the same technology (that means group 3 showing the least interest and group 5 more closer to the average but still bellow that level).

In terms of animal traction use households in consolidation, fission and decline are reported to use more of the technology, respectively and groups 1, and 2 and 6 (group 2 and 6 showing the same level of interest) showing the least interest in the technology, respectively.

In the use of tractor power households in consolidation report to use the highest level followed by group 4 and 5 with the same level and slightly above average. Groups 1, and 5 and 6 reported to use tractor power bellow average levels respectively.

In order to check how productively households are using their technologies, areas of farms were calculated and averaged per each group and type of technology. From the average for the Rural 94, households using JMP achieve the lower levels of area per household, equivalent to 1.74 Ha/Hhold. However averages for the use of animal traction and tractor do not show the expected differences. Households using tractors show an average of 2.74 Ha/Hhold which when compared to 2.72 Ha/Hhold for the average of animal traction does not at all resemble the figures commonly encountered in the literature.

One important issue from Table 14.3 is seen in group 3 in consolidation (which presents more labor per household when compared to the other groups). We would expect this group to show higher rates in manual power. Instead consolidation group are the one reporting values above average in the use of tractor power as well as in animal traction. The same trend, but with less demarcation is verified for group 4 in fission. This indication favors the opinion that technology use or introduction is expected to succeed where there's enough hands to deal with it. Groups 1 in establishment and group 6, female headed with almost the same characteristics in respect to household size and consumer/producer ratios, show almost the same tendencies in their reported technology use. In terms of acreage per household, female headed households show the least productivities in almost all technologies.

Implicit in the same Table 14.3 is another factor worth to note at this stage. There seems to be an upper limit in terms of area of farm per household that is independent of technological choice. This upper limit, with a maximum, 3.86 Ha/Hhold, for group 3 in consolidation and the use of animal traction. Intermediate values of 3.36 and 3.42 Ha/Hhold respectively for the use of JMP and tractor are found for the same group 3. This strongly indicates that households may not use either animal traction or tractors in all farm operations, but instead, for some operations (may be all other operations than tillage) being the use of manual power the limiting factor in enlarging the acreage. Many reasons may be behind the fact that households using other forms of energy than manual power do not do so for all farming operations. Different hypotheses should be investigated, but again we should not forget that the use of these technologies would require that more land is put into production or/and landless households would increase, and most of all a favorable marketing system should exist.

In terms of technology introduction, a regional investigation should be done and it may be facilitated if initiated in regions where the use of the technology is already traditional (as they represent dynamic centers of excellence). This is not the case only because of better farmer-researcher interaction, but also because these farmers would be the poles for divulging information: In a way, working as extensionists for the more remote areas.

14.3 Technology Use in Farming Operations and Labor Relationships

In Table 14.4 we can observe possible savings as well as trends in terms of labor and time with the use of the 3 above mentioned power technologies. One more group was also introduced. This group is a sub-group of Animal Traction, the difference is that only households that own draught animals are considered. Values in this Table were based on around 35 to 40% (those who answered the specific questions) of the interviewed households and large deviations from the average were encountered. The author recommends more detailed analysis on this data, probably the introduction of a control, before they can be used with confidence.

In Table 14.4 three farm operations were selected, tillage, weeding and harvesting. Results in this Table clearly show that the use of tractor power in tillage operations originate savings in labor per hectare as well as labor per household. 7.41 Man-Days per Ha and 26 Man-Days per household per Ha was obtained when averages were calculated for all groups using tractor power. When compared to the use of tractor for tillage, households using manual power would require 7.4 times more labor, or 4.43 more labor per household per each tillage Ha. Households using animal traction would do that using 3.5 times more labor, or 3.26 times more labor per household, or if they own their draught animals they would cultivate the same hectare using 1.58 times more labor or 1.82 times more labor per household.

In other farm operations, differences do not seem to be so clear cut as in tillage. Manually done operations are reported to last as much as double the time when compared to other types of technology, while differences for animal traction use and tractor use are not so clear. However, it can be seen that weeding seems to demand a larger amount of the time and labor when compared to other operations. This does not seem strange, because the use of pesticides or herbicides is non-existent. Harvesting seems to demand the least amount of time and labor. At this stage the data provide some indication that differences in time and labor savings in other farm operations due to different technology use is relatively small. This probably indicates that households on average use animal traction or tractor more productively in tillage. Being the other farm operations very much related to the use of manual power. Technically this represents a large constraint which should be investigated.

One important issue behind the data in the Table 14.4 is the time actually consumed in each operation and how households use time and labor to accomplish them. This investigation requires a more detailed analysis by groups of households, as it is very much connected to 'de Facto' work forces and the labor declared to be used in each farm operation and each group of household.

The last aspect in this subject is the difference between the group of households using animal traction in general and its sub-group which only includes those who own the animals. However, in the other operations this is probably shadowed because in the first group (animal traction) the second is also included (owning animals), in tillage the difference is clear. The author expects to find deeper differences if those two groups are separately analyzed.

TABLE 11.4- Days & Labor in Farm Operations							
	Establish. Group 1	Expansion Group 2	Consolid. Group 3	Fission Group 4	Decline Group 5	Female H Group 6	Rural 94
TILLAGE OPERATION							
Using Manual Power							
Man-Days per Hh. per Ha	53,89	67,62	68,95	76,11	62,25	68,66	62,31
Man-Days per Ha in Tillage	49,20	52,71	26,21	51,03	51,88	87,13	54,91
Using Animal Traction							
Man-Days per Hh. per Ha	53,93	51,13	66,20	39,66	51,89	24,69	45,77
Man-Days per Ha in Tillage	42,04	38,39	51,77	17,94	29,36	12,84	26,10
Using Animal Traction (PowConst)							
Man-Days per Hh. per Ha	28,00	6,00	39,20	23,51	26,64	15,71	25,62
Man-Days per Ha in Tillage	18,67	6,00	28,99	7,78	11,16	8,04	11,68
Using Tractor							
Man-Days per Hh. per Ha	4,68	4,31	27,40	24,78	20,02	9,45	14,04
Man-Days per Ha in Tillage	1,85	1,78	12,26	24,81	12,89	5,80	7,41
WEEDING OPERATION							
Using Manual Power							
Man-Days per Hh. per Ha	53,63	67,71	54,46	106,31	61,60	67,38	63,55
Man-Days per Ha in Weeding	48,96	52,36	20,70	70,69	51,21	85,38	55,83
Using Animal Traction							
Man-Days per Hh. per Ha	33,08	58,15	54,61	44,84	70,78	23,05	50,34
Man-Days per Ha in Weeding	27,17	44,83	42,70	18,43	40,22	11,99	28,38
Using Animal Traction (PowConst)							
Man-Days per Hh. per Ha	44,00	43,06	66,27	39,14	89,13	34,33	59,67
Man-Days per Ha in Weeding	44,00	41,21	49,02	10,89	37,33	17,56	26,72
Using Tractor							
Man-Days per Hh. per Ha	36,77	32,35	48,20	78,34	63,16	39,52	49,35
Man-Days per Ha in Weeding	13,82	14,86	23,28	82,46	39,30	26,82	27,07
HARVESTING OPERATION							
Using Manual Power							
Man-Days per Hh. per Ha	29,32	35,56	37,72	46,42	38,05	35,72	34,59
Harvesting Man-Days per Ha	26,52	26,56	14,19	30,25	30,99	44,72	29,94
Using Animal Traction							
Man-Days per Hh. per Ha	18,48	21,71	30,50	25,14	20,90	13,54	21,02
Harvesting Man-Days per Ha	15,18	16,74	23,85	11,67	11,88	7,05	12,22
Using animal Traction (PowConst)							
Man-Days per Hh. per Ha	43,75	28,71	43,93	36,19	17,95	12,79	25,77
Hravesting Man-Days per Ha	43,75	27,47	32,50	12,57	7,52	6,54	12,44
Using Tractor							
Man-Days per Hh. per Ha	12,82	15,81	36,88	47,53	29,80	12,35	23,64
Harvesting Man-Days per Ha	4,82	6,35	15,42	45,51	18,46	8,17	12,09
obs. PowConst, means that in the group were only included households that owned draught animals							

14.4 Technology Use and Crop Production

On Table 14.5 an attempt is made to check if crop production is enhanced by the use of the above mentioned technologies. Cotton and sugar cane were used as the cash crops, and most of the staple crops were used for this checking.

From the averages and except in very few cases, the use of any other type of technology other than manual power seems to be negative in terms of crop production. An explanation for this unexpected results, may be that technology use by households does not have the primary objective of increasing yields, but most of the time is used to do the most arduous operations, like tillage. The other plausible explanation may come from the fact that it was not possible, from the way the inquire was designed, to be sure that the crops were actually tended by using different technologies. For example, in other words, the production of cotton with the use of animal traction does not necessarily mean that cotton was cultivated with the use of the technology. It might be that the household in fact used animal traction to cultivate maize that could be planted in another plot of his/her farm area, or to complicate matters worse maize could have also been in the same plot with cotton. This might be easily corrected if in the inquiry about the plots, the technology questions were included (instead of at the level of household as it is presently).

14.5 Technological Improvements and Expected Impact

The introduction of fertilizers, improved seeds or any other yield increasing and labor saving innovations, such as mechanization which increase yields per labor hour, may not be associated with a significant increase in food production for sale (or consumption). In the family sector agriculture innovations may be adopted by most farm households because they save time in the production of a subsistence food (or Z goods) and allow more time to be spent on income earning activities or the provision of other non market Z goods or leisure. If we divide household's available time between home production and leisure. Leisure may be enjoyed as such or used in work. The household can buy time (hiring a maid or buying kitchenware) and the more of such goods purchased, the more home production time is saved leaving the amount of time that can be spent on either leisure or work activities to increase. Thus, the household can buy leisure indirectly.

The effect of the introduction of an improved good (kitchenware) that increases productivity of home time is that it increases the total amount of time that can be devoted to work or in leisure. This reasoning from Sharir 1975, can be used to think of technology as a good to increase productivity of a subsistence crop as being analogous to a household labor saving device which involves a substantial increase in material input costs (px/t, in the household behavior model), but saves on time and therefore reduces the overall labor charge for completing household tasks. This situation can be observed better if we analyze the western household behavior. The western household may invest in a washing machine (as the Moçambican invest in technology innovation) because: a) it may get all the household's washing done more cheaply than before when the laundry had to be used or, b) because doing the washing by hand is arduous, c) because time saved on washing may be spent on activities that give greater benefits than the extra costs of doing the household washing by machine rather than manual or d) because hiring somebody to do it may be expensive. Only rarely will the purchase of a washing machine result in a household deciding to undertake washing as a commercial enterprise. More often the time saved will be used to seek employment away from home, to undertake other household tasks or in leisure activities. This I believe is the general case for the household farming sector in Moçambique.

Usually, in the analysis of alternative activities (other than farming) only wage employment is considered to simplify the analysis. We have to bear in mind that in reality market and non-market activities may be taken up with the time saved (Negrao, 1995), ranging from informal markets, beer brewing, handicrafts, child care, etc. These activities, I believe are very important and in some cases may represent the major form of household income.

TABLE 14.5 Crop Production & Technology Use per Domestic Development Group							
	Establish. Group1	Expansion Group 2	Consolid. Group 3	Fission Group 4	Decline Group 5	Female H Group 6	Rural 94
Hholds Using Just Manual Power							
Cash Crop per Producer							
Cotton	364	366	0	432	357	230	358
Sugar Cane	536	791	355	1810	1227	1084	952
Stapple per Producer, Kg							
Maize	492	528	758	684	538	294	504
Cassava	824	757	578	1000	789	414	748
Beans	91	126	78	180	136	67	108
Rice	205	196	265	304	304	195	235
Sorghum & Millet	298	159	383	215	240	158	238
Groundnuts	96	79	52	124	71	40	81
Other Stapple	92	147	123	102	154	137	121
Hholds Using Animal Traction							
Cash Crop per Producer							
Cotton	270	0	0	315	0	180	259
Sugar Cane	780	0	0	0	1238	200	847
Stapple per Producer, Kg							
Maize	1211	906	1169	527	314	374	647
Cassava	127	194	264	205	261	272	231
Beans	116	151	132	70	71	53	86
Rice	118	180	592	249	177	233	240
Sorghum & Millet	395	142	397	150	198	112	231
Groundnuts	104	107	52	66	52	53	63
Other Stapple	21	47	500	169	178	123	133
Hholds Using Tractor							
Cash Crop per Producer							
Cotton	810	2734	20	2400	2716	0	1849
Sugar Cane	1875	14	403	289	1183	750	821
Stapple per Producer, Kg							
Maize	743	546	542	749	519	506	598
Cassava	78	612	407	363	255	248	310
Beans	455	61	80	61	98	117	181
Rice	421	454	593	78	874	635	579
Sorghum & Millet	186	344	52	355	169	72	197
Groundnuts	27	46	95	282	127	28	85
Other Stapple	120	563	514	315	257	273	325

15 The Purposed Model

In order to introduce new technologies in the semi-subsistence farming systems it is better first to try to illustrate and explain behavioral procedures, and to get a better view of the way resources are looked upon and used by the farmer. It is with that intention that borrowing from a production function approach to consumer behavior and the adoption of Low (1982) model I will try to provide an analytical framework suitable to the farm production situation in Moçambique. Data presented confirm part of the assumptions of the model and as well as to prove why other models do not seem appropriate.

In understanding the production systems at the household level adapted models of Chayanov (1) and Nakajima (2) would be approached to the situation of the farmer in the semi-subsistence level. Since the Nakajima model departs somewhat from the Chayanov's original thinking which may appear to be particularly relevant to the Moçambican situation, an adaptation made by Low (1982) using Becker's (3) model seems to be suitable. This model is attractive because of it's simplicity and potential possibilities to easy adaptation to different situations.

According to Chayanov's theory of peasant economy, a peasant farm household works till it achieves an equilibrium between the increasing drudgery of family labor and the decreasing marginal utility of goods produced. These drudgery and utility curves are subjective and thus likely to change. While C/W-ratios (consumer/producer), rents, capital accumulation, interest on debts and desire for urban goods would affect the marginal utility curve, soil fertility, market prices of crops, distance to markets and availability of machinery are some of the important factors affecting the drudgery curve.

Becker's theory of time allocation give more space to considering non-market activities, effects of wage rate differentials within household members and dedicate special attention to the domestic development cycle defined by Chayanov as having major influence on farm production.

The relevancy of these three factors may contribute in understanding how the farm household manage their resources and at the same time study sustainable opportunities to technology introduction in order to achieve better productivity.

15.1 Criticism to the application of Nakajima model in Rural Mocambique

Nakajima's and other market oriented profit models to the family farm in Moçambique:

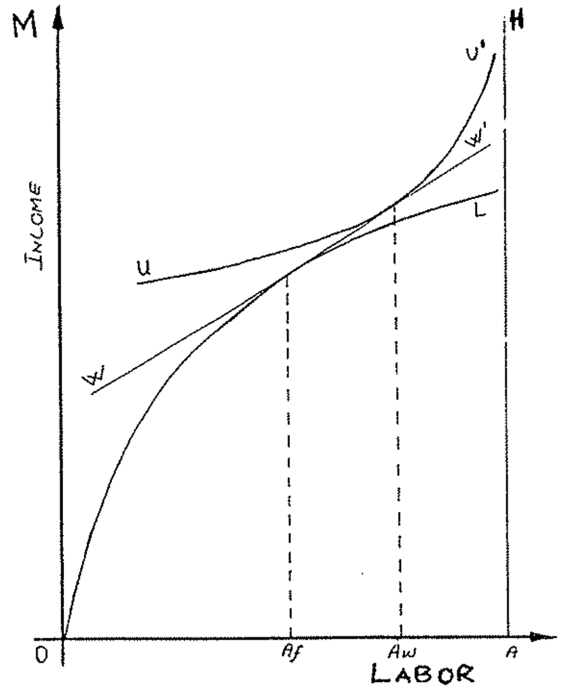


Figure 15.1- Nakajima Model

Family income - **OM**

Labor availability- **OA**

Household production possibility curve- **OL**

Competitively determined wage rate- **W-W'**

Indifference curve *- **U-U'**

* represents the marginal rate of substitution of family labor for money.

The family subjective equilibrium:

Units of labor employed in farm production- **O-Af**

" " " allocated to wage employment- **Af-Aw**

Balance consumed as leisure- **Aw-A**

The objective equation: Profit = p*F - I - w*f; Where "p" is the market price of farm production; "F" is the output of farm production; "I" is the cost of inputs other than labor; "w" is the average wage rate; "f" is the amount of labor input to farm production.

Criticism:

Main critics to the application of this model in Moçambique resides in the three main assumptions that do not automatically apply.

In terms of diminishing returns to farm labor in face of fixed land availability, mostly true in regions at the end of the moving frontier do not apply in general to the case of family farmer. There is a strong indication in Tables 14.4, 14.5 and 14.6 that farm-households with expanding populations and labor forces can expect to obtain access to more land as they expand, since larger farm-households have better claims to land than smaller ones.

The criticism to the second assumption of using a single household wage rate (the average family wage rate) to cost family labor employed in the farm is a over simplification that may not be accepted when wage rates differ markedly between members, like in the south the miners that migrate to RSA, and in general a better wage to male labor than female and child labor. Instead, and according to Chayanov, farm-household labor would be applied to farming according to its "internal equilibrium" which is determined not in terms of maximizing profit, but in terms of equating marginal family demands and needs with marginal drudgery involved in meeting them. Again as mentioned before off-farm labor is a common practice, and this is a strong indication of wage differentials between on-farm and off-farm labor.

The third and last assumption to critic is about pricing the consumption portions of farm production. It is questionable if same market prices should be used to both the self-subsistence and market production parts of the semi-subsistent farm. Fisk 1975, suggested that these should be treated separately until the point where wage labor or cash cropping provides a more rewarding means of acquiring the "essentials of life" than self-subsistent production.

Where the situation applies in Moçambique in general has to be investigated (preliminary data from Inq/94 under preparation will be used in order to check if households produced enough for their own consumption and if any was sold), but it appears that families grow part of their staple food requirements as well as purchase some of it, so the value grown for own consumption will be quite different from the value placed on that portion of the crop destined for sale. On Table 14.2 an exhaustive list of variables will be enumerated which complemented with other necessary data will be used to validate and/or modify the proposed model.

15.2 The Purposed Approach

According to Becker's theory of the allocation of time, households combine time and market goods in the production of the basic commodities, called Z_i which are not marketable and enter directly into their utility functions. Maximizing income subject to Becker's full income constraint implies that the household acts as a cost minimizing firm in the production of household goods. Thus a household requiring a quantity of commodity Z and having for example two members with different wage earning potentials, W_n and W_m, would be faced with the choice of producing Z at two cost levels:

$C_n = p_x + t^*W_n$ (eq. 15.1) or $C_m = p_x + t^*W_m$ (15.2)

where: p_x is the cost of the market inputs needed to produce a unit of Z

t is the time required to produce a unit of Z

C is the total cost of a unit of Z

The marginal cost of obtaining Z per unit of time assuming equal efficiencies for the two members also called sometimes the unit labor charge would be:

$(p_x / t + W_n)$ if Z produced by member n or $(p_x / t + W_m)$ if Z is produced by m.

In trying to minimize the cost the family will look to the member with the lowest charge to produce the Z good. We can think of the subsistence crop as a Z good and try to study management decisions in the allocation of the labor of their members to produce income through wage employment or commercial farming and to combining market inputs and time on the farm to produce subsistence goods.

Explaining the model

Assumptions:

1) Population and work units are homogeneous in respect to farm production and food consumption requirements. Each unit consumes/produces the same as any other unit.

2) Non-homogeneity in respect of wage income. Some units have higher earning capacities than others. This suppose that household members can be standardized in terms of what they consume and produce on the farm. E.g. one 30 years old male equivalent is the same as one and half 15 years old in terms of farm production and food consumption. But wage earning potential of 30 years old is likely to be higher than one and half times of a 15 years old.

3) A minimum amount of labor (independent of their wage potentials) in farming is always present in the rural family in order to maintain traditional rights like allocated land for crop production, and social security obtained by continued membership to the ethnic group. These goods cannot be purchased in the market place they are obtained by direct application of labor to land. This have nothing to do with productivity of these labor in terms of crop or livestock output. Due to this the cost of procuring other Z goods (than land and security) through traditional arrangements will generally be much lower than the market cost of purchasing them in the market.

4) The household will procure a basic minimum level of the staple food and

5) Maximization of potential surplus income after meeting the first two basic objectives.

If we start by considering a two member family farm where the production activity possibilities are either subsistence crop production on the farm or wage employment in the market or even commercial production. We can see the model in Figure 15.2

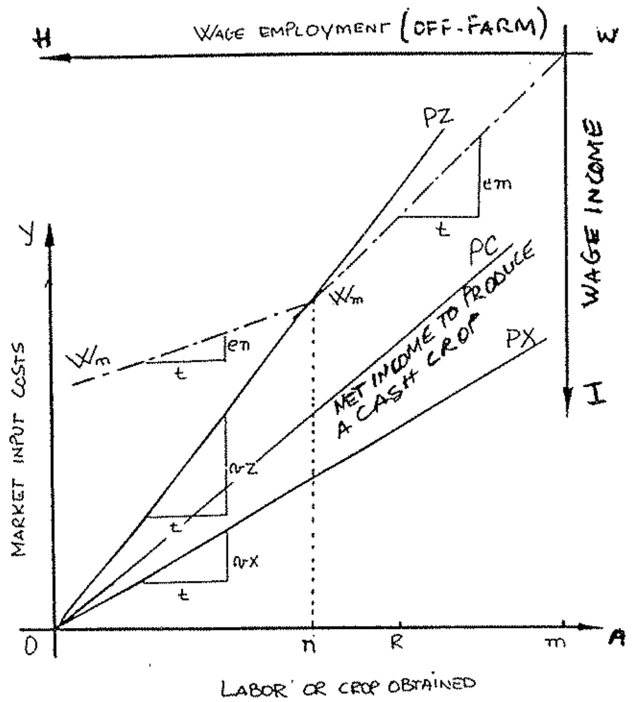


Figure 15.2 - Two different waged person family

OA axis represents labor applied to the farm and since returns are assumed constant the amount of crop produce obtained.

On represents labor input of member n (and the amount of subsistence crop member n could produce).

Om-On represents labor input of member m.

OR household's requirement of the product Z

OY measures market input costs .

PX line represents the ratio (vx/t) in which market input costs are combined with labor time in the production of the subsistence crop.

PC net income line to produce a cash crop

PZ purchase alternative line instead of growing

WH axis is the corollary of the OA axis and measures the amount of labor applied to wage employment.

WW_m and WW_n represents the wage of the respective members.

Member "n's" unit labor charge in producing the subsistence crop Z is (vx + en) and it is less than that of member "m" whose unit charge is (vx + em). The time of member "n" would be allocated to farm production of Z. However, if the household's requirement for Z was greater than member "n" could produce alone, say OR, then part of member "m's" time would need to be allocated to farm production and the unit cost of procuring the household's Z good requirement would increase.

Given the possibility of obtaining Z through direct purchase in the retail market, the household is faced with an alternative method of obtaining its differential requirement (OR-On). This direct purchase alternative would save on time required to grow the requirements on the farm, but would entail a substantial increase in market input costs. Compared with growing the crop the time required for purchase is negligible and can be ignored. Thus all the time needed to grow the crop can be saved by the purchase alternative, which is represented by the PZ line in figure 15.2. This line have the same slope as the opportunity cost of purchase:

$$(PZ / t) - (p_x / t) \qquad (15.3)$$

The slope of PZ, vz/t, is the market input cost of saving a unit of labor time by purchasing rather than growing Z on the farm. Since we have assumed zero time requirement for this alternative, it is also the total cost of saving a unit of labor in the provision of Z.

When the unit labor charge of a member used to produce Z on the farm rises above the cost of saving on a unit of this labor through direct purchase, the household requirement will be obtained more cheaply by direct purchase than by on-farm production. This is the case in figure 15.2 with (em + vx) being greater than (vz) and the household would therefore grow On of its requirement (using labor of member n to do so) while the balance of requirements (OR-On) are purchased with part of the income earned by member m in wage employment.

Using previous arithmetic's, the equilibrium position between direct purchase and own farm production of Z is given by the marginality condition:

$$PZ / t = (p_x / t) + W_i \qquad (15.4)$$

or

$$W_i = (PZ / t) - (p_x / t) \qquad (15.5)$$

where PZ is the cost of purchasing a unit of Z and W_i is the wage of member "I".

If we call the right end side of equation 15.5 the opportunity cost of purchase, we can say that the time of household members with the lowest potential wage rates will be allocated to the farm production of Z first, followed by members with increasingly higher wage rates, until either the household requirements for Z goods are satisfied, or the next member's wage rate becomes greater than the opportunity cost of purchase, in which case the balance of requirements will be purchased.

Of course the particular household members who produce Z on the farm and the extent to which Z is purchased rather than produced will therefore depend on the household member's wage earning potentials, the amount of Z required and the efficiency and cost of farm production compared with direct purchase of Z. The above mentioned model also called geometrical model is a simplified way to enable us to consider how many and which of the household work units will be used in the on farm production of goods for self consumption, commercial crop production and wage employment, without having to consider the consumption, farm production and wage potentials of each household member separately.

Crops cease to be equivalent to a Z good as soon as it is grown for sale rather than for own consumption. Once the basic consumption needs are met, the production decision making framework reverts to that given by the conventional Nakajima type model:

$$W = VMPa \qquad (15.6)$$

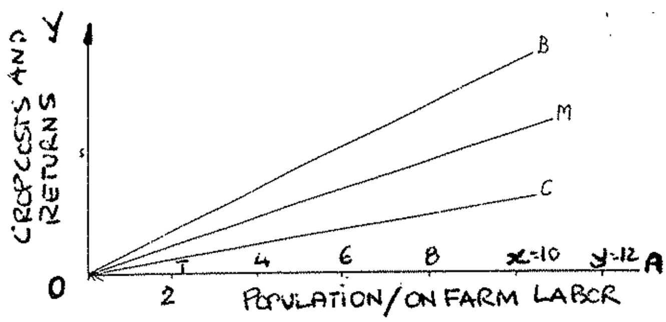
(where W is wage rate) with the value of the marginal product (VMPa) being calculated at the market price.

Thus while the Nakajima analyses may be applicable for farm-households producing for sale but retaining some for own consumption, it is less so when the prevailing situation is household production to satisfy some of their requirements and purchase the balance. Moreover the application of the time allocation approach says something about which as well as how many members engage in farm production. This model has the benefit of simple comprehension and at the same time could be very useful as a basis for more complex situations. Easily could be used for more than one family, and as well for multi-person families with different wage potentials. The introduction of new technologies will have the main effect on the reduction of work units necessary to produce the crop for self sufficiency and may be change the slopes of the cost curves to produce the crop for self consumption and for cash. If cash crop income curve OPC comes closer to the off-farm wage slope (in theory if the slope is bigger than the slope of wage potential) then opportunities will arise in terms of more labor being diverted to commercial cropping instead of off-farm employment. The model is also very helpful in giving some possible explanations why in general cash crops do not compete with subsistence crops like maize.

Lets suppose that: we have the market retail price for maize and that is 900 Mts/kg (Mts are the abreviature for Meticais, the Mocambican currency) against a producer price of 550 Mts/kg, the input costs for maize (produced manually without external resources) is 120 Mts/kg, than the net sales value (550-120) will be 430 Mts/kg and net opportunity purchase value (900-120) will be 780Mts/kg. If applying the same rationale to cash crops we would achieve their net sale value which (supposedly) could be comparable to the ones found for maize. If so they will be less than almost twice (780/430) of those of commercial maize, which is the same as saying that the cash crops would not compete well with maize for own consumption, although they may do compete with maize as a cash crop.

Referring to our model and using figure 15.3 :

Figure 15.3- Labor Returns to Crop Production



OM represents labor returns to commercial maize or income line 430 Mts/kg and OB represents the returns to growing maize for own consumption or income line 780 Mts/kg. Cash crops may even given returns higher than OM, but if they do not generally give returns equivalent to OB (which has almost twice the slope of OM) they would not present advantages, and so would not prevail as commercial crops.

The same way different technologies, like manual power, animal traction and the use of tractor may be put into perspective when compared to each other or trends in agriculture activity may be found when evaluations are made within the technological system.

16. Recommendations and Concluding Remarks

1. The use of different methods of systems analysis and valuation are an important tool in order to achieve conclusive arguments about more sustainable agricultural production systems. Each method enhance particular factors that may not be enlightened by other methods of analysis.

2. In National Agricultural Surveys acquiring data through interviews are probably the quickest and cheaper way to do it. However in order to provide a way to control the quality of data acquired, empirical data should also be collected parallel to the interviews, though in much smaller samples. Measured areas (Inq/94 actually provided for empirical area assessement,

but it seems that the officers "adjusted" those measured areas to the ones cited by the farmers) as well as crop production should be inputted in the data base without adjustments. These measured values should be used to check for deviations (from cited areas and crop production and the ones measured). This deviations are a good source of information that can be used in order to achieve more real data.

3. Because households in Moçambique have two to three plots per farm, and the use of household's resources in agriculture production in those plots may differ, it is very appropriate that resource use and crop production be associated with the plot unit (like it was done in Inq/94 for example for labor and fertilizer used) instead of being only associated to the household unit.

4. The use of qualitative data in terms of the relative area occupied by the different crops planted in the same plot, already existing in the actual database, was not used at this stage but its use might probably give a more accurate figure in relation to crop production per Ha.

5. Domestic development groups were used. This has provided a great deal about how household set their priorities in terms of resource allocation and production characteristics which can be used in order to improve the introduction of new technologies.

6. Consumption of food was difficult to analyse as figures obtained after statistical analysis of the raw data were very small. Probably the best way would be to have that question in a different unit like daily consumption instead of yearly consumption. The other way round would be to just consider figures given by FAO/WHO as standards.

6. Data showed that different farm operations are carried out with differential use of resources. Tillage seemed to be the operation carried out most efficiently in terms of type of power used. Weeding and harvesting do not seem to be affected by the increase of power use, however operations carried manually took more time in average than those carried on by households using animal traction and the tractor. Crop production does not seem to be greatly affected by the use of different technologies. This is not very strange, because households in general do not use fertilizers nor do they irrigate their farms. These two inputs are crucial in the production cycle, we can say in terms of yield increasing these two inputs associated with improved or hybrid seeds may probably provide more than three times the average production per household.

7. Groups of households in consolidation phase, Group 3, with an average size of around 12 members of which 7 are in working age, also have the larger amounts of cultivated land per household. Though in this group area size is not as significantly affected by the use of either animal traction or the tractor as they are in other groups with less members. Actually a maximum limit of 3.86 Ha/household was found for the group. This might be a strong indication that households in fact carry some of the operations manually, like harvesting and mainly weeding even though they may use animal traction or the tractor for the tillage operation. This fact leaves an ample space towards improvements in technology use, like training and agriculture tools adaptation. However we have to bear in mind that the increase in crop production (over self subsistence levels) is only favorable if off-farm alternatives do not offer better rewards to labor than commercial agricultural production. Households in consolidation, fission and decline (41% of the households), are the groups that use animal traction and the tractor above the averages, which might indicate that they are in a better position (social and economically) to afford it. This trend might probably be true for other resources like cattle production and ownership.

8. More data should be collected in order to establish the coefficients and slopes of the curves in the model. This model validation would provide a better understanding of the rural family production characteristics and will also provide a general framework and criteria to establish agricultural product prices that could be favourable to keep more household members in agriculture production than elsewhere.

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04-12-1996

APPENDIX 1- Sampling Weights and District Selection.

This is the data created by the Ministry of Agriculture used to facilitate the stratification of the districts. It is also used for the automatic calculation of sampling weights.

Strata ZAP	Code	Name	Rural Pop. 1994	Zone Agro Ecological	Populat. per District	% of the country	Nº of distr. chosen	(check) % de 60
		Moçambique rural	**12.858.249**			**100,00%**	**60**	
	01	**NIASSA**	**675.128**		**675.128**	**5,25%**	**4**	**6,67%**
01A	0102	LAGO	49.791	1	191.619	**1,49%**	**1**	**1,67%**
	0111	SANGA	31.762	1				
	0113	MUEMBE	23.764	1				
	0116	LICHINGA CIDADE	0	1				
	0103	LICHINGA	86.302	1				
01B	0101	CUAMBA	27.548	6	400.668	**3,12%**	**2**	**3,33%**
	0104	MAJUNE	27.931	6				
	0105	MANDIMBA	77.813	6				
	0106	MARRUPA	37.616	6				
	0107	MAUA	60.955	6				
	0109	MECANHELAS	97.612	6				
	0112	METARICA	30.189	6				
	0114	NGAUMA	41.004	6				
01C	0108	MAVAGO	20.130	6	82.841	**0,64%**	**1**	**1,67%**
	0110	MECULA	18.131	10				
	0115	NIPEPE	44.580	10				
	02	**CABO DELGADO**	**1.229.790**		**1229790**	**9,56%**	**5**	**8,33%**
	0203	IBO	0	0				
02A	0209	MUEDA	118.286	5	178.065	**1,38%**	**1**	**1,67%**
	0215	MUIDUMBE	59.779	5				
02B	0210	NAMUNO	173.943	6	296.825	**2,31%**	**1**	**1,67%**
	0214	BALAMA	122.882	6				
02C	0201	ANCUABE	90.897	10	754.900	**5,87%**	**3**	**5,00%**
	0202	CHIURE	175.352	10				
	0204	MACOMIA	82.834	10				
	0205	MECUFI	43.119	10				
	0206	MELUCO	36.479	10				
	0207	MOCIMBOA DA PRAIA	75.620	10				
	0208	MONTEPUEZ	87.812	10				
	0211	PALMA	39.995	10				
	0212	PEMBA	38.707	10				
	0213	QUISSANGA	34.482	10				
	0216	NANGADE	49.603	10				
	0217	PEMBA CIDADE	0	10				
	03	**NAMPULA**	**2.462.083**			**19,15%**	**11**	**18,33%**
	0323	ILHA DE MOCAMBIQUE-C	0	0				
03A	0306	MALEMA	106.766	6	215.385	**1,68%**	**1**	**1,67%**
	0320	RIBAUE	108.619	6				
03B	0317	MURRUPULA	114.782	7	1.867.641	**14,52%**	**8**	**13,33%**
	0302	ERATI	81.658	10				
	0308	MECONTA	101.692	10				
	0309	MECUBURRI	119.535	10				
	0310	MEMBA	209.444	10				
	0311	MOGOVOLAS	264.217	10				

	0313	MONAPO	235.079	10				
	0314	MOGINCUAL	108.977	10				
	0315	MOSSURIL	75.638	10				
	0316	MUECATE	57.153	10				
	0318	NACALA-A-VELHA	103.286	10				
	0319	NAMPULA	99.059	10				
	0321	LALAUA	40.669	10				
	0322	NAMAPA	256.452	10				
	0324	NACALA CIDADE	0	10				
	0325	CIDADE DE NAMPULA	0	10				
03C	0301	ANGOCHE	159.988	11	379.057	**2,95%**	**2**	**3,33%**
	0312	MOMA	219.069	11				
	04	**ZAMBEZIA**	**2.959.743**			**23,02%**	**13**	**21,67%**
O4A	0404	GURUE	197.954	4	286.158	**2,23%**	**1**	**1,67%**
	0414	NAMARROI	88.204	4				
04B	0409	MILANGE	240.229	6	240.229	**1,87%**	**1**	**1,67%**
04C	0401	ALTO-MOLOCUE	109.322	7	1.060.943	**8,25%**	**5**	**8,33%**
	0403	GILE	144.414	7				
	0405	ILE	338.229	7				
	0407	LUGELA	155.972	7				
	0412	MORRUMBALA	313.006	7				
04D	0402	CHINDE	205.018	11	1.372.413	**10,67%**	**6**	**10,00%**
	0406	INHASSUNGE	96.372	11				
	0408	MAGANJA DA COSTA	247.488	11				
	0410	MOCUBA	145.352	11				
	0411	MOPEIA	144.628	11				
	0413	NAMACURRA	143.199	11				
	0415	PEBANE	188.740	11				
	0416	NICOADALA	201.616	11				
	0417	QUELIMANE-CIDADE	0	11				
	05	**TETE**	**817.426**			**6,36%**	**4**	**6,67%**
04A	0501	ANGONIA	110.529	2	206.125	**1,60%**	**1**	**1,67%**
	0506	MACANGA	33.534	2				
	0512	TSANGAMO	62.062	2				
05B	0508	MARAVIA	59.833	8	128.726	**1,00%**	**1**	**1,67%**
	0511	ZUMBU	39.916	8				
	0513	CHIFUNDE	28.977	8				
05C	0502	CAHORA BASSA	66.516	12	482.575	**3,75%**	**2**	**3,33%**
	0503	CHANGARA	112.174	12				
	0504	CHIUTA	55.166	12				
	0505	MAGOE	24.803	12				
	0509	MOATIZE	139.241	12				
	0510	MUTARARA	84.675	12				
	0514	TETE-CIDADE	0	12				
	06	**MANICA**	**603.259**			**4,69%**	**4**	**6,67%**
06A	0601	BARUE	69.474	3	324.598	**2,52%**	**2**	**3,33%**
	0602	GONDOLA	113.418	3				
	0604	MANICA	81.978	3				
	0607	SUSSUNDENGA	59.728	3				
	0611	CHIMOIO-CIDADE	0	3				
06B	0603	GURO	72.199	9	278.661	**2,17%**	**2**	**3,33%**
	0605	MOSSURIZE	68.364	9				
	0610	MACOSSA	27.036	9				
	0608	TAMBARRA	42.350	12				

	0609	MACHAZE	68.712	14				
	07	**SOFALA**	**1.080.215**			**8,40%**	**5**	**8,33%**
07A	0705	CHIBABAVA	93.520	9	276.773	**2,15%**	**1**	**1,67%**
	0707	GORONGOSA	90.041	9				
	0712	NHAMATANDA	93.212	9				
07B	0701	BUZI	218.394	11	562.674	**4,38%**	**3**	**5,00%**
	0704	CHERINGOMA	74.486	11				
	0706	DONDO	68.463	11				
	0708	MARROMEU	96.916	11				
	0709	MACHANGA	71.296	11				
	0711	MUANZA	33.119	9				
	0713	BEIRA-CIDADE	0	11				
07C	0702	CAIA	98.202	12	240.768	**1,87%**	**1**	**1,67%**
	0703	CHEMBA	61.314	12				
	0710	MARINGUE	81.252	12				
	08	**INHAMBANE**	**1.332.638**			**10,36%**	**6**	**10,00%**
08A	0801	GOVURO	89.761	13	1.129.476	**8,78%**	**5**	**8,33%**
	0802	HOMOINE	103.510	13				
	0803	JANGAMO	123.116	13				
	0804	INHARRIME	93.074	13				
	0805	MASSINGA	229.766	13				
	0806	MORRUMBENE	134.950	13				
	0808	VILANKULO	131.986	13				
	0810	ZAVALA	109.951	13				
	0811	INHASSORO	113.362	13				
	0814	MAXIXE-CIDADE	0	13				
	0815	INHAMBANE-CIDADE	0	13				
08B	0807	PANDA	82.128	14	203.162	**1,58%**	**1**	**1,67%**
	0812	FUNHALOURO	67.852	14				
	0813	MABOTE	53.182	14				
	09	**GAZA**	**1.073.103**			**8,35%**	**5**	**8,33%**
09A	0906	XAI-XAI	115.752	13	270.164	**2,10%**	**1**	**1,67%**
	0908	MANDLAKAZI	154.412	13				
	0914	XAI-XAI CIDADE	0	13				
09B	0902	BILENE-MACIA	143.710	14	630.910	**4,91%**	**3**	**5,00%**
	0903	GUIJA	97.008	14				
	0904	CHIBUTO	204.807	14				
	0907	CHOKWE	141.526	14				
	0909	MASSINGIR	43.859	14				
09C	0905	CHICUALACUALA	47.535	15	172.029	**1,34%**	**1**	**1,67%**
	0911	MABALANE	45.315	15				
	0912	MASSANGENA	29.599	15				
	0913	CHIGUBO	49.580	15				
	10	**MAPUTO**	**624.864**			**4,86%**	**3**	**5,00%**
10A	1003	MANHICA	170.694	14	236.765	**1,84%**	**1**	**1,67%**
	1004	MARRACUENE	66.071	13				
10B	1001	BOANE	63.052	14	388.099	**3,02%**	**2**	**3,33%**
	1002	MAGUDE	110.920	14				
	1005	MATUTUINE	85.315	14				
	1006	MOAMBA	95.898	14				
	1007	NAMAACHA	32.914	14				
	1008	MATOLA-CIDADE	0	14				

Source: Inquerito Agrícola ao Sector Familiar, MINAG, Mocambique 1994.

APPENDIX 3- Sections of Interest Covered by the Questionnaire

Questionnaire used to interview farmers in Inq. 93/94

D. 'Household (Hh) members' information'

D0. N° of members (1-99)
D1. List of...(1-12) if more...
D2. Sex of ... (1 or 2), 1 for male
D3. Age of ....(whole numbers)
D4. Relationship with the head of family (1-8)
D5. Civil status (1-5)
D6. Read and write Portuguese? (1 yes - 2 no) if not go to...
D7. Last accomplished standard
D8. Live in another house? (1-2)
D9. Usually live here or in another house? (1 here - 2 there)
D10. Usually work in the household farm? (1-2) only for members more than 10 years.

A. 'Other Hh information'

A1. Family always lived here? (1-2) if yes go to A6
A2. Since when? from 1900
A3. Where lived before? (country-province(code)-district(code))
A4. What reason made the family move? (1-3, 4 others in alpha)
A5. Wish to come back to origin? (1-2)
A6. Normally used language? (code)
A7. How many farms, parcels in total Hh owns? Whole n°. if not go to A9
A8. Situation of farms and responsible member.
A9. Have any other parcel not considered as farm but still good for agricultural production? if not go to A13
A10. What is the area of A9 (in Hectares or in square meters)
A11. What use is given to this parcel? (1-fire wood, 2-fruit trees, 3-pasture, 4- if other what?
A12. How the family obtained that land? 1-traditional, 2-formally, 3-rented, 4- borrowed, 5-occupation, 6- bought, 7- inherited, 8-if other indicate
A13. Where the family collect water? 1-private well, 2-well or standpipe, 3-river or lake.
A14. How long does it take to carry water daily? (in hours and minutes)
A15. How long does it take to carry firewood daily?......
A16. In terms of feeding which were the most difficult months in the last 12 months?

I. 'Production factors and inputs'

I1. Which implements do you use and how many u own? (1-6 manual tools owned- borrowed) (7-animal traction plow owned- borrowed) (Total rented - cost,)
I2. Use any storage? how many of the following (8-11, owned, borrowed, rented, cost)
I3. Which type of bags, cans, or other means are used to carry and keep the harvested produce? (1-17 different measurement units all either in kilos or in liters)
I4. Use of motor-powered means? How many of the following (12-tractor with plow, 13-plows for tractor, 14-water pumps, own, borrow, re, cost)
I5. Use of transportation means? (16-tractor and trailer, 17-animal, 18-cart, 19-truck, 20-light truck van.)
I6. were any of the implements bought or donated in the 93/94 campaign?
I7. Have animals for traction? how many oxen, how many donkeys?

CL. 'Information on cultivated crops on the agricultural campaign 93/94'

CL0. which crops were planted?
CL1. From where did u get seeds? 1-own, 2-emergency help, 3-locally acquired, 4-bought, 5-other sources.
CL2. quantity of seeds used.
CL3. Which month was the seeding operation carried out in the first season?.
CL4. Which month was seeding operation carried out in the second season ?
CL5. Which month harvested the first season crop?

CL6. which month harvested the second season crop?
(if there was any harvested crop refer to section P1.2)

AA. Information on fruit threes
AA0. which fruit trees do u own?
AA1. How many trees in total
AA2. new trees in growing stage
AA3. trees in production
AA4. non-productive trees, old trees
AA5. number of trees planted by u
AA6. in this campaign did u collect any fruit? if yes refer to section P3.
AA7. what is the occupied area for the fruit trees? In Ha.

P1 Production and use of the main staples crops
P1.0 main basic crops
P1.1 obtained production in the last campaign?
p1.2 how much was sold and at what price?
P1.3 to whom did u sell?
P1.4 how much reserved for seed?
P1.5 how much consumed in the household?
P1.6 how much was taken for gifts, pay in kind, or other ways?
P1.7 how much is stored now?

P2 Production of cash crops
P2.0 which cash crops?
P2.1 how much produced in this campaign?
P2.2 how much was sold?
P2.3 to whom was sold?

P3 Production of fruit trees
P3.0 which fruit trees do u have?
P3.1 how much do u produced?
P3.2 how much was sold?

P4 Vegetable production
P4.0 which vegetables and other crops did u practiced?
P4.1 how much did u produce?
P4.2 how much did u sell?
P4.3 how do u water the parcel? 1-manual, 2-mechanized, 3-gravity

P5 Animal production
P5.0 type of animals
P5.1 how many animals do u have at the moment?
P5.2 how many were born?
P5.3 how many were donated?
p5.4 how many were bought?
P5.5 how many were sold?
P5.6 how many animals were consumed?
P5.7 how many were lost or robed?
P5.8 how many were used as gifts or payment in kind?

F1 Off-farm employment
F1.1 how many members have worked outside the Household farm for payment in cash or kind?
F1.2 members of the Household working outside in the last 12 months?
F1.3 what type of work was done? 1- agricultural production, 2-artistry, 3-fishery, 4-business, 5-state apparatus, 6-other kind
F1.4 was the work at full time or part-time?

F1.5 how many weeks did u work off-farm in the last 12 months?
F1.6 what kind of wage? 1-in cash, 2-in kind, 3-mixed
F1.7 how much in cash did u get in the last 12 months?

X1 External labor working in the Household
X1.1 how many people from outside came to work at the farm for payment in cash or kind?
X1.2 external labor that worked at the farm in the last 12 months?
X1.3 sex
X1.4 how many weeks
X1.5 what form of wage?
X1.6 in total how much in cash was paid?
X1.7 did they plow the land?
X1.8 seeding and transplanting?
X1.9 weeding?
X1.10 harvesting?
X1.11 post-harvest operations?
X1.12 sell of produce and or animals in the market?
x1.13 pasture the animals?

M1 Farm or field/parcel information
M1.0 farm/field n°, local,
M1.1 in which year the Household started exploring this farm/parcel?
M1.2 how did the family got this farm?
M1.3 what use was given to this land in the last 12 months? 1-cultivated, 2-fallow, 3-pastures, 4-abandoned
M1.4 use irrigation?
M1.4.1 how do you irrigate?
M1.5 how long does it take from home to the farm?
M1.6 how many days per week go to this field?
M1.7 how many days does it take to plow? weed? and harvest?
M1.8 how many people Plowed? weeded? harvested?
M1.9 which crop were planted and what was their relative area.
M1.10 what is the characteristics of the soil?
M1.11 which crops were planted in 'consecution'?
M1.12 who decides about the seeding operation?
M1.13 What kind of yield-increasing inputs are used?
M1.14 area of the field?
M1.15 how long has the field been fallow?