Land Use Dynamics, Tree Diversity and Local Perception of Dry Forest Decline in Southern Burkina Faso, West Africa

Souleymane PARÉ

Faculty of Forest Sciences
Department of Forest Genetics and Plant Physiology
Umeå

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Swedish University of Agricultural Sciences

Cover: Forests (left), Shifting cultivation (center), illegal grazing in the Sissili protected forest (right).
    (photo: S. Paré)

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Abstract

Conversion of tropical forests into cropland and pasture has risen incessantly during the last few decades. With the aim of providing evidence for informed-decision on sustainable forest management, this thesis examined the dynamics of land use change in Sissili province, southern Burkina Faso, whether tree diversity and natural regeneration are favored in protected forests under varying human population pressures and local perception of forest decline. Spatial analysis revealed a rapid land use change both at local and regional scales over the past 16 years, characterized by a high conversion rate of forest to agricultural land, driven by rural immigration, changes in farming systems and fuelwood extraction. The protected forest harbored relatively less species (45) than the unprotected forests (58). Irrespective of the forest conservation status, stem density and basal area were higher in a site with higher human population density than otherwise. Shannon's measure of evenness and Fisher's diversity index were significantly high in the less populated site and unprotected forests, respectively. Seedling density did not vary significantly between protected and unprotected forests and sites with varying human pressures, and the majority of the species was characterized by very low seedling density, with a clumped population distribution. A survey on uses of forests and perception on their decline revealed 82 plant species that are being used for various purposes (food, medicine, energy, animal feed and construction), suggesting the key role the forest resources play in poverty reduction and sustaining seasonal shocks (like food scarcity or income generation). The thesis draws the following major conclusions: 1) the size of cropland increases at the expense of declining forest cover both at local and regional levels; 2) the designation of protected areas by itself appears ineffective in ensuring conservation of tree diversity and natural regeneration in the Sudanian dry forest reserves; and 3) the local people depend on the forests to meet their subsistence, energy, income and medicinal needs, with distinct variability between gender, residence status, and ethnic group. The decline of the dry forest in the region has been perceived by the various stake-holders. To effectively protect the remaining dry forests, the forest management strategy should promote the idea of "conservation by utilization" where ownership and management right should be devolved to the local people and equitable benefit-sharing mechanisms established.

Author's address: Souleymane Paré, Department of Forest Genetics and Plant Physiology, slu, SE-901 83 Umeå, Sweden
E-mail:souleymanepare62@yahoo.fr

Dedication

To my late father Ousmane Lahoko Paré, who passed away during the period of my PhD work; rest in peace dear daddy
To my mother, Bougnan Korotoumou
To my children, Abdoulaye Laogon and Cheik Razake Bientan

Contents

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List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I   Souleymane Paré, Ulf Söderberg, Mats Sandewall, Jean Marie Ouadba (2008). Land Use analysis from spatial and field data capture in Southern Burkina Faso, West Africa. *Agriculture, Ecosystems & Environment* 127, 277–285.

II Souleymane Paré, Mulualem Tigabu, Patrice Savadogo, Per Christer Odén, Jean Marie Ouadba (2008). Does designation of protected areas ensure conservation of tree diversity in the Sudanian dry forests of Burkina Faso? *African Journal of Ecology* (*Accepted*)

III Souleymane Paré, Patrice Savadogo, Mulualem Tigabu, Per Christer Odén, Jean Marie Ouadba (2008). Regeneration and spatial distribution of seedling populations in Sudanian dry forest in relation to forest conservation status and human pressure (*manuscript*)

IV Souleymane Paré, Patrice Savadogo, Mulualem Tigabu, Per Christer Odén, Jean Marie Ouadba (2008). Consumptive values and local perception of dry forest decline in West Africa (*manuscript*)

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Abbreviations

CBD   Convention of Biological diversity
CSD   Convention of Sustainable Development
ETM+   Enhanced Thematic Mapper Plus (ETM+) of satellite Landsat 7
IPCC   Intergovernmental Panel on Climate Change
ITTO   International Tropical Timber Organization
NGO   Non-Governmental Organization
TM   Thematic Mapper of the satellite Landsat 4
UNCED   United Nations Conference on Environment and Development
UNDP   United Nations Development Program
IUCN   International Union for Conservation of Nature

1 Introduction

1.1 Background

Tropical dry forests comprise more than 40% of all tropical forests (Murphy & Lugo, 1986) and are the most threatened of all tropical forest types. More than half of the tropical dry forests (54.2%) are located within South America. The remaining area of dry forest is almost equally divided between North and Central America (12.5%), Africa (13.1%), and Eurasia (16.4%), with a relatively small proportion in Australasia and insular southeast Asia (3.8%) (Miles *et al.*, 2006). A prominent feature of tropical dry forests is their seasonality with respect to rainfall (Mooney, 1995), with a long dry season (4 – 8 months) and a somewhat unreliable rainy season in comparison to the rainforests where rain occurs year-round. According to Holdridge´s system of life form classification (Holdridge, 1967), tropical and subtropical dry forests and woodlands are found in frost-free areas where the mean annual biotemperature is above 17ºC, the annual rainfall ranges from 250 to 2000 mm, and the ratio of potential evapotranspiration to precipitation exceeds one. This classification encompasses woodland and forest ecosystems that are usually transitional between semi-desert or savanna and moist forests (Murphy & Lugo, 1986; Vieira & Scariot, 2006). Dry forests grow during the rainy season as do wet forests, but their growth decreases or even stops during the dry seasons, when temperature increases and humidity and water courses decline or dry up. In addition, plant species of this ecosystem have slower growth rates and more restricted reproductive episodes than tropical rain forest species, making them more susceptible to disturbance (Kalacska *et al.*, 2004).

African dry forest and woodland vegetation types are occurring within the savanna biome (Menaut *et al.*, 1995) and are characterized by a more or

less continuous tree cover (70%), and cover approximately 43% of the total area of the continent. They have been under exploitation for thousands of years (Murphy & Lugo, 1986) due to their attractive environment, and consequently are the most threatened and less protected than other ecosystems (Mertz *et al.*, 2007). Tropical dry forests in Africa have often been preferred for human settlement to wetter forest zones for biological and ecological reasons: they are easier to cut for agriculture; crop pests and weeds tend to be less aggressive; soils are often fertile; climate is more suitable for livestock; numerous food crops are more productive (Murphy & Lugo, 1986; Janzen, 1988), as well as rampant occurrence of trypanosomes in the more drier savannas and historic confrontation between different civilizations (e.g. the conflict between the Fulani civilization and the farming and hunting civilizations). They are also subjected to disturbances such as cutting for charcoal and fuelwood, in addition to grazing and frequent forest fire (Savadogo, 2007). These disturbances constitute the major sources of forest and soil degradation in tropical Africa (Murphy & Lugo, 1995). Several studies in the past indicate that Africa is undergoing unprecedented forest degradation as a result of climate change and mainly change in land use activities (Lambin, 1999; Stephenne & Lambin, 2001; Darkoh, 2003; Wardell *et al.*, 2003), although this trend tends to be reversed in recent years in some places (Rasmussen *et al.*, 2001; Herrmann *et al.*, 2005; Olsson *et al.*, 2005; Hiernaux & Le Houerou, 2006; Wezel & Lykke, 2006).

1.2 Land use and land cover change

Land use is defined as the intention underlying anthropogenic exploitation of land cover, while land cover refers to the biophysical state of the earth's surface and immediate sub-surface, e.g., biota, surface water, ground water, soil, topography, and human structures (Turner II *et al.*, 1993; Turner II *et al.*, 1995). For instance, forest (a type of land cover) may be exploited for timber production (the land use), whereas grassland may be devoted to pasture, but in both instances land use is the main cause of changes in land cover. Land cover change can be sub-classified as land cover conversion or land cover modification. Land cover conversion is the complete replacement of one cover type by another, whereas land cover modification refers to subtle changes that affect the character of land cover, but do not necessarily change its overall classification. Hence, land use is the modification of land cover type, an example of which would be the intensification of agricultural use.

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According to Veldkamp & Fresco (1996), land use is determined by spatial and temporal interactions between biophysical factors (e.g. soils, climate, vegetation and topography) and anthropogenic factors (e.g. population size and density, technology levels, economic conditions, the applied land use strategy, and social attitudes and values). Agarwal *et al.* (2002) developed an analytical framework that better illustrates this interaction, which summarizes models of human-environmental dynamics based on three critical dimensions: time, space and decision-making. Time and space are the first two dimensions, as all biophysical and human processes operate within them, and the third dimension of decision-making becomes relevant where human processes are involved.

1.3 Drivers of land use change

The biophysical factors, socio-economic activities, and cultural contexts associated with land use change show high spatial and temporal variability (Geist & Lambin, 2001). Furthermore, identifying the causes of land use change requires an understanding of how people make land use decisions, and how various factors (at local, regional, and/or global scales) interact in specific contexts to influence those decisions. Hence, drivers of land use change can be classified into two main categories: proximate and underlying cause (Ojima *et al.*, 1994; Lambin *et al.*, 2003; Leemans *et al.*, 2003). Underlying causes are formed by complex relationships between social, political, economic, demographic, technological, cultural, and biophysical variables that constitute initial conditions in the human-environment relations. They originate from regional (districts, provinces, or country) or even global levels, with complex interactions between different levels of organization. Underlying causes are often exogenous to the local communities that manage land, and are thus uncontrollable by them, with only a few local-scale factors being endogenous to decision-makers.

The conceptual framework represents a simplified version of land use change and process drivers (Fig. 1). The effects of each major driver and process are reviewed below. Since the biophysical factors cross-cut the various drivers, they are reviewed within each driver and process, as deemed relevant.
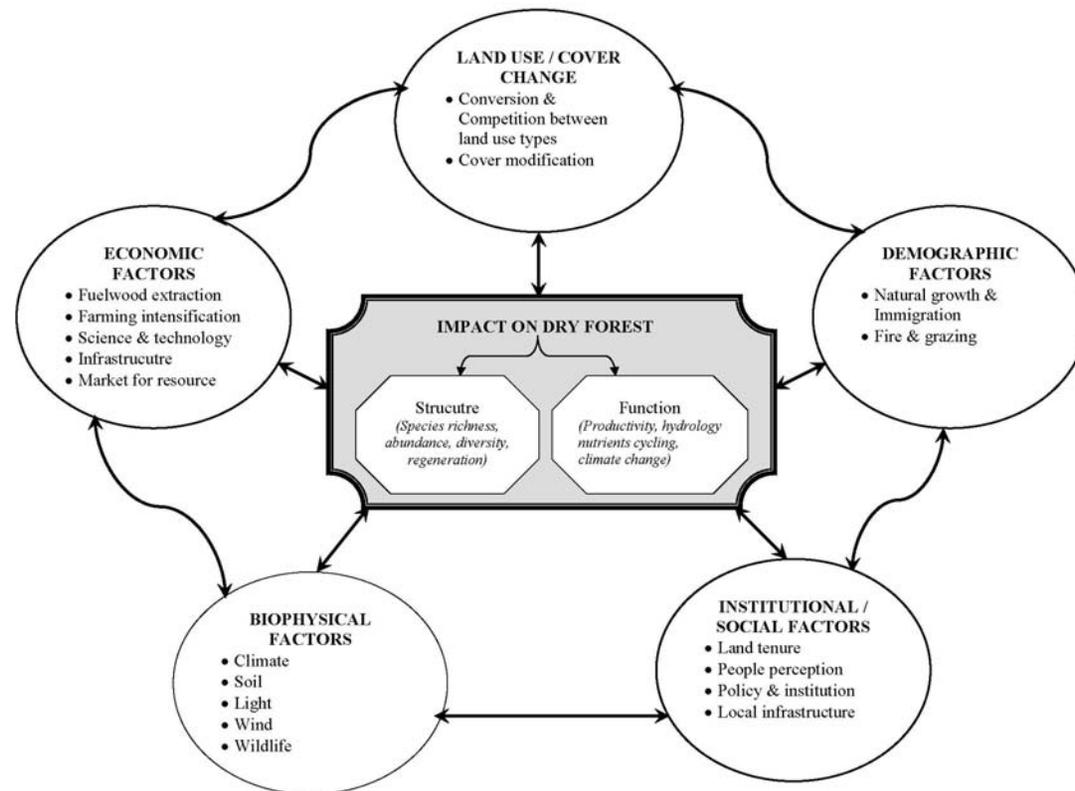
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Figure 1. The conceptual framework illustrating the relationship between major drivers of land use change and the ultimate impact on forest ecosystem.

1.3.1 Demographic drivers

The exact role of population growth as a major driver of environmental change is strongly debated (Veldkamp & Fresco, 1996; Ningal *et al.*, 2008), with neo-Malthusian and Boserupian theories dominating the discussion (Perz *et al.*, 2005; Perz *et al.*, 2006). According to Malthus (1989), population growth is a function of agricultural productivity. This theory, supported by various authors, is founded on the potential for human population growth to exceed the capacity of the available resources to sustain it (Ehrlich, 1968; Norgaard, 2001). Indeed, population growth is considered as a major cause of increasing demands for food, fuelwood, fodder, and other ecosystem services. Furthermore, people often face additional challenges when population growth is recorded, including low economic growth and limited means of income generation outside the utilization of local ecosystem services. Conversely, the theory of Boserup (1965) suggests that agricultural development is a function of population increase, resulting in changes to production methods and improvements in land fertility. Hence, population growth is seen as a cause of prosperity, and agricultural intensification (changing agricultural methods to raise production concentration at the cost of more work at lower efficiency) is mainly due to technological improvements that sustain population growth. She formulated her theoretical understanding of the relationship between population growth and agricultural change on historical Europe. Due to periodic famines and plague in Europe prior to the 18th century, the population was not large enough for the long-term benefits of more intensive agriculture. For that reason, more intensive methods, such as irrigation, were used in a few more densely populated areas. Boserup asserts that agricultural intensification, or the gradual change towards patterns of land use which make it possible to crop a given area of land more frequently than before is an important mechanism for increasing production. In describing this development, she states that small sparsely distributed populations use the land intermittently, with heavy reliance on fire to clear fields and fallowing to restore soil fertility in the wide-spread practice of 'slash and burn' farming. However, rising population density requires production concentration (output per unit of land per unit of time) to rise and fallow times to shorten. Thus, a growing population can use land more frequently and increase output by substituting technological inputs such as fertilizer or irrigation for fallow to retain soil fertility. If Boserup's theory holds, one can expect the degradation of forest quality due to wide-spread shifting cultivation practices when population is low, albeit better

potential for recovery of secondary forests on abandoned fallows. At higher population level, the practice of fallowing is negligibly existed, thus leading to permanent change of the forest cover or simply deforestation. This, in turn, results in loss of biodiversity. However, direct examination of these theories remains elusive, despite their importance, largely because of the complexity of human interventions and their various effects on ecosystems (Luck, 2007). Boserup depicted agricultural intensification as a universal process cross-cutting all environments, but her model relied heavily on agro-ecological features of fire and fallow that are hardly universal; i.e., the relationship between production concentration and efficiency (output: input) may be quite variable among environments. Social context affects both the demands for agricultural products and the relative efficiency of different production methods, which in turn vary culturally. Another important aspect missing in her model is the role external economic systems play in shaping agricultural change through its effect on the cost of inputs and value of output beyond local energetic. Above all the variation in farmers' ability to intensify agriculture as they wish or totally resorting into another alternative to intensification (mainly migration) is totally overlooked. Bilsborrow (2002) developed an alternative approach based on demographic-economic responses to migration. This recent approach emphasizes cultural and political factors when assessing population impacts on the environment (Perz *et al.*, 2005). Indeed, the importance of policy factors in land use change were illustrated by Veldkamp & Lambin (2001), who suggested that international environmental treaties, such as the Kyoto Protocol, may drive significant changes in global land use. This evolution of the land use concept has favored models that capture the inherent complexity of population dynamics more completely, while also allowing the analysis of future trends (Kummer & Turner, 1994; Veldkamp & Fresco, 1996; Stephenne & Lambin, 2001). For instance, the simulation model of land use change in the Sudano-Sahelian region (Stephenne & Lambin, 2004) identifies pastoral lands, together with natural vegetation and croplands, as the land use types that generate the population's basic resources. Nevertheless, Miles *et al.* (2006) reported that virtually all tropical dry forests are exposed to a variety of threats that are largely caused by human activities. Consequently, population growth and food production increases the pressure on ecological systems, and is a major environmental concern in tropical countries (Nagendra *et al.*, 2004; Wright, 2005; Etter *et al.*, 2006; Pacheco, 2006).

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1.3.2 Institutional and social drivers

In addition to demographic driver, land use is affected by socio-cultural, policy and institutional issues. In attempts to understand the effects of culture as a driver of ecosystem change, it is useful to consider culture as the values, beliefs, and norms that a group of people share (Cotton, 1997). In this sense, culture conditions individuals' perceptions of the world, influences what they consider to be important, and suggests appropriate or inappropriate courses of action. Nevertheless, cultural differences have important impacts on direct drivers (Nelson *et al.*, 2006). For example, cultural factors can influence consumption behavior (what, and how much, people consume) and may therefore be a particularly important driver of environmental change.

Socio-political drivers are those forces that influence the decision-making process, and include the quantity of public participation, the make-up of participants in public decision-making, the mechanisms of dispute resolution, the role of the State relative to the private sector, and levels of education and knowledge. Where public involvement in decision-making is concerned, recent trends towards democratic institutions have helped to empower local communities, women, and resource-poor households. However, the relationship between a country and its position and role in the global economy (i.e. dependency theory) has also been connected to environmental degradation (Ehrhardt-Martinez, 1998). For instance, deforestation may result from three types of dependency: export/trade dependency, debt dependency, and an influx of foreign capital. Globalization has also been suggested to underlie those processes that affect tropical land use change through, for example, expansion and liberalization of the markets, and agricultural intensification (Diouf & Lambin, 2001). During the past two decades, international initiatives have greatly contributed to the evolution of the national environmental policies and institutional changes (Glicken, 2000; Benjaminsen, 2001; Pearce *et al.*, 2003) throughout the world. However, in Francophone West Africa, the participatory and community-based forest management have not been able to dismantle a long tradition of forest management which separates rights and users into two distinct categories: the commercial for the citizens and Government, and the subsistence for the rural people (Ribot, 2001). In addition, institutional factors, such as land tenure and legislation, can lead to land use/cover changes in tropical countries (Feder & Feeny, 1991; Reid *et al.*, 2000).

1.3.3 Economic drivers

Economic activity is the consequence of human efforts to improve the quality of life, the outputs of which are determined by natural resources (Nelson *et al.*, 2006). Although land use practices vary greatly across the world, the ultimate intention is generally the same; the acquisition of natural resources for immediate human needs, often at the expense of environmental conditions. By clearing tropical forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centers, anthropogenic activity is changing the world's landscapes in pervasive ways (DeFries *et al.*, 2004). Globally, croplands and pastures are the largest biome on the planet, covering almost 40% of the land surface (Asner *et al.*, 2004). Many land use practices, such as fuelwood collection, livestock grazing and road expansion, can degrade forest ecosystems in terms of productivity, biomass, stand structures, and species composition, irrespective of whether such practices actually change the forested area (Foley *et al.*, 2005). Furthermore, agricultural expansion is generally recognized as the primary economic driver of land use/cover changes in African dry ecosystems (IPCC, 2001; M.A., 2003; Carpenter *et al.*, 2006). Commercial woodfuel extraction adds into the economic drivers of land use change, particularly in big town or city neighborhoods (Arnold *et al.*, 2006). Overall, the growth in human and animal populations, which in turn increases demand for food and forage crops, drives the expansion of cropland and pastoral land, respectively. Kuznets (1955) has developed an alternative view of economic growth as a driver the environmental degradation in the developing countries, with a so called "*Environmental Kuznet's Curve*". According to this principle, poverty and rapid population growth may result on negative effects on the environment during the early stages of economic development, but this trend will be counteracted by later environmental quality improvements as incomes and living standards improve. However, Darkoh (2003) pointed out the necessity of appropriate interventions such as soil conservation measures and land-use policies, to prevent the inevitable degradation of land that will rise. Using cross-section data of protected areas for several countries, Dietz & Adger (2003) did not find an environmental Kuznet's curve for species richness, and found that the conservation of biological diversity is a multi-faceted issue with spatial and cultural differentiation, confirming the complexity of the relationship between income per capita and environmental quality.

1.4 Effects of land use change

1.4.1 Effect of land use change on species diversity

Biodiversity conservation has gained global importance since the 1992 United Nations Conference on Environment and Development (UNCED). Biodiversity can be defined as the variety and variability among living organisms and the ecological complexes in which they occur (Darkoh, 2003). It is now a central issue in sustainable development due to the growing awareness of its importance for human survival and economic security, and the massive reduction in biodiversity that is anticipated to result from human activities (Forester & Machlis, 1996; Singh, 2002; Trombulak *et al.*, 2004).

Human consumption patterns have exceeded the earth's production capacity since the mid-1970s, and the demand for energy, food, and forest products continues to increase (Meffe *et al.*, 2005). This increased pressure has resulted in 83% of the earth's surface being affected by human activities, and related threats to biodiversity can be grouped as follows (Groom, 2005): habitat degradation, overexploitation causing local or global extinction of species or populations, invasive species threatening the dynamics or abundance of native species, and reductions in species diversity. Furthermore, poverty compromises the ability of people to conserve biodiversity in many developing countries. If current trends in global population density and growth continue, the increase in habitat degradation will instigate a 35% level of species extinction in Afrotropical zone species and an 8 to 10% level globally, by 2050 (Groom *et al.*, 2005).

There is a close correlation between biodiversity status or change (e.g. species richness, forest cover) in African ecosystems and the spatiotemporal variation in human population density. This suggests that increases in population density may amplify threats to biodiversity (Wright & Muller-Landau, 2006; Cordeiro *et al.*, 2007; Luck, 2007). Dry forests contain important and valuable resources, such as timber, medicinal substances, industrial materials and services (e.g. soil conservation, flood control, water supply), which are being reduced at an increased rate through deforestation mediated by population growth (Maass, 1995; Laurance, 1999; Darkoh, 2003; Foley *et al.*, 2005). Three types of population-linked factors have been identified as contributors to dry ecosystem deforestation: changes in cultivation by local people,

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spontaneous settlers (i.e. agribusiness actors), and government resettlement projects (Thapa & Weber, 1990), although the latter is not the case in West Africa. The conversion of dry forests to agriculture and pasture is occurring rapidly and causes significant destruction of forest structure and composition, while disrupting ecosystem functions. Furthermore, such high impacts on forest cover can alter the local or regional climatic conditions, in particular leading to decreases in rainfall (Charney *et al.*, 1975) and increases in erosion and/or runoff and temperature (Maass, 1985; Lal, 1990). However, several studies in the Sudano-Sahelian zones have revealed the complexity of local land use situations, which are often difficult to predict and therefore need more investigation (Warren, 2002; Wardell *et al.*, 2003; Burgos & Maass, 2004).

1.4.2 Impact of land use change on dry forest recovery

Forest cover in tropical areas is generally built up through natural processes, in which plants are replaced or re-establish by seed production (sexual reproduction) and/or asexual or vegetative reproduction (Bellefontaine, 2005b). Tree regeneration processes can be influenced by several seed-related factors, such as dispersal modes, viability, dormancy, and predation (Teketay, 1997; Condit *et al.*, 2000; Khurana & Singh, 2001). In addition, tree regeneration can be influenced by various environmental factors, such as soil moisture, temperature, micro-scale disturbance, canopy cover, wind direction and speed, and slope gradients (Yamamoto, 2000; Ceccon *et al.*, 2006; Vieira & Scariot, 2006). Biotic factors, such as herbivory and intra/inter-specific competition (for water, nutrients and space), can also influence seedling dynamics (Nagamatsu *et al.*, 2002; Picard & Bar-Hen, 2002; Dembele *et al.*, 2006). Many dry ecosystem species are characterized by asexual reproduction, which is generally induced by disturbances like fire, herbivory, and cutting (Bellefontaine, 1997; Gignoux *et al.*, 1997; Bellefontaine *et al.*, 2000; Sawadogo *et al.*, 2002; Bationo *et al.*, 2005; Bellefontaine, 2005a). Changes in human activities (e.g. conversion between land use types and changes in disturbance regimes, such as wood cutting, fire or grazing) may also directly or indirectly affect the regeneration of species (Scholes & Walker, 1993; Menaut *et al.*, 1995; Kennard *et al.*, 2002; Hoffmann & Solbrig, 2003). However, not much is known about the interrelationships of these abiotic, biotic, and anthropogenic factors, particularly in the Sudanian dry forests. Therefore, understanding natural regeneration and the pattern of population distribution is crucial when examining forest growth and

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composition (Tesfaye *et al.*, 2002; Ceccon *et al.*, 2006), and when attempting to develop appropriate guidelines for regional restoration programs.

1.4.3 Impact of land use change on climate

The most pressing issues in global change are land cover and climate changes, with anthropogenic land modification and conversion being the predominant contributing factors (Turner II *et al.*, 1993). Land use and cover influence biogeophysical, biogeochemical and energy exchange processes (Hulme, 1996; IPCC, 2001), and variations in these processes affect local, regional, and global climate patterns. Key processes include: uptake and release of greenhouse gases by the terrestrial biosphere through photosynthesis, respiration, and evapotranspiration; the release of aerosols and particulates from surface land cover perturbations; variations in sensible heat exchange between the surface and atmosphere due to land cover changes; variations in absorption and reflectance of radiation, as land cover changes affect surface reflectance; and surface roughness effects on atmospheric momentum that are land cover-dependent. Human activity can and does alter many of these processes and attributes, but weather and climate, as well as geological and other natural processes, are also important. For example, factors that cause land-cover changes, e.g. forest fires, alter ecosystems and release carbon dioxide, methane, carbon monoxide, and aerosols to the atmosphere. They also change land surface reflectivity, which determines how much of the sun's energy is absorbed and available as heat, while vegetation transpiration and surface hydrology determine how this energy is partitioned into latent and sensible heat fluxes.

Studies on land use and cover provide critical information for the large-scale assessment of vegetation biomass and forest cover, which are key components of the carbon cycle. Goals for future studies of land use and cover change include the acquisition of very accurate biomass estimates for refining knowledge of carbon storage in vegetation; the understanding of regional land use changes that affect biomass; and the quantification of links and feedbacks between land use and cover change, climate change, and other related anthropogenic and environmental processes. The global climate and carbon storage processes are impacted by changes in forest cover, particularly those occurring in the tropics. However, the pattern of land use change is characterized by large variations between regions (Laurance, 1999).

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1.5 Participatory management of forests

Participatory approaches in strategic planning and forest policies were adopted relatively recently (in the 1980s) in developing countries compared to the traditional forest conservation management, and have become a central decision-making tool (Buttoud, 1999). Forest conservation generally used to be achieved through formally designating certain areas as reserves or protected forests. However, conserving forest diversity in the reserves, although crucial for credible conservation strategy, is not sufficient for protecting all the diversity because 92% of world's forests are outside formally protected areas (Lindenmayer *et al.*, 2006; Boffa *et al.*, 2008). This traditional conservation model of "National Parks", pioneered in the USA, has been replaced by the new approach of "participatory conservation" for several reasons. First, this approach is based on the recognition of the local communities' rights and increased integration of traditional knowledge and views in conservation policies (Colchester, 2004). Traditional ecological knowledge has become relevant to contemporary sustainable resource management, understanding complex systems, and solving emerging issues like global and climate change (Ford, 2000; Sen, 2005). Local knowledge of species decline and/or conservation is increasingly considered in forest conservation strategies (Lykke, 2000; Ouinsavi *et al.*, 2005), and even in rangeland and livestock forage plant management (Farooquee *et al.*, 2004), as it is acquired over long periods of time, and such observations are important sources of information when developing sustainable management practices for natural resources in general (Stringer & Reed, 2007), and forest ecosystems in particular (Shrestha & Dhillion, 2003; Ssegawa & Kasenene, 2007; Tabuti & Mugula, 2007). Environmental NGOs have especially contributed to the advancement of local knowledge in international initiatives, such as the Convention on Biological Diversity (Dumoulin, 2003). Second, a remarkable attention has been given to the role of forests and forestry in poverty reduction strategies in recent years, as one aspect of the Millennium goals (UNDP, 2003). In general, forests and the forestry sector can contribute to poverty reduction by addressing subsistence and vulnerability, income generation, energy, as well as agricultural and rural development. In many developing countries, there is a high dependence of people on forest resources for multiple uses (Bergeret & Ribot, 1990; Lykke, 2000; Ræbild *et al.*, 2007) however this dependence may be crucial particularly for the very poor or landless farmers who often consume wild products to meet their daily subsistence needs and to reducing the vulnerability to external shocks (attenuate the need of consumption in time

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of food scarcity (Ganemtoré, 2002)). Products derived from forests and trees are important sources of cash income and employment for the rural poor. An estimated 15 million people in Sub-Saharan Africa earn cash income from forest related activities, which are important especially for the most vulnerable groups including women and children (Oksanen & Mersmann, 2003). Numerous are those that use or sell wood as main source of energy. In Sub-Saharan Africa, an estimated 70 – 90% of the population relies on fuelwood and charcoal for energy. Forests and trees contribute to crop and livestock production by providing soil nutrient and animal fodder, averting soil erosion while maintaining water supply, and regulating weeds and pests, which are especially important for poor farmers working in marginal environments as most of them have no access to improved farming inputs.

These twin objectives – biodiversity conservation and poverty reduction – can be effectively achieved by devolving ownership and management of forest resources to local communities, lifting excessive regulations over the use of forest resources, and increasing the political capital of the poor, which are the essence of participatory forest management. FAO (2001) highlighted the guidelines to allow the benefits to local livelihoods from people-centered forestry to include rights to access, control and use of forest and tree resources; more say in decisions over use and management of forest resources; reduced vulnerability, not only through secure forest resources but also political empowerment; income from forest goods and services; improved governance though more effective local institutions; partnership to enhance capacities; direct benefits from environmental services; and increased powers of negotiation.

The participatory approach of natural resource management and the concept of decentralization reforms in West Africa took place over the last two decades (Ouedraogo, 2004). These reforms aimed to improve local management and development by transferring management responsibility and powers to local institutions (Ribot, 1999; Hermosilla, 2000). However, suitable conditions for more equitable and efficient management have not yet been established in Africa (Ribot, 2003; Anderson *et al.*, 2006) and the real incorporation of the local communities' priorities remains questionable (Ribot, 2001; Mwangi & Dohrn, 2008). During the last 15 years, several projects in forestry (80) have been initiated in Burkina Faso in cooperation with FAO, mostly focusing on fuelwood exploitation from the natural forests with local communities' participation (MECV, 2004). The results

obtained in some forest exploitation areas by the project "Regional Program for the Traditional Energy Sector" - RPTES (from 2001 to 2004) are encouraging and in contrast with previous view of over-exploitation of Burkina natural forest (Ouédraogo & Nianogo, 2005). In some forest exploitation areas, such as Bougnounou-Nébielianayou, located in the southern region of Burkina Faso, local capacities were improved in all aspects of the management including fire control, direct seedling, reforestation, extraction techniques, exploitation of non-wood products, and restoration of degraded soils. More generally, these experiences demonstrate that natural forest exploitation in Burkina can contribute to poverty reduction strategies through income generation and their diversification (exploitation of wood, raising, apiculture, fishing, market gardening) for the benefit of poor people (Ouédraogo, 2005; Ouédraogo & Nianogo, 2005).

1.6 Forest management and land use issues in Burkina Faso

In Burkina Faso, dry forests cover ca. 6,794,000 ha, representing 25% of the total land area and 48% of vegetation cover (FAO, 2006). Some of these forests are located in protected areas, such as national parks, fauna reserves, and classified forests or forest reserves, which collectively account for 27% of the country's total vegetation cover. Some clusters of dry forests are also located in the densely vegetated non-protected areas of the south-western part (Fontes & Guinko, 1995). Management of forests and woodlands in West Africa has been influenced by the political and environment histories of the region. In Burkina Faso, it is dated back to the colonial era. During this time, all forests and wooded areas and their rich fauna were open for exploitation by the local people to satisfy their basic needs in accordance with their customs. Restriction rose following the establishment of state classified forests in 1935 by the colonial power, with a status of total protection. The protected areas delineated were used as wildlife sanctuaries to prevent forests from being converted to cropland and its expansion (Shepard, 1992; Bellefontaine *et al.*, 2000). The policy of total protection was based on the assumption that nature has the capacity of self regulation of natural disturbances, and therefore actions that can harmfully exceed this regulation capacity were forbidden. The severe Sahelian drought of the 1970s revealed the limitations of this approach and measures of soil and water conservation emerged in the northern part severely affected by the desertification. The importance of the

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environmental issue is illustrated in the National Plan to Combat the Desertification of 1996: *"The struggle against the desertification in a country as Burkina Faso, whose economy is essentially based on agriculture and husbandry, is not only a simple question of an ecologist vision, but instead a question of survival".* This regulation was characterized by a dualism between citizens and rural people in the control and management of the forests. Under this separation, forest services and the elite typically gain the rights to harvest, transport and market valuable forest products, while the poor rural dwellers can access forest products with little or no commercial value (Ribot, 2001).

As in many countries of Francophone West Africa countries, the forestry sector in Burkina Faso was characterized by a lack of notable attention from the decision-makers for several decades after the independence (1960s). The development priorities were given to agriculture, and forest products were considered as picking-gathering products because of their low economic value (Nouvellet, 1993). Large-scale plantation projects initiated after the drought of the 1970s to provide fuelwood to the urban cities, but were not successful due to prohibitive cost and a lack of involvement of local people (Ouedraogo, 2001; Zida, 2007). With the development of village forestry in 1980s, the rural people stated to involve in the environment protection activities through tree planting, soils conservation, agroforestry improvement, construction of wind breaks and the use of improved stoves. During this time, the participatory approach to forest management emerged based on the involvement of local communities, which was more promising than the former top-down approach (Ouedraogo, 2002; Ouedraogo, 2003a; Kaboré, 2004). In the 1990s, under international initiatives (e.g. *UNCED, the CBD, the CSD, Agenda 21, Helsinki and IITO and Dry Zone Africa processes*) forests policies were revised and oriented towards sustainable development and biodiversity conservation (Glicken, 2000; Kaboré, 2004). In line with the recent evolution of environmental concept, most of the protected areas were managed mainly for provision of basic needs such as energy wood, environmental benefits (biodiversity conservation, wildlife), and curtailing forest degradation (Bellefontaine *et al.*, 2000). The forest policy evolution was characterized by various legal dispositions directly or indirectly linked to forestry sector, including the Agrarian and Land Act, the Decentralization process, the Program Framework for management of national heritage, the National Program of rural land and territory management (i.e. PNGT), the Environmental Code, the National Program

of Forest management, the Forestry Code, the National Plan of Action for Environment, the Strategic plan for the scientific and technological research, the Integrated Rural Development Plan, the various National Plans of Action to Struggle against the desertification, Several National Strategic plans (e.g. for Biodiversity conservation, Climate change, Sustainable development and Poverty reduction). In the elaborated action plans, technical, political and legal aspects of natural forest management for the protected forests were incorporated, which includes the regulation of disturbance factors such as fire, tree cutting and livestock grazing, and also local communities efficient participation (Ouedraogo, 2003a; Kaboré, 2004; Zida, 2007).

As in many areas of West Africa, forest ecosystems of Burkina Faso are still subjected to common disturbances (e.g. agricultural clearing, wood extraction and grazing), which are exacerbated by human population growth (Attwell & Cotterill, 2000; Wezel & Lykke, 2006; Morton, 2007). Annual rate of deforestation in Burkina Faso is estimated as 0.35% per annum (FAO, 2006). In addition, forest reserves and national parks are not very well protected, leading them to be considered as 'paper parks' (Myers, 1994). The strong dependence of rural households on forests for croplands, grazing, and firewood, together with demands from cities for wood energy, is exacerbating pressures on the forests (Forester & Machlis, 1996; McKee *et al.*, 2004; Neke *et al.*, 2006). These pressures are amplified by migrant farmers who find these areas suitable for agriculture (Boutillier, 1985; Camp, 1992; Henry *et al.*, 2003; Ouedraogo, 2003b). The migration zones of Burkina Faso are also subject to increasing pressure from livestock breeding leading to new territorial construction between various actors (Botoni, 2003; Augusseau *et al.*, 2004)In the southern region of the country, where human pressure is accelerating forest degradation, institutional weaknesses are additional contributors to forest reserve deterioration (Ouedraogo, 2003a). Forest degradation, in turn, negatively affects the livelihood of rural people (Darkoh, 2003), and thus the forested zones of Burkina Faso need sustainable land management policies. Such management requires detailed knowledge of land use patterns; the structure, composition, and regeneration capacity of the existing forests. Also traditional local knowledge of plant use and resource management can be efficiently incorporated into sustainable land management policies, therefore, improving our understanding of the complex socio-economic and biophysical factors involved in land use dynamics and assisting in an informed decision-making on sustainable forest ecosystem management and biodiversity conservation in the region.

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2 Objectives

The general aim of the work presented in this thesis was to gather information on land use change and its implication on the conditions of the Sudanian dry forest. The knowledge gained will hopefully support sustainable forest management and biodiversity conservation in the region. Specifically, the various studies presented in this thesis addressed the following questions:

1. Did the extent of the various land use types change over the last 16 years? What was the impact of this land use dynamics on the condition of the Sudanian dry forest in Southern Burkina Faso? (Study I);
2. Given a large decrease in forest cover in the region, does designation of protected areas ensure conservation of tree diversity under different human pressure situations? (Study II);
3. Again given a decline in forest cover, do conservation status of the dry forest and the extent of human pressure favor the regeneration and spatial distribution of tree seedling populations differently? (Study III);
4. Do the local people and various stake-holders perceive the decline in the dry forest in the region? What measures do they recommend to circumvent the current trend and better manage the forest? (Study IV).

3 Materials and Methods

3.1 Study sites

The first study was conducted in Sissili and Ziro provinces (11°02'-12°00' N and 01°30'- 2°80'W), study IV in Sissili province alone, and studies II and III in the district of Bieha (Boala and Yale villages) located in Sissili province. All sites are located in the southern region of Burkina Faso, West Africa (Fig. 2). The area is characterized by low relief with an average altitude of 300 m a. s. l. and consists primarily of settlements, cultivated lands, open savanna woodlands, and clusters of dry forests. Phytogeographically, the study sites are situated in the Sudanian regional centre of endemism in the south Sudanian Zone (White, 1983). The vegetation includes protected and unprotected forests; the former are legal gazetted, such as Sissili protected forest and Kabore Tambi national park while the latter encompass forest formations around the villages, including secondary forests on fallows and parklands. The park and ranch of the region contain a rich fauna essentially composed of elephants, buffalos, springbuckk, waterbuck, warthogs, monkeys, hyenas, crocodiles. The flora of the region is dominated by perennial grass species such as *Andropogon gayanus* Kunth, *A. ascinodis* C.B. Cl, and *Schizachiryum sanguineum* (Retz) Alston (Fontes & Guinko, 1995). The ligneous species are represented mostly by *Afzelia africana* Smith ex Pers, *Khaya senegalensis* (Desv.) A. Juss and *Pterocarpus erinaceus* Poir which are important fodder species. The occurrence of scattered trees of species like *Vitellaria paradoxa* Gaertn. f., *Parkia biglobosa* (Jacq.) R. Br ex G. Don. and *Tamarindus indica* L. on croplands (often known as parklands) is also a common feature of the study area. The climate is dry tropical with a unimodal rainy season lasting from May to October (National Weather

Forecast Center). The mean (± SE) annual rainfall for the years 2000-2003 was 875.6 ± 26.0 mm, with 55 ± 2 rainy days per annum. The average annual temperature was 28°C, with a maximum average monthly temperature of 37.9°C in April and a minimum average monthly temperature of 17.6°C in December.
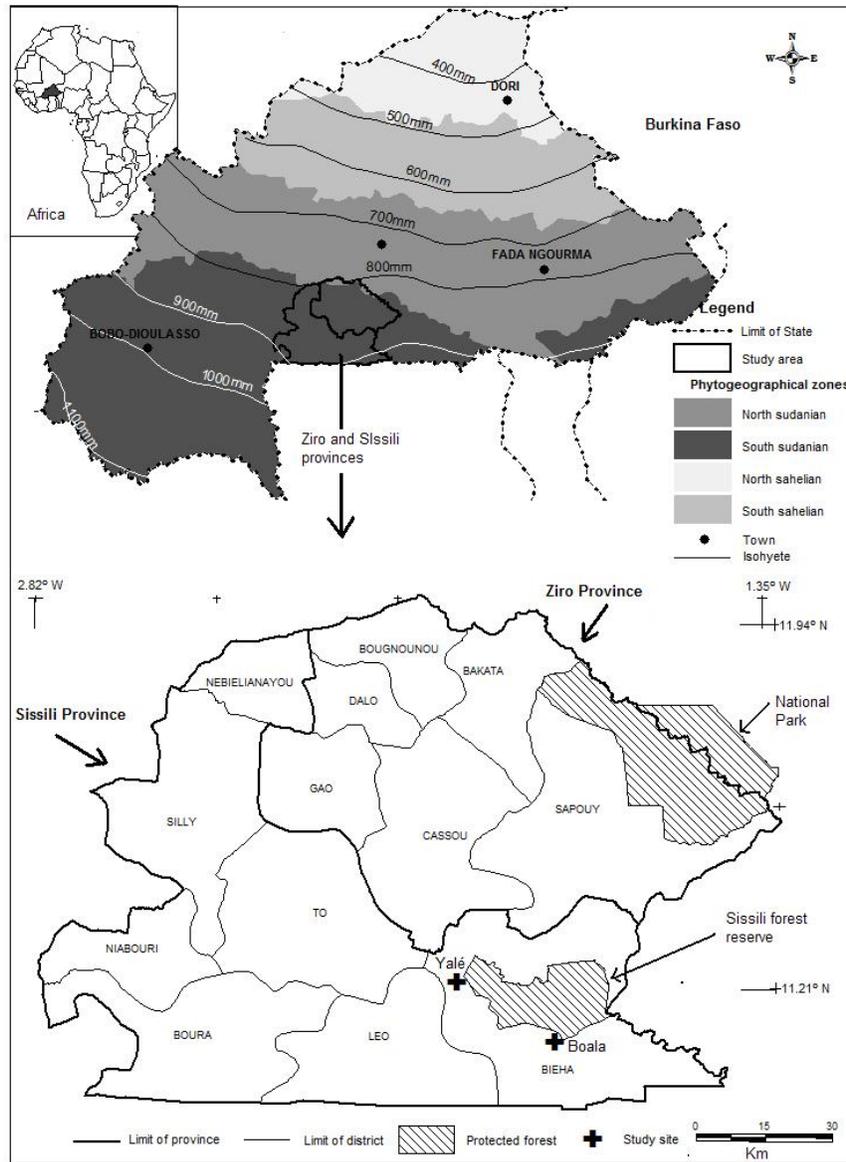

Figure 2. Location of the study area

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Most frequently encountered soils are Lixisols (tropical ferruginous soils), poorly to fully leached, overlying sandy, clayey-sandy and sandy-clayey material (Driessen *et al.*, 2001).

The dominant agricultural system in the study area is traditional subsistence farming with cereals (such as sorghum, millet, and maize) and tubers (yam and sweet potatoes). Since a decade ago, there is a high competition between this traditional farming system and a more lucrative productive system: fuel wood extractions, cultivation of cash crops (with cotton and fruit-tree plantation) and ranching. In addition, rural migration is currently increasing the population density in the region, leading to an increase in pressure on the natural resources by various ethnic groups. The population is constituted of native ethnic group of Nouni, and migrant groups composed mainly of Mossi (originating from the centre and northwest of Burkina Faso), and Fulani (originating from northern Burkina Faso). The average population density is 30 inhabitants/km^2 in Sissili and 33 in Ziro province.

Like in other rural areas, the Gurunsi territories are ruled by traditional authorities composed of two chiefs (the chief of village and the chief of land ownership and traditional divinity). Although their power is being progressively weakened by the modernization process, the traditional social structures are still involved in all important decisions within the village territory and are solicited extensively for problem-solving of social conflicts, access to land and natural resources, or local administration issues, implementation of the development or conservation projects, plans or programs at local scale (MED, 2005).

3.2 Methods

3.2.1 Study I

The first study assessed the land use changes at regional (Sissili and Ziro provinces) and local scales (Boala and Yale villages) over a period 16 years and its impact on the forest ecosystem. For this purpose, two satellite images from 1986 and 2002 were visually interpreted and processed to map land cover changes. The basic data source was Landsat satellite images (TM and ETM+): Path195 and Row 52 from November 1986 and October 2002, with 30 m spatial resolution. For the local scale analysis, aerial photographs from 1984 and 1997 and the satellite image from 2002 were

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visually interpreted. To assess disturbances in the forests, a systematic stratified sampling design was applied where the protected and unprotected forests within a village were demarcated first, and then systematically sampled by laying circular plots (55 m radius) on grids. In Yale, the plots (91) covered 0.9% of the protected area of the village, and the same in the remaining unprotected area. In Boala, the plots (66) represented 1% of the total area of the village. The assessment included number of stumps of trees cut for fuelwood and local construction, number of trees pruned for animal feed, number of trees uprooted by elephants and the percentage of the plot with indicators of grazing (animal trails, hoof print and herbage removal). For both cases, additional secondary data sources (i.e. administrative, topographic and forest maps) were used, as well as ground control information.

3.2.2 Studies II & III

The second and the third studies examined the diversity of woody vegetation (II) and natural regeneration (III) in relation to forest conservation status (protected versus unprotected) and human population density (serving as proxy for human pressure) at two villages, Boala (14 inhabitant/km^2) and Yale (30 inhabitant/km^2), located close to the Sissili forest reserve. A stratified systematic design was applied where the study site was first stratified based on human pressure as low (Boala) and high (Yale) and then based on the conservation status as protected and unprotected forests. Sample plots were selected and laid using a vegetation map obtained by visually interpreting aerial photographs from 1997. The number of plots in each unit was proportional (1%) to the size of each forest. Hence, a total of 127 circular plots (each with a 12 m radius) were used for collecting data on vegetation attributes. Species were identified *in situ* and nomenclature of species followed Arbonnier (2002).

In study II, all woody individuals that had a diameter ≥ 2.5 cm at breast height (dbh) and a height ≥ 1.5 m were counted in each plot. These size classes enabled us to include individuals of short stature, which are typical of dry forests/woodlands. Disturbance indicators (e.g. lopping, cutting, and elephant damage) were also recorded at each plot in order to determine the extent of such damage. The relative ecological importance of each woody species and each family were expressed using the importance value index (IVI) and family importance value (FIV), respectively (Heikkinen & Birks, 1996; Galeano *et al.*, 1998). A variety of diversity indices were calculated in order to permit a more precise comparison of the alpha diversity in each

forest type (Magurran, 2004). To compare diversity between forest types, β-diversity was calculated using Jaccard´s coefficient of similarity and Horns' modification of Morisita´s index of similarity.

In the third study, woody individuals with a diameter at breast height (dbh) < 2.5 cm and below 1.5 m of height were recorded and considered as seedlings. The seedling species composition in the protected and unprotected forests at each site was compared using Sorensen's similarity index (Krebs, 1999). The spatial distributional patterns of the seedling populations within the different sites and forest conservation types were analyzed using the standardized Morisita's index of dispersion (Ip), since it is relatively independent of population density (Krebs, 1999).

3.2.3 Study IV

The fourth study reports on an investigation of the utilization of tree species by local people, their perceptions of changes in the surrounding forests, and suggested solutions in the Sissili province of southern Burkina Faso. A combination of participatory rural appraisal, household interview and observational methods were used to collect the data. A participatory approach was implemented to gather information on the peoples' perception of forest resource dynamics in the region by holding an opinion-exchange meeting at Leo (the provincial city) in August 2003, with the participation of three groups of stakeholders. These included a group of 17 grass-root actors (villagers from Boala and Yale and ranch managers), a group of 22 decision-makers (delegates from the Environment, Animal Resources and Agriculture Ministries and the Ministries' district and provincial offices) and finally a support group of six persons composed of delegates from NGO, the National Program of Land and Territory Management, the local cotton company and the training and extension officers. The information collected was related to the local natural resources, including forests and arable lands. The participants were asked to address the following specific questions. What is your understanding of land use changes around the two villages and the current condition of the forest ecosystem in Sissili province? What are the causes and consequences of these changes? What suggestions do you have for improving the management of forest resources?

Detailed information on local people's uses of woody species was obtained by conducting a household interview at Boala and Yale villages. Households were selected in which the head of the household was more

than 25 years old and had been resident in the village for at least 20 years at Yale and 10 years at Boala, assuming that people who satisfied these conditions were sufficiently qualified to provide accurate information regarding the use of species and forest dynamics. A sample size of 30% of eligible households was selected, which yielded 44 and 92 respondent households in Boala and Yale, respectively. The questionnaire was semi-structured, organized in seven sections: personal information, species present in the parkland and their dynamics, uses of the different species, the parts of plant used, product extraction modes (cutting, collection or pruning), location of their extraction sites (field, fallow or the forest), and observations on vegetation changes.

3.3 Data analysis

Land use data, as well as data from the interviews and field assessment were analyzed using descriptive statistics (study I). ANOVA was performed to examine whether conservation status and human population density affected the calculated diversity indices (study II) and the seedling richness and density (study III). The magnitude of any significant effects was determined by a statistic called partial eta squared (η_P^2), and the effect was considered to be small, moderate or large if the value of this statistic was 0.01, 0.06 or 0.14 respectively (Cohen, 1988). Curve-fitting was used to find the best function for describing the relationship between seedling and adult tree densities (study III). Principal Component Analysis (PCA) was carried out on species-seedling density and species-frequency of occurrence in sample plots to examine the regeneration conditions at individual species level (study III). PCA was also performed on species-use and plant parts-use matrices (study IV). The statistical analyses were performed using SPSS 15 software (Copyright SPSS for Windows, Release 2006. Chicago: SPSS Inc) and PCA using the software package CANOCO 4.5 and the ordination diagrams drawn in CANODRAW (ter Braak & Smilauer, 2002).

4 Results

4.1 Land use change and its drivers

The assessment of land use change over a 16-year period showed that the trend was similar between the villages, although the magnitude of land use change differed. In both villages, cropland and grazing areas increased at the expense of decreasing forestlands (Table 1). The size of the forest land was diminished nearly by half in 2002 compared to its coverage in 1984, while the size of the gallery forest did not change much. In Yale, the size of croplands and grazing lands increased by 9% and 18% in 2002 compared to the sizes in 1984, while the forest land and the gallery forests declined by nearly 50% (Table 1). Locally, the annual rate of conversion to cropland was estimated at 0.4% to 0.5%.

At the regional level, the various land use types included extensive grazing areas, pastoral management units, subsistence and commercial agriculture, protected forests, and production forests mainly for fuelwood extraction. The actual size and proportion of the different land use types changed during the study period. In 1986, the grazing land had much higher proportion of the total regional area than other land use types while the size of croplands was substantially higher after 16 years (Table 2). The size of other land use types decreased during the study period; particularly the decrease was more notable in the gallery forest and grazing land. Interestingly, the annual conversion rate to croplands varied among districts within provinces. In Ziro province, the lowest conversion rate was observed in Cassou (0.1%) and the highest in Bougnounou (1.3%). In Sissili province, the lowest and highest conversion rates were observed in Silly (0.3%) and Niabouri (1.5%) districts, respectively.

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Table 1 *Land use change at a local level for the period 1984-2002*

A. Boala

Land use type	1984		1997		2002	
	Total (ha)	(%)	Total (ha)	(%)	Total (ha)	(%)
Croplands	586	7%	957	12%	1145	14%
Grazing lands	1038	13%	3616	44%	3719	45%
Forest lands	6434	78%	3614	43%	3323	40%
Gallery forests	191	2%	62	1%	62	1%
Total	8249	100%	8249	100%	8249	100%

B. Yale

Land use type	1984		1997		2002	
	Total (ha)	(%)	Total (ha)	(%)	Total (ha)	(%)
Croplands	2184	21%	2735	26%	3205	30%
Grazing lands	3169	30%	5006	47%	5112	48%
Forest lands	4411	41%	2282	21%	1879	18%
Gallery forests	877	8%	618	6%	445	4%
Total	10641	100%	10641	100%	10641	100%

Table 2. *Regional land use dynamics in Sissili and Ziro provinces, southern Burkina Faso during 1986 to 2002*

Land use type	1986		2002		
	Area (ha)	(%)	(ha)	(%)	Annual change (%)
Forestlands	209561	17	197747	16	-0.38
Grazing lands	738176	60	632828	51	-0.88
Gallery forests	75949	6	55919	5	-1.63
Croplands	213414	17	340606	28	+3.75
Total area	1237100	100	1237100	100	0

The main drivers of land use change at local and regional scale were increase in human population, change in farming system and infrastructure development. There was an increase in population at both regional and local levels during the study period. At a regional scale, the annual rate of increase in population density was 3.3% with remarkable variation within district (from 1.8% to 9%). At a local level, there was also a similar increase in population with distinct difference in population density between the villages during the period 1985-2002. At Boala the influx ranged from 5 to 7 inhabitants/sq km while at Yale the corresponding values were 23 to 30 inhabitants/sq km.

The farming system was characterized by large scale commercial farming and subsistence farming (in the form of shifting cultivation and only for household consumption). Large size farming of commercial crops, such as cashew nuts, maize and beans, was found in seven districts within the region with varying land size; the highest being in Cassou (1228 ha) and the lowest in Bakata (120 ha). Cutting for fuelwood and local construction was a common disturbance on crops in Boala while it was common on grazing lands in Yale. Pruning of branches and grazing influence was largely observed on grazing lands in both villages while elephant damage was disproportionately higher on forest lands in Boala than Yale.

4.2 Structure and diversity of Sudanian dry forest

A total of 69 species, representing 52 genera and 26 families were found; 59 species across 48 genera were found at the site with high population pressure (HHP), while 58 species across 43 genera were recorded at the low population density (LHP) site. ANOVA revealed no significant differences in species richness between sites differing in population pressure or forest conservation status, nor was the interaction significant (Table 3).

The species abundance patterns displayed that the majority of the tree species were represented by a few individuals, while only a few species were represented by many individuals. ANOVA revealed that Shannon's measure of evenness was significantly higher at the less populated site than the highly populated site ($F_{[1, 122]}$ = 6.22; p = 0.014; η_p^2 = 0.048). The difference due to conservation status of the forest was significant, with

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moderate effect, for Fisher's diversity index ($F_{[1, 122]}$= 5.73; p = 0.008; η_p^2 = 0.045) being significantly higher in unprotected forests.

Table 3. *Tree diversity measures and structural attributes for protected and unprotected forests in sites with low (Boala) and high (Yale) human population pressure in southern Burkina Faso*

	Boala		Yale	
	Protected forest	Unprotected forest	Protected forest	Unprotected forest
Diversity indices				
No. of individuals recorded, N	312	1138	1620	788
Total number of species recorded, S	8 ± 1	9 ±1	9 ±1	9 ±1
Rate of species increase per individual enumerated, S/N	0.026	0.008	0.006	0.011
Shannon-Wiener index, $H' = -\sum p_i \log_2 p_i$	1.73 ± 0.13	1.83 ± 0.07	1.75 ± 0.07	1.78 ± 0.10
Shannon's measure of evenness, $J' = H'/\ln S$	0.87 ± 0.03	0.88 ± 0.02	0.83 ± 0.02	0.83 ± 0.02
Margalef's index of species richness, $D_{Mg} = (S-1)/\ln N$	2.17 ± 0.23	2.44 ± 0.12	2.25 ± 0.12	2.26 ± 0.17
The reciprocal of Simpson's index, $1/\lambda = \sum n_i(n_i-1) / N_i(N_i-1)$	5.50 ± 1.02	5.00 ± 0.56	5.47 ± 0.56	5.42 ± 0.78
Fisher index of diversity $\alpha = N(1-x)/x$, x is the log series parameter	3.19 ± 0.65	5.47 ± 0.36	4.41 ± 0.33	4.40 ± 0.50
Structural characteristics				
Stem density per hectare	531 ± 88	572 ± 48	703 ± 49	796 ± 90
Average dbh (cm)	10.6 ± 1.2	10.3 ± 0.8	11.0 ± 0.6	15.3 ± 3.9
Basal area ($m^2 ha^{-1}$)	6.55 ± 1.1	6.20 ± 0.64	9.28 ± 0.87	15.92 ± 3.4

There was also a moderately significant interaction effect of human population pressure and conservation status on Fisher's diversity index (p = 0.017; η_p^2 = 0.045). In contrast, no significant differences were seen due to population pressure, conservation status, or their interaction for either Shannon-Wiener's index, the reciprocal of Simpson's concentration index, or Margalef's index of tree species richness. The comparison of species similarity (using Jaccard's index) between forests types associated with the two sites showed a fairly low similarity between protected and unprotected

forests, with 59% and 49% similarity in HHP site and LHP site, respectively. A higher similarity, 66% and 82% for Jaccard's and Morisita's indices, respectively, was observed between the unprotected forests of both sites. In the protected forests, *V. paradoxa* (IVI= 44.28%) and *Crossopteryx febrifuga* (Afzl. ex G. Don) Benth. (IVI= 38.46%) stood out as the most abundant species at the site with LHP*,* while *Detarium microcarpum* Guilt. & Perr. (IVI= 53.35%) and *V. paradoxa* (IVI= 59.47%) were the most common species in HHP site. Other common species to both forest types were *Burkea africana* Hook. f. and *Terminalia avicennioides* Guilt. & Perr. The rarest species in the protected forests of both sites was *Terminalia glaucescens* Planch., which accounted for 0.81% of the IVI in LHP site and 0.21% in HHP site. The relative FIV revealed that Combretaceae (FIV= 122.89% and 92.52% for the protected and unprotected forests, respectively) was taxonomically diverse and constituted the largest group at LHP site irrespective of conservation status. This family was followed by Rubiaceae in the protected forests and Caesalpiniaceae in the unprotected forests. At the HHP site, Combretaceae was the most specious family in the protected forests, and was followed by Caesalpiniaceae. Other families with relatively high FIV values were Mimosaceae, Anacardiaceae, and Sapotaceae, the latter of which was solely represented by *V. paradoxa*.

A total of 1499 individual trees/ha with a dbh $\geq$ 2.5 cm and a height > 1.5 m were recorded at highly populated site, while 1103 trees/ha were found at the less populated site; the corresponding values for the basal area were 25.2 and 12.8 m^2/ha (Table 3). The mean stem density was significantly higher at HHP site than LHP site (p = 0.004), and the magnitude of this effect was moderate (η_p^2 = 0.066). Basal area was also significantly greater at HHP site (p < 0.001), and this effect had a relatively large magnitude (η_p^2 = 0.107). There was also a significant interaction of small magnitude between site and conservation status on the mean basal area (p = 0.044; η_p^2 = 0.032). The dbh class distribution in the two sites exhibited a similar pattern for each forest type, and the dominant class was comprised of individuals with 5-10 cm dbh. However, the pattern of the dbh class distribution varied between the selected species and conservation status mainly for *V. paradoxa*, *D. microcarpum* and *B. africana*. The height class distribution displayed a negative exponential trend for each site and conservation status. The height of trees generally ranged between 2.5 and 10 m. The assessment of disturbance indicators revealed that the trees in both sites were affected by human impacts (lopping and cutting) and

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damage by elephants. Damage incurred by elephants was found to differ between the sites (p = 0.004; η_p^2 = 0.066; with a mean occurrence per plot of 4 ± 1 and 1 ± 0 uprooted trees for LHP site and HHP site, respectively). A total of 28 endangered and vulnerable species of high conservation importance were identified based on the IUCN Red List of Threatened Species (IUCN, 2004) and their national conservation status.

4.3 Regeneration and spatial pattern of seedling population

A total of 63 species, representing 23 families and 48 genera, were recorded as seedlings; 43 species representing 35 genera were found in the protected forest, and 56 species representing 44 genera were recorded in the unprotected forest (Appendix 1). The families with the highest number of species were Combretaceae and Caesalpiniaceae, which jointly accounted for one third of the total species richness of the study sites. These were followed by Rubiaceae and Mimosaceae, which together accounted for one third of the total seedling species recorded. *D. microcarpum* and *V. paradoxa* were the most frequently occurring species in both forest types. Both forest types were generally characterized by a low proportion (18%) of abundant species (those with, for example, > 40 individuals ha^{-1}) and a low frequency of occurrence; however, the proportion of abundant species was higher in the unprotected forests (19%) than in the protected ones (5%).

At plot level, ANOVA revealed that there was no significant effect of conservation status on the species richness of seedlings (p > 0.05) while human pressure decreased ($F_{[1, 122]}$ = 8.94; p = 0.003; η_p^2 = 0.068) richness after significant adjustment by the covariate, distance to forest edge (p = 0.008). The interaction between conservation status and site did have a significant effect on species richness of moderate magnitude ($F_{[1, 122]}$ = 6.01; p = 0.016; η_p^2 = 0.047). Species richness was slightly higher in the non-protected forest at Boala than Yale. A comparison, using Sorensen's similarity index, of the seedling population richness between the forest types of the two sites showed that plots in the protected area of Yale and the unprotected area of Boala had the greatest similarity in species composition. The unprotected forests of the two sites had the least similarity.

The overall mean seedling population density was 731 ± 79 individuals ha^{-1}. There was significant decrease ($F_{[1, 122]} = 10.48$; $p = 0.002$; $\eta_p^2 = 0.079$) on seedling population density due to human pressure. However, conservation status had a marginally significant effect ($p = 0.064$). The average density of seedlings was slightly higher in the unprotected than in the protected forests at both sites. The highest density was observed in the unprotected forests of Boala (1120 ± 199 individuals ha^{-1}), while the lowest was seen in the protected forests of Yale (468.50 ± 51.28 individual ha^{-1}). The species with the highest densities were *Pteleopsis suberosa* EngI. & Diels in Boala and *D. microcarpum* in Yale, irrespective of forest type (Appendix 1). The pattern of juvenile-adult density relationship varied from quadratic to exponential depending on the forest type, and the relationship was significant but the magnitudes were generally low ($r^2 < 0.50$) in all cases.. The spatial dispersion analysis revealed that the seedling populations displayed clumped distribution for all species examined at both sites except *Prosopis africana* (Guilt. & Perr.) Taub. in the protected forest of Yale that showed a uniform pattern.

4.4 Uses and local perception of Sudanian dry forest decline

The survey revealed that local people consider the forest as their granary, their source of medicine, fuelwood, grazing area and material for construction. Extraction of various wood and non-wood products was said to occur either seasonally or temporally according to the people's needs and the availability of the materials. Overall, about 82 tree species, representing 30 families and 65 genera (Appendix 2), were said to be exploited for one or more of products. The species-use ordination made by PCA explained 83% of the total variance in the data with the first two components. The local people appeared to prefer species such as *T. indica* and *P. biglobosa* for food, while *D. microcarpum* and *V. paradoxa* were preferred for medicine (Fig. 3). Some species, such as *Ficus sycomorus subsp. gnaphalocarpa* (Miq) CC. Berg, *B. africana*, *Afzelia africana* and *Pterocarpus erinaceus* were mainly used as fodder.

In general, 30 species were found to be highly preferred by the local people (Fig. 4). The highest ranking species, irrespective of the informants' residence status or ethnic group, included *V. paradoxa*, *P. biglobosa*, *Psidium guajava* Linn.*, Mangifera indica* L.*, Lannea acida* (A. Rich.) Oliv.*, D. microcarpum* and *T. indica.* The highest numbers of records (> 46

%) was found for species such as *M. indica, P. biglobosa,* and *T. indica,* while the lowest (< 8%) was found for *Combretum collinum* Fresen*., Piliostigma thonningii* (Schumach.) Milne-Redh*., Strychnos spinosa* Lam. Almost half of the species were found to have similar importance for both men and women, although men appreciated *Sarcocephalus latifolius* (Smith) Bruce*, P. erinaceus,* and *B. africana* more than women, who had preferences for *Bombax costatum* Pellegr. & Vuillet*, Citrus limon* (L.) Burm. F*.,* and *Lannea microcarpa* Engl. & Krause. In addition, most of the species were found to vary strongly in importance between migrants and natives, and only few species (six) were equally valued by both groups. This difference in importance was particularly prominent for species such as *C. collinum, K. senegalensis, P. erinaceus* and *F. sycomorus.*

There were also variations in species' importance amongst ethnic groups, and only few species (e.g. *A. africana, Diospyros mespiliformis* Hochst. Ex A. Rich*.,* and *M. indica*) had similar levels of worth for the Fulani, Gurunsi, and Mossi. Species with the highest importance for each ethnic group (Fig. 4) were *M. indica* for the Mossi (mentioned by 78%), *K. senegalensis* and *Ximenia americana* L. for the Marka (13%), *V. paradoxa* for the Gurunsi (83%), and *P. biglobosa* for the Fulani (69%).

The survey also indicated that the local people employed several modes of extraction: branch cutting, fruit collection, lopping, and root and bark extraction to obtain fiber for cordage and materials for medicine peels. Products from species such as *V. paradoxa*, *D. microcarpum, Eucalyptus camaldulensis* Dehn, *P. biglobosa* and *P. erinaceus* were obtained through stem cutting, lopping of branches and leaves, and collection of nuts. Some species were specifically subjected to a particular type of extraction, for example *Annona senegalensis* Pers. and *Hymenocardia acida* Tul. (cutting); *B. costatum*, *D. mespilioformis* and *Gmelina arborea* Roxb (lopping); and *Acacia seyal* Del. (pod collection). Some species, such as *Parinari. Curatellifolia* Planch. Ex Benth, *Balanites aegyptiaca* (L.) Del. *F. agrestis*, *Citrus Sinensis* (L.) Osbeck and *Saba senegalensis* (A. DC.) Pichon were exploited by few people.

The plant part-use category analysis revealed that the first two Principal Components explained 83% of the total variance in the data. Fruits, flowers, bark, sap and root extracts appeared to be the most frequently used plant parts from species such as *P. biglobosa, V. paradoxa, M. indica, T. indica, S. senegalensis* and *L. microcapra*. Species mostly cut and lopped

were *P. erinaceus, A. africana, B. africana, D. microcarpum* and *K. senegalensis.*
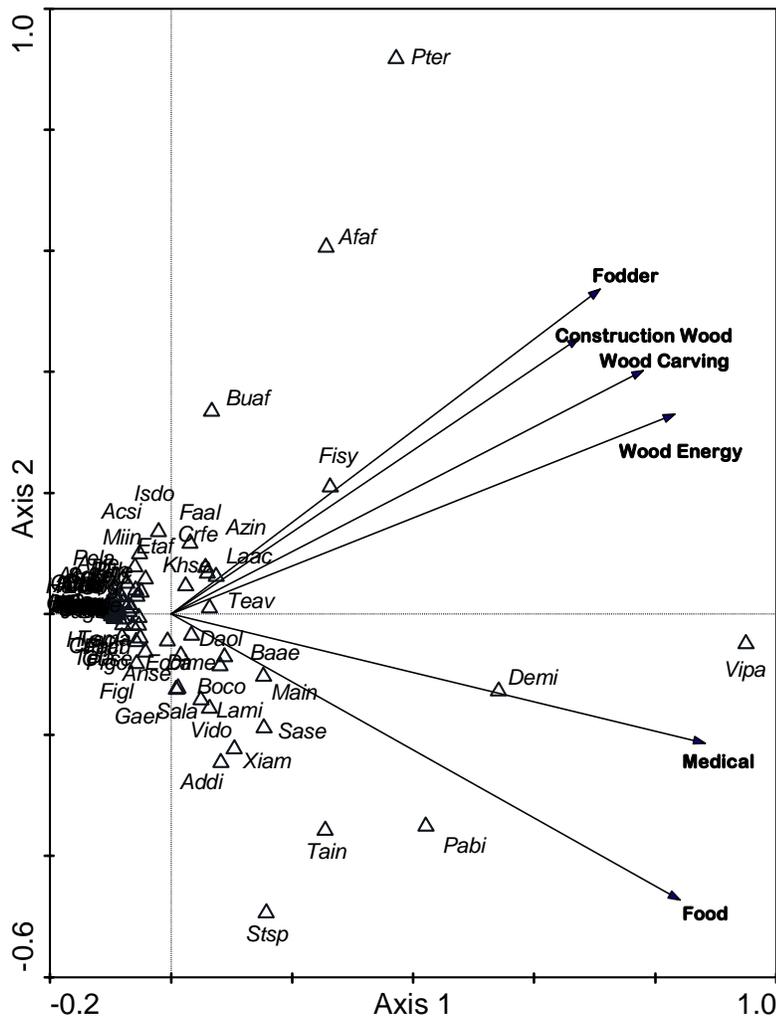

Figure 3. Principal Component Analysis of plant organs - use categories in relation to species (Full species names are given in Appendix 2)

The locations of woody species exploited for various purposes were different. The species exploited in the plantations and woodlands were mainly fruit-species (such as *M. indica, P. guajava, C. limon* and *C. sinensis*) and timber species (such as *E. camaldulensis* and *Azadirachta indica* A. Juss.), respectively. Products from species such as *P. erinaceus, A. africana, B. africana, K. senegalensis,* and *D. microcarpum* were mainly

extracted from croplands (parklands), fallows or protected forests. The local people were also observed to be highly dependent on farm tree species, including *V. paradoxa, T. indica, P. biglobosa, L. microcarpum, Lannea acida* (A. Rich.) Oliv.*, F. sycomorus, D. microcarpum, B. costatum, A. africana,* and *Adansonia digitata* for wood and non-wood products.
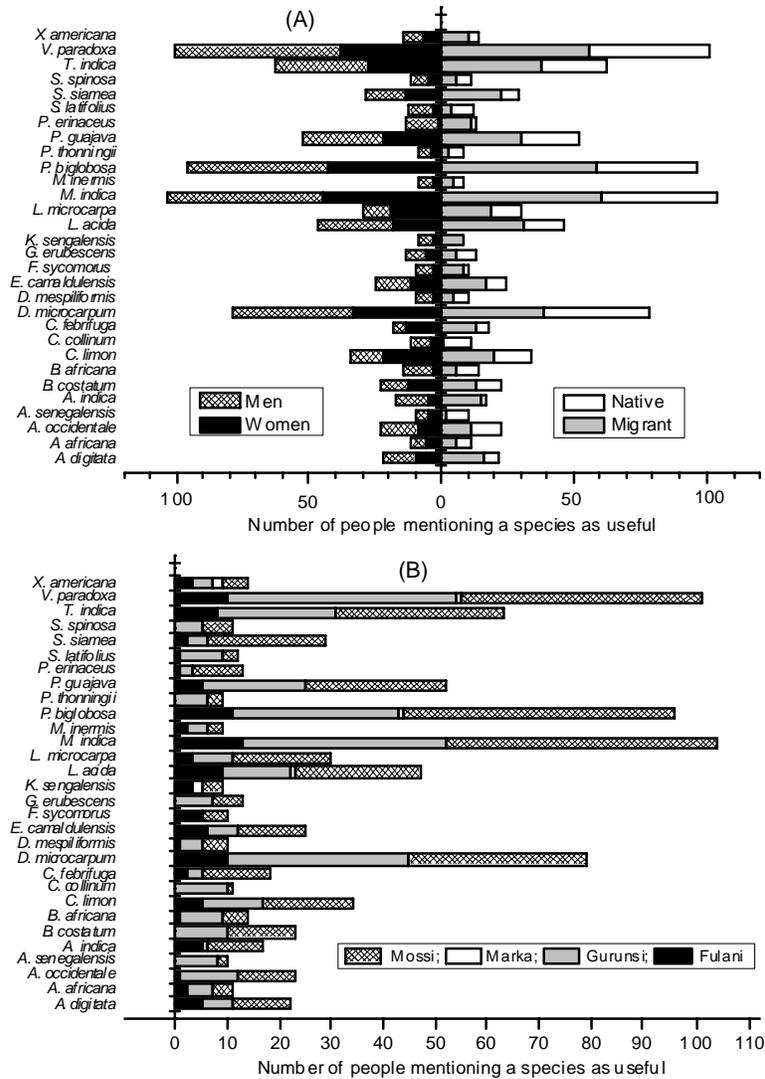

Figure 4. Species mentioned as highly useful by local people according to gender and residential status (panel A) and ethnic group (panel B) in southern Burkina Faso.

Most of the respondents perceived that clearing of vegetation for cultivation of cash crops (agri-business) was the major driver of vegetation change. The informants mentioned that the decrease in rainfall over the last 20 to 30 years was one of the major abiotic constraints on vegetation growth. Another important factor mentioned was the population increase, which was primarily caused by rural immigration into the region since the 1970s. Furthermore, institutional weaknesses underlie these causes of vegetation change, resulted in a poor level of protection of forest reserves and insecurity in land tenure. Other factors that have affected the forest cover were fire management, tree planting, and forest regeneration. Interviewees expressed both wishes and suggestions for vegetation management, while raising awareness of the rate of deforestation and increasing efforts to reduce it (Table 4). The decision-makers and support groups pointed out the need to promote integrated land management policies, while enhancing local capacities. Monitoring of the forest ecosystems and increasing the available scientific knowledge were strategies that were especially stressed by the decision-makers.

Table 4. *Local people suggestion for the improvement of forest resources management in the Sissili province, southern Burkina Faso*

Types of suggestions	Detailed answers	GA%	DM%	SG%
Fire management	Control of bush fires	18	4	16
Grazing management	Regulate the grazing density	10	10	16
	Create corridors for grazing			
	Increase the number of pastoral zones			
Fallow practice	Improve the practice of fallows	1	0	0
Tree domestication	Domesticate multipurpose trees	3	12	0
	Plant trees along the roads network			
Reduce deforestation rate	Reduce the size of clearings from agribusiness	6	12	16
Protection of forest reserves	Reinforce the protection of forest reserves	12		0
Land tenure security	Adapt the Land Reform to the local context	7	12	0
Immigration rate	Regulate immigration flux	8	0	0
Awareness	Awareness of people on forest degradation	30	16	16
Monitoring of ecosystems	Follow up of land use and vegetation changes	0	12	0
Integrated management	Promote an integration of production systems	0	10	17
Enhance capacities	Reinforce local capacities in management	0	0	17
Increase scientific knowledge	studies on environmental impacts	0	12	0

GA: Grassroot actors; DM: Decision Makers; SG: Support Group; Note: 5% of the Grassroots actors mentioned has "no idea"

5 Discussion

5.1 Land use change in southern Burkina Faso

The result from the present study revealed that there was a rapid land use change both at local and regional scales. At the local scale, the size of cropland and grazing lands increased at the expense of decreasing forest cover with distinct variation in magnitude of change between villages. This land use dynamics was driven by the increase in population due to migration particularly in Yale village, where local migration is dated backed to the 1975 (pers. comm. with villagers). Apparently, the proximity of Yale to the road made influx of people higher than in Boala, which is in line with the important synergetic cause-effect relation between population-infrastructure and agricultural expansion on tropical deforestation (Geist & Lambin, 2002). The increased influx of people to the village accounts for increased crop land area, as migrants are involved not only in subsistence farming but also in cultivation of commercial crops such as cotton, cashew and beans. The increase in grazing land in both villages pertains mainly to the installation of cattle herders on part of the protected area of Yale in 1997 (the Fulani ethnic group). In practice the installation was extended to all open access areas of the region. In recent years the high density of the cattle herds and uncontrolled grazing practices have increased crop insecurity, and the episodic conflicts between herders and farmers have become more frequent (Ouedraogo, 2003b).

Most of the land use dynamics issues observed at a local scale is also reflected at the regional scale. First, there was an increase in the size of cropland and population density as well as a change in farming systems, mainly geared towards cash crop cultivation. This increase in population

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density is associated with a continuous flux of immigrants, which in turn alters the traditional agriculture production systems (Henry *et al.*, 2003). The important consequence of the population increase from influx of people was the high rate of conversion to croplands observed in several districts. The regional rate of conversion to croplands (0.6%) is twice higher than the national rate (0.3%) for the period 1990-2005 (FAO, 2006). Similarly, the annual rate of change in cropland (3.7%) was higher than the national rate of 1.4% from 1984-1997 as reported by Stephenne and Lambin (2001). One important consequence of this conversion is the degradation of the Sissili protected forest in addition to the increasing illegal activities such as charcoal production, hunting, and bush fire occurring every year.

The second important factor is the increasing pressure from grazing that led to excessive pruning of fodder trees and increasing threats to crops due to grazing, thus resulting in deterioration of social relations between herders and farmers (Petit, 2003; Gautier *et al.*, 2006). The third aspect is the land tenure, which is the same for the region in the sense that all the rural lands of the region are under the hands of the native ethnic group (Nouni). At regional scale too, tree-planting by migrants is not allowed and women has no right to own land (Rocheleau & Edmunds, 1997). As in the case of most areas in Burkina Faso, our study site experiences land tenure insecurity, particularly due to increasing land transactions for expansion of agri-business (Mathieu, 2001; Bologo, 2004). Several factors contribute to a more complex land use dynamics pattern when studied at a regional scale. The first is the various types of production and resource management systems including, the traditional subsistence farming of cereals, intensive farming of cash crops, fuel wood extractions, ranching/pastoral activities. The second factor is the weak dialogue and/or consensus between the multitude of actors (e.g., native subsistence farmers, migrant farmers, migrant cattle breeders, private actors) on the access to land and/or its occupation (personal communication with local stakeholders).

Lockwood's (1997) study in the northern part of Nigeria has revealed contrasted results of the theories on population growth and environment. The general view is that poor people in poor countries overuses their natural resources, either out of ignorance or because of poverty. The Malthusian's decision-making model, according to which every region facing environmental problems would have a fertility rate no higher than that for the northern Italy, was examined; but this theory did not applied to

the area. For example, the northern part of Nigeria was characterized by a high density of population and also subjected to environmental degradation but still high human fertility persists. Hausa people are responding to the increasing population by a continuous cultivation without fallow, and they attribute the decline of yields to the weak availability of fertilizer, to rainfall decline or to the hand of God. The Hausa land was a remarkably managed savannah, ecologically stable with highly labor intensive that continues to absorb a large number of people in the rural labor force, a locally sustainable system like the case of the Machakos in Kenya. These examples are in accordance with Boserup's theory on agricultural systems dynamics. Some of these features were also found in our study sites. The increased population density led to disappearance of fallows in Yale village and a high reduction in Boala. The local farmers did adopt strategies to adapt to the climate change and also to the increase of population pressure including: use of drought-tolerant cultivar of cereals, combination of crops in the same field, diversification of their crops between several fields mainly practiced by the natives. In Boala, to avoid the reduction of their fallow time, famers are temporary cropping on the land of another village (i.e. Nakoayaro) through a negotiation. In both villages, as in many rural areas, local farmers are also breeding small ruminants as secondary activities to generate additional income. The practice of cattle breeding by the native or migrant farmers is generally related to the intensification (i.e. use of oxen plough) which is supported by the State's agricultural extension program and rural development projects. In this area, Fulani herders possess large herd of cattle and their strategy of land use and resource utilization is similar to the Hausa's system in the northern Nigeria (Lockwood, 1997) or the same as in the southern region of Burkina (Liehoun-Botoni, 2003; Augusseau *et al.*, 2004). In the herder's perception, land is not viewed as delineated area with fixed boundaries, but a flexible patch-work of pieces of land, potentially accessible through social relationship. Consequently, the boundaries are not absolute, but are to varying extents permeable and expandable. This perception is totally contrasted with the native and migrant farmers whose activities are imbedded in a territorial concept with fixed borders, land tenure and ownership rights. The conciliation of theses logics of territory construction is very difficult and the high competition in land use and access to resources has led to a conflictive relation between herders and farmers in the region, with frequent crisis (Kamuanga *et al.*, 2001; Ouedraogo, 2003b). Admittedly, it is evident that the environmental conditions and constraints (climate, natural features and their characteristics) play an

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important role in the understanding of the natural resources management, the ways they are valued by the people can differed profoundly and constitute a constraint in the generalization of the theories and models. The cultural values are important factors that explain the variation and specificities of situations, which cannot always be grasped by the regional or general theoretical models. It is also important to notice these traditional systems of production or land resource management are being progressively altered by various interventions from the State institutions, NGOS and also projects through various programs.

The complexity of the current land use dynamics suggests a need for integrated management in the region. Insecure access and use of land is often caused by exogenous factors that are not adapted to the local conditions (Reenberg & Lund, 1998). However adaptation of traditional land tenure rights to the socio-economic context of land use change is important for the improvement of natural resource management systems (Mwangi & Dohrn, 2007). To this end some important conditions are needed, which include local rights recognition, equity in benefits for actors, and consensus on collective choices as well as devolution of ownership and management responsibilities (Hermosilla, 2000; Sulser, 2000; Ribot, 2001; Anderson *et al.*, 2006).

5.2 Human population pressure and conservation of dry forest diversity

The species composition and richness of the forests were not significantly affected by either conservation status or human population density contrary to the theory of population growth and environmental degradation. According to the Boserup's theory, fallowing decreases as population density rises; and hence one expects a decline in forest cover and associated biodiversity. Although fallowing appeared to decline in our study sites, the species richness didn't vary between sites with differing population density. One possible explanation could be the loose protection of the protected forests at both sites, leading to legal and illegal exploitations (e.g. part of the protected forest was open for ranching in Yale). The other explanation would be better tenure security in the unprotected forest, as it includes secondary forests derived from abandoned fallows that are owned privately. Overall, the species enumerated in this study accounted for one quarter of the native woody species previously recorded in the country (Lebrun, 1991). However, values from the present study are slightly lower than those

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reported for the Tiogo State forest reserve, located in the transition from the North to South Sudanian Zone, where 29 families, 66 genera, and 89 species were recorded (Savadogo *et al.*, 2007b). Site conditions, such as soil fertility, moisture, or humidity conditions (Scholes & Walker, 1993; Fontes & Guinko, 1995; González-Rivas *et al.*, 2006; Traore *et al.*, 2008), may explain the differences between our results and those from other studies. The most common families in all forest types were Combretaceae and Caesalpiniaceae. A study performed in Tanzania reported similar FIVs for Caesalpinaceae, Ebenaceae, and Moraceae as those seen in our study (Huang *et al.*, 2003). The presence of exotic species in the unprotected forests of Yale may be explained by ornithophilic seed dispersal, which is known in species such as *A. indica* (Rajendran *et al.*, 2001). Seed input resulting from such dispersal mechanisms could lead to establishment of new species, which in turn may affect the phytodiversity of forest stands.

The stem density and basal area from the surveyed area can be compared to those from other studies in tropival dry forests (González-Rivas *et al.*, 2006; Savadogo *et al.*, 2007a). The significant difference observed in both basal area and stem density between site differing in human population density was mainly related to the prevalence of abundant species (i.e. those with > 24 stems ha^{-1}), and the high number of species with a large diameter (dbh > 25 cm). The high number of young trees (those with a dbh of 2.5 - 5 cm) found in all the forest types also indicates the potential for vegetation renewal (Zegeye *et al.*, 2006). However, the diameter class distribution observed in the selected species revealed some regenerative constraints for species such as *B. africana*, *V. paradoxa* and *D. microcarpum,* and signs of selective cutting were also seen in *T. avicenoides*. The pressure from cutting is generally higher on *D. microcarpum,* since it is one of the preferred fuelwood species (Sawadogo *et al.*, 2002; Wezel & Lykke, 2006), while *B. africana* and *T. avicenoides* provide good material for poles and house construction (Kristensen & Balslev, 2003).

More diversity was expected in the protected forests, but the results reveal a low level of variation in both villages, with only Shannon's measure of evenness and Fisher's index of diversity showing differences in relation to forest conservation status. Fisher's diversity index (the most stringent measure of diversity) showed that the unprotected forests were somewhat more diverse than the protected forests at both sites irrespective of human population density; this is most likely due to tenure security in

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the former that includes forest on fallows and loose protection in the latter. There was also a marginally significant interaction between site and conservation status as measured by Fisher's index. The differences observed between the sites and forest types can also be explained by several factors. For instance, the spatial heterogeneity of the species due to the mosaic of soil and termite mounds that is common in the savanna-woodland (Scholes & Walker, 1993; Fontes & Guinko, 1995). Another influencing factor is the late fire that occurred in the study area (personal observation), and the effect of fire on tree species diversity in this ecosystem is well documented (Sawadogo *et al.*, 2002; Savadogo *et al.*, 2007a).

Several threatened species, based on the IUCN Red List (IUCN, 2004) and the National List, were found in the study sites that were characterized by a lower abundance irrespective of forest conservation status. For example, endangered species such as *A. africana*, and vulnerable species such as *S. latifolius* and *D. mespiliformis*, had a lower abundance in all areas. Even though no significant differences in species richness and human disturbances were found due to conservation status or site, the substantial population influx into Yale and the high conversion rate to croplands may still eventually lead to species losses. This situation clearly calls for systematic conservation strategies for the unprotected areas (Boffa *et al.*, 2008; Munishi *et al.*, 2008), given the similar tree species diversity in both protected and unprotected forests of this area and likely better tenure security.

5.3 Human population pressure and tree regeneration

Overall, 62 seedling species were recorded across the surveyed area. The number of seedling species seen in the protected forests (43) was lower than the numbers observed in the transition of North to South Sudanian Zone (Zida *et al.*, 2007) or in the Nazinon reserve (Alexandre, 1992; Ky-Dembele *et al.*, 2007). It was also found that most of the species had low frequencies of seedlings and generally low densities, consistent with results obtained in a study of the Nazinon forest (Ky-Dembele *et al.*, 2007). In addition, 13 species out of all those recorded at the plots have previously been identified as root suckers (Alexandre, 1992; Bationo *et al.*, 2005; Bellefontaine, 2005b; Ky-Dembele *et al.*, 2007), although they also regenerate by seeds.

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The favorable regeneration conditions (higher seedling density) observed in the unprotected forests are similar to those recorded by Mwima & McNeilage (2003). The protected and unprotected forests were highly similar in their seedling species composition and richness. This is due to a similar prevalence of common species from the four dominant families, which forms two thirds of the total seedling species recorded. Protected forests are generally assumed to be less affected by external disturbances, and hence favor natural regeneration processes. For example, species such as *B. africana*, *L. acida*, and *Anogeissus leiocarpus* (DC.) Guill. & Perr. had lower frequencies and seedling densities in the protected forests (and were sometimes completely absent) than in the unprotected forests. Contrary to our expectations, most of the species had a marginally lower seedling density in the protected forests probably due to the dominance of species with few individuals, which is a characteristic of African savanna-woodlands (Menaut *et al.*, 1995; Luoga *et al.*, 2004). In addition to species composition, several abiotic factors (e.g water, nutrients and space) also affect the regeneration of plant species in dry forest ecosystems (Scholes & Walker, 1993; Menaut *et al.*, 1995; García & Zamora, 2003; Ceccon *et al.*, 2006; Singh & Kushwaha, 2006). It is also important to note that changes in the management regimes of the protected forests at the sites, institutional weakness, and increases in anthropogenic disturbances (Ouedraogo, 2001; Ouedraogo, 2006) may affect seedling population density.

The seedling flora in the sampled plots was dominated by two species: *V. paradoxa*, one of the most socio-economically valued species (Lamien, 2006), and *D. microcarpum*, the most highly valued fuelwood species in the country (Sawadogo *et al.*, 2002). These are two of the common species that are subjected to over-exploitation for food and fuelwood by rural households. The natural regeneration of these species could be affected if households collect fruits or cut small trees excessively. Overall, the forest conservation status does not appear to favor seedling species richness or abundance contrary to the expectations. The high seedling species richness in the unprotected forest of Boala could be explained by the relatively low human population density (15 inhabitants/ km^2), and hence (presumably) moderate anthropogenic disturbance. In contrast, the low richness in the unprotected forest at Yale can be explained by the increased pressure associated with a comparatively high human population density (30 inhabitants /km^2). The spatial distributional pattern of the recorded species was clumped irrespective of forest type, except *P. africana* that showed

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random distribution. This may reflect the dominance of the clonal propagation mode common in most African savanna ecosystems (Bellefontaine, 1997; Hoffmann, 1998; Bellefontaine, 2005a; Bellefontaine, 2005b).

5.4 Local perception of vegetation decline and priorities for conservation

All 136 informants, along with each group of stakeholders, considered themselves to be dependent on tree-based resources. In total, 82 woody species in the study area provided the locals with timber and non-timber forest products. This number is lower than previously reported in the same ecological zone (Belem *et al.*, 2007) but slightly higher than previously observed in the western part of the country (74 species; Taïta, (2003)). These differences may be due to differences in sampling, ecological conditions, or relevant traditional knowledge of the local people. However, the importance of the forests to the people in the present study is in agreement with earlier studies on dry forest ecosystems (Lykke, 2000; Kristensen & Balslev, 2003; Taïta, 2003; Belem *et al.*, 2007).

Six categories of plant use were identified: fodder, construction, arts and crafts, fuelwood, medicinal, and food. Considering all use categories, species such as *V. paradoxa*, *P. biglobosa, D. microcarpum*, *T. indica*, *A. africana*, *E. camaldulensis*, and *P. erinaceus* appeared to be the most exploited, and therefore are the most useful to the local people. The number of species that had medicinal uses (75) was within the range found in earlier studies performed in tropical dry forests (Tapsoba & Deschamps, 2006; Okello & Ssegawa, 2007; Parveen *et al.*, 2007). This high number demonstrates the valuable role that tree species play in the health care of the local people, which is also seen in many other developing countries (Shrestha & Dhillion, 2003; Parveen *et al.*, 2007; Ssegawa & Kasenene, 2007). Species used for energy purposes also accounted for a high proportion (67%) of the total species mentioned. Species such as *V. paradoxa* and *P. biglobosa* were mainly used as important sources of food, which makes them the most valuable species in the country (Teklehaimanot, 2004; Nikiema, 2005; Lamien, 2006; Belem *et al.*, 2007). Furthermore, some species were exclusive to a given use category, such as *P. erinaceus*, *K. senegalensis* and *A. africana*, which were specifically used as fodder.

In addition to the natural factors that drive changes in land use, pressures on the various plant species are also influenced by socio-cultural factors, including gender, residence status, ethnic group, and extraction methods. For example, fodder species, such as *A. africana, P. erinaceus*, and *F. sycomorus*, were found to be exploited mainly by Fulani herders in fallows and protected forests; women appeared to have greater preferences for *B. costatum*, *C. limon* and *L. microcarpum* than men (20-37% vs. 14-16%), while men seemed to prefer *S. latifolius*, *P. erinaceus* and *B. africana* (12-16% vs. 2-5 %). There were also some differences between and among the migrant and native ethnic groups (Fulani, Gurunsi and Mossi), probably due to differences in intra- and inter-cultural dissemination of ethno-botanical knowledge (Cotton, 1997). The species that are exploited intensively are most likely to be threatened, as observed elsewhere (Begossi, 1996; Tabuti & Mugula, 2007).

The informants stated that natural and anthropogenic factors were the main responsible factors for changes in land use. They also stated that these factors result in declining vegetation cover, with associated decline in biological diversity and non-timber forest products. This is in accordance with earlier studies on African dry ecosystems (Lamb *et al.*, 2005; Wezel & Lykke, 2006; Tabuti & Mugula, 2007). These factors are increasing the vulnerability of most rural households, since their livelihood is strongly dependent on forest-based resources (Forester & Machlis, 1996; Ogle, 1996; McKee *et al.*, 2004; Neke *et al.*, 2006). The stakeholders' concerns regarding vegetation dynamics could best be addressed and their suggestions for improvements incorporated into forest management strategies, using an integrated approach. Such a cross-sectional policy between forest management and other sectors should focus on reducing deforestation, as well as providing the forests with better protection as well as securing the right of the local people to access the forest. It should also be able to reconcile conflicting interests and/or priorities amongst various stakeholders and social groups, which is not often considered in the forest management of Burkina Faso (Hagberg, 2000). In this context, issues such as local rights on forests, land tenure security, devolution of ownership and management, and securing the common need more consideration to allow sustainable use of the forests (Ribot, 2001; Delville *et al.*, 2002; Ouedraogo, 2002; Amanor, 2003; Anderson *et al.*, 2006).

6 Conclusions and recommendations

Recent land use changes in southern Burkina Faso and its consequences on surrounding dry forests were evaluated, together with local perception of forest decline. The major conclusions drawn from this thesis work are:

1. The land use dynamics analysis showed that in one and a half decade the land use change both at local and regional levels is moving toward increasing cropland at the expense of forest destruction, mainly due to population growth, immigration and change in agricultural production systems from subsistence farming to more complex production systems.

2. Given this overall picture of dry forest decline in the region, the designation of protected areas by itself appears ineffective in ensuring conservation of tree diversity in the Sudanian dry forest reserves. The unprotected forests that include fallows and parklands appear to be relatively diverse, most likely due to a better tenure security.

3. The regeneration of Sudanian dry forest in southern Burkina Faso is not favored by the conservation status of the forest (assumed to have fewer disturbances) and the human pressure. Apparently other factors, biotic or abiotic, seem to influence seedling recruitment and the spatial distribution of seedling populations. The notable finding is that a large number of species are represented by few individuals irrespective of the conservation status of the forests and the human pressure.

4. The local people depend on the forests to meet their subsistence, energy, income and medicinal needs, with distinct variability between gender, residence status, and ethnic group. The various stake-holders perceived that the region's forests are shrinking mainly due to agricultural expansion, population increases and climate variability as well as institutional and policy weaknesses.

In light of these findings, it is recommended that more attention must be oriented towards integrated resource management through education, local dialogue among stakeholders, controlled migration, reduction of anthropogenic disturbances and empowerment of local communities. To effectively protect the remaining dry forests, the forest management strategy should promote the idea of "conservation by utilization" where ownership and management right should be devolved to the local people and mechanisms for equitable distribution of benefits among all stake-holders established. Since a substantial number of species (28) found in both protected and unprotected forests are classified as endangered or vulnerable according to the IUCN Red List and the National List of biodiversity conservation, priority should be given to these species when designed restoration/conservation strategy. Conservation of tree diversity in the unprotected forest should also be given due attention, since these ecosystems contain as many species as the forest reserves in the one hand, and due to secured tenure system particularly in fallows and parklands, on the other. The natural regeneration of the Sudanian dry forest appears to be unsatisfactory, as evidence for large number of species with few seedlings and the overall low seedling density in this study sites compared to similar Sudanian dry forests. Therefore, measures, such as direct seeding, planting high quality seedlings and/or manipulation of the site, which expedite the natural regeneration processes inside and outside the forest reserve, should be taken.

Appendix 1. Species composition, life forms, density (number /ha) and frequency (number of plot in which a species occur) of seedlings at sites with low (Boala) and and high (Yale) human population pressure in southern Burkina Faso

A. Protected Forest

Family	Species	Code	Density		Frequency	
			Boala	Yale	Boala	Yale
Annonaceae	*Annona senegalensis* Pers.	anse		29		16
	Hexalobus monopetalus (A. Rich.) Engl. & Diels.	hemo	177		1	
Anacardiaceae	*Lannea acida* A. Rich.	laac		35		1
	Lannea velutina A. Rich.	lave	22	33	1	1
Caesalpiniaceae	*Burkea africana* Hook. f.	buaf	140		3	
	Cassia sieberiana DC.	casi		22		2
	Daniellia oliveri (Rolfe) Hutch.& Dalz.	daol	66	22	1	1
	Detarium microcarpum Guilt. & Perr.	demi	97	226	5	37
	Isoberlinia doka Craib & Stapf	iso	22	75	1	1
	Piliostigma thonningii (Schumach.) Milne-Redh.	pith	22	102	1	19
	Tamarindus indica L.	tain		59		1
Celastraceae	*Maytenus senegalensis* (Lam.) Exell	mase	22	22	1	2
Combretaceae	*Anogeissus leiocarpus* (DC.) Guill. & Perr.	anle		85		3
	Combretum glutinosum Perr. ex DC.	cogl	122	64	2	10
	Combretum molle R. Br. ex G. Don	como	44	50	1	4
	Combretum nigricans Lepr, ex Guilt. & Perr.	coni		71		3
	Pteleopsis suberosa Engl. & Diels	ptsu	323	62	8	13
	Terminalia avicennioides Guilt. & Perr.	teav	210	71	4	9
	Terminalia glaucescens Planch.	tegl		62		4
	Terminalia macroptera Guilt. & Perr.	tema	519	80	2	10
Fabaceae	*Lonchocarpus laxiflorus* Guilt. & Perr.	lola		22		1
	Pericopsis laxiflora (Benth.) van Meeuwen	pela		39		1
	Xeroderris stuhlmannii (Taub.) Mendonca & E.P. Sousa	xest		44		2
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. Rich.	dime		37		1
Euphoriaceae	*Bridelia ferruginea* Benth.	brfe		22		1
Loganiaceae	*Strychnos spinosa* Lam.	stsp	154	55	1	4
Meliaceae	*Pseudocedeala kotschyi* (Schweinf.) Harms	psko		59		3

Appendix 1*A* *Protected forest* (continued)

Family	Species	Code	Density		Frequency	
			Boala	Yale	Boala	Yale
Meliaceae	*Trichilia emetica* Vahl	trem	22		1	
Mimosaceae	*Acacia dudgeoni* Craib. ex Hall.	acdu	55	88		4
	Acacia macrostachya Reichenb. ex DC.	acma		177		3
	Dichrostachys cinerea (L.) Wight. & Arn.	dici		44		2
	Prosopis africana (Guilt. & Perr.) Taub.	praf	22	28	1	5
Moraceae	*Ficus sycomorus subsp. gnaphalocarpa* (Miq) CC. Berg	fisy	22		1	
Olacaceae	*Ximenia americana* L.	xiam	66	33	2	11
Rhamnaceae	*Ziziphus mucronata* Willd.	zimu		44		2
Rubiaceae	*Crossopteryx febrifuga* (Afzl. ex G. Don) Benth.	crfe	66	98	3	9
	Feretia apodanthera Del.	feap	287		1	
	Gardenia aqualla Stapf & Huch.	gaaq	154	22	1	1
	Gardenia erubescens Stapf & Hutch.	gaer	66	33	2	4
	Gardenia ternifolia Schumach. & Thonn.	gate		44		1
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn.	vipa	98	74	7	22
Sterculiaceae	*Sterculia setigera* Del.	stse		22		1
Tilaceae	*Grewia bicolor* Juss.	grbi		22		2

Appendix 1 *B*   *Unprotected Forest* (continued)

Family	Species	Code	Density		Frequency	
			Boala	Yale	Boala	Yale
Annonaceae	*Annona senegalensis* Pers.	anse	44	57	4	3
	Hexalobus monopetalus (A. Rich.) Engl. & Diels.	hemo	83		4	
Anacardiaceae	*Lannea acida* A. Rich.	laac	37		3	
	Lannea microcarpa Engl. &K. Krause	lami	44		1	
	Lannea velutina A. Rich.	lave	22		1	
	Ozoro insignis Del.	ozin	22		1	
Bignoniaceae	*Stereospermum kunthianum* Cham.	stku	33		2	
Bombaceae	*Bombax costatum* Pellegr. & Vuillet	boco	44		1	
Caesalpiniaceae	*Afzelia africana* Smith ex Pers.	afaf	22		1	
	Burkea africana Hook. f.	buaf	113		8	
	Cassia sieberiana DC.	casi	44		1	
	Daniellia oliveri (Rolfe) Hutch.& Dalz.	daol	94		11	
	Detarium microcarpum Guilt. & Perr.	demi	133	164	26	11

Appendix 1 *B* *Unprotected Forest* (continued*)*

Family	Species	Code	Density		Frequency	
			Boala	Yale	Boala	Yale
Caesalpiniaceae	*Isoberlinia doka* Craib & Stapf	isdo	55		3	
	Piliostigma thonningii (Schumach.) Milne-Redh.	pith	99	177	11	10
	Pterocarpus erinaceus Poir.	pter	265	22	1	1
Celastraceae	*Maytenus senegalensis* (Lam.) Exell	mase	58	27	5	3
Chrysobalanaceae	*Parinari curatelli folia* Planch. ex Benth.	pacu	232		2	
Combretaceae	*Anogeissus leiocarpus* (DC.) Guill. & Perr.	anle		162		1
	Combretum collinum Fresen.	coco	44		1	
	Combretum fragrans F. Hoffm.	cofr	96		3	
	Combretum glutinosum Perr. ex DC.	cogl	69	74	9	7
	Combretum molle R. Br. ex G. Don	como	472	100	3	1
	Combretum nigricans Lepr, ex Guilt. & Perr.	coni	131	71	13	4
	Pteleopsis suberosa Engl. & Diels	ptsu	546	80	18	5
	Terminalia avicennioides Guilt. & Perr.	teav	236	102	13	5
	Terminalia laxiflora Engl.	tela		354		1
	Terminalia macroptera Guilt. & Perr.	tema	447	22	9	1
Fabaceae	*Xeroderris stuhlmannii* (Taub.) Mendonca & E.P. Sousa	xest	77		2	
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. Rich.	dime	48	52	6	1
Euphoriaceae	*Bridelia ferruginea* Benth.	brfe	66		1	
Hymenocardiaceae	*Hymenocardia acida* Tul.	hyac	22		1	
Loganiaceae	*Strychnos spinosa* Lam.	stsp	150	44	14	1
	Strychnos innocua Del.	stin	44		2	
Meliaceae	*Azadirachta indica* A. Juss.	azin	66		2	
	Pseudocedeala kotschyi (Schweinf.) Harms	psko	656		3	
	Trichilia emetica Vahl	trem	66		1	

Appendix 1 *B*   *Unprotected Forest* (continued)

Family	Species	Code	Density Boala	Density Yale	Frequency Boala	Frequency Yale
Mimosaceae	*Acacia dudgeoni* Craib. ex Hall.	acdu	111		11	
	Acacia macrostachya Reichenb. ex DC.	acma	88		1	
	Acacia sieberiana DC.	acsi	177		1	
	Dichrostachys cinerea (L.) Wight. & Arn.	dici	348	22	4	3
	Parkia biglobosa (Jacq.) R. Br. ex G.Don	pabi	22		1	
	Prosopis africana (Guilt. & Perr.) Taub.	praf	22	44	1	1
Moraceae	*Ficus thonnigii* Blume	fith	105		4	
Olacaceae	*Ximenia americana* L.	xiam	33		5	
Polygalaceae	*Securidaca longepedunculata* Fres.	selo	575	22	1	1
Rhamnaceae	*Ziziphus mucronata* Willd	zimu		22		1
Rubiaceae	*Fadogia agrestis* Schweinf. Ex Hiem	faag		22		1
	Feretia apodanthera Del.	feap		44		1
	Crossopteyx febrifuga (Afzi. Ex G. Don) Benth.	crfe	234	88	7	2
	Gardenia erubescens Stapf & Hutch.	gaer	157	74	23	2
	Sacrcocephalus latifolius (Smith) Bruce	sala	22		1	
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn.	Vipa	93	92	19	9
Sterculiaceae	*Sterculia setigera* Del.	Stset	22		1	
Tilaceae	*Grewia bicolor* Juss.	Gebi	265		1	
	Grewia lasocdiscus K. Schum.	gela	22	44	1	1

Appendix 2. List of species mentioned by the informants and their uses E: Energy; F: food; C: wood carving; D: Fodder; M: traditional medicine; P: construction wood

Scientific name	Family	code	Uses types
Acacia dudgeoni Craib. Ex Hall.	Mimosaceae	acdu	M, C, D
Acacia macrostachya Reichenb. ex DC.	Mimosaceae	acma	F, M, D
Acacia pennata (Linn.) Willd.	Mimosaceae	acpe	M, D
Acacia seyal Del.	Mimosaceae	acse	E, M, D
Acacia sieberiana DC.	Mimosaceae	acsi	E, M, P, C, D
Adansonia digitata L.	Bombacaceae	addi	E, M, P, C, D
Afzelia africana Smith ex Pers.	Caesalpiniaceae	afaf	F, E, M, P, C, D
Albizia chevalieri Harms	Mimosaceae	alch	M, P, D
*Anogeissus leiocarpu*s (DC) Guill. & Perr.	Combretaceae	anle	E, M, P, C, D
Anacardium occidentale L.	Anacardiaceae	anoc	F, M, D
Annona senegalensis Pers.	Annonaceae	anse	F, E, M, P, C, D
Annona squamosa L.	Annonaceae	ansq	F
Azadirachta indica A. Juss.	Meliaceae	azin	F, E, M, P, C, D
Balanites aegyptiaca (L.) Del.	Balanitaceae	baae	F, E, M, P, C, D
Bombax costatum Pellegr. & Vuillet	Bombaceae	boco	F, E, M, P, C, D
Burkea africana Hook. f.	Combretaceae	buaf	E, M, P, C, D
Calotropis procera (Ait.)Ait. f.	Asclepiadaceae	capr	M
Cassia sieberiana DC.	Caesalpiniaceae	casie	E, M, P, D
Citrus limon (L.) Burm. f.	Rutaceae	cili	F, M
Combretum fragrans F. Hoffm.	Combretaceae	cofr	F, E, P, D
Combretum glutinosum Perr, ex DC.	Combretaceae	cogl	F, E, M, P, D
Combretum micranthum G. Don	Combretaceae	comi	F , M
Combretum molle R. Br. Ex G. Don	Combretaceae	como	E, M,C
Combretum nigricans Lepr. ex Guill. & Perr.	Combretaceae	coni	F, E, M, P, C,
Crossopteryx febrifuga (Afzl. ex G. Don) Benth.	Rubiaceae	crfe	F, E, M, P, C, D
Daniellia oliveri (Rolfe) Hutch. & Dalz.	Caesalpiniaceae	daol	F, E, M, P, C, D
Detarium microcarpum Guilt. & Perr.	Combretaceae	demi	F, E, M, P, C, D
Diospyros mespiliformis Hochst. ex A. Rich.	Ebenaceae	dime	F, E, M, P, C, D
Eucalyptus camadulensis Dehn	Myrtaceae	ecca	F, E, M, P, C, D
Entada africana Guilt. & Perr.	Caesalpiniaceae	etaf	F, E, M, P, C, D
Fadogia agrestis (Schweinf. Ex Hiern)	Rubiaceae	faag	E, M, P, D
Feretia apodanthera Del.	Rubiaceae	feap	M, P, D
Ficus glumosa Del.	Moraceae	figl	F, E, M, D

Appendix 2. (continued)

Scientific name	Family	code	Uses types
Ficus thonnigii Blume	Moraceae	fith	F, M, P, C, D
Ficus platyphylla Del.	Moraceae	fipl	F, M, D
Ficus sur Forssk.	Moraceae	fisu	M
Ficus sycomorus subsp. gnaphalocarpa (Miq) CC. Berg	Moraceae	fisy	F, E, M, P, C, D
Gardenia erubescens Stapf & Hutch.	Rubiaceae	gaer	F, E, M, P, D
Gardenia ternifolia Schumach. & Thonn.	Rubiaceae	gate	F, P, C
Gmelina arborea Roxb	Verbenaceae	gmar	M, D
Grewia bicolor Juss.	Tilaceae	grbi	D
Guiera senegalensis J.F. Gmel.	Combretaceae	guse	F, E, M, P, C
Hannoa undulata (Guill. & Perr.) Planch	Simaroubaceae	haun	C
Hexalobus monopetalus Engl. Et Diels.	Annonaceae	hemo	E, M, P
Hymenocardia acida Tul.	Hymenocardiaceae	hyac	F, E, M, P
Isoberlinia doka Craib & Stapf	Caesalpiniaceae	isdo	F, E, M, P, C, D
Jatropha curcas L.	Euphorbiaceae	jacu	F, P
Jatropha gossypifolia L.	Euphorbiaceae	jago	F, E, M, P
Khaya senegalensis (Desr.) A. Juss	Meliaceae	khse	F, E, M, P, C, D
Lannea acida (A. Rich.) Oliv.	Anacardiaceae	laac	F, E, M, P, C, D
Lannea microcarpa Engl. & K. Krause	Anacardiaceae	lami	F, E, M, P, C, D
Lannea velutina A. Rich.	Anacardiaceae	lave	F, E, M, D
Lonchocarpus laxiflorus Guilt. & Perr.	Fabaceae	lola	M, P, D
Mangifera indica L.	Anacardiaceae	main	F, E, M, P, D
Maytenus senegalensis (Lam.) Exell	Celastraceae	mase	F, E, M, D
Mitragyna inermis (Willd.) O. Ktze.	Combretaceae	miin	F, E, M, P, C, D
Ozoroa insignis Del.	Anacardiaceae	ozin	F, M, P, C, D
Parkia biglobosa (Jacq.) R. Br. Ex G. Don	Mimosaceae	pabi	F, E, M, P, C, D
Parinari curateli folia Planch. Ex Benth	Chrysobalanaceae	pacu	F, E, M, P, C, D
Pericopsis laxiflora (Benth.) van Meeuwen	Fabaceae	pela	F, E, M, P, C, D
Psidium guajava Linn.	Myrtaceae	psgu	F, M, D
Piliostigma reticulatum (DC.) Hochst.	Caesalpiniaceae	pire	F, E, M, P, C, D
Piliostigma thonningii (Schumach.) Milne-Redh.	Caesalpiniaceae	pith	F, E, M, P, C, D
Prosopis africana (Guilt. & Perr.) Taub.	Mimosaceae	praf	F, E, M, P, C, D
Pterocarpus erinaceus Poir.	Caesalpiniaceae	pter	F, E, M, P, C, D
Pteleopsis suberosa EngI. & Diels	Combretaceae	ptsu	F, E, M, P, C, D
Sarcocephalus latifolius (Smith) Bruce	Rubiaceae	sala	F, E, M, P, C, D
Saba senegalensis (A. DC.) Pichon.	Apocynaceae	sase	F, E, M, P, C, D
Sclerocarya birrea (A.Rich.) Hochst.	Anacardiaceae	scbi	F, D
Securidaca longepedunculata Fres.	Polygalaceae	selo	F, E, M, P, C, D
Securinega virosa (Roxb.) Baill.	Euphorbiaceae	sevi	M, P, C, D
Sterculia setigera Del.	Sterculiaceae	stse	F, M, C, D
Strychnos spinosa Lam.	Loganiaceae	stsp	F, E, M, P, D
Tamarindus indica L.	Caesalpiniaceae	tain	F, E, M, P, C, D
Terminalia avicennioides Guilt. & Perr.	Combretaceae	teav	F, E, M, P, C, D
Terminalia laxiflora Engl.	Combretaceae	tela	F,M, D

Appendix 2. (continued)

Scientific name	Family	code	Uses types
Terminalia macroptera Guilt. & Pen.	Combretaceae	tema	F, E, M, P, C
*Trichilia emetica*Vahl	Meliaceae	trem	M
Vitex doniana Sweet.	Verbenaceae	vido	F, E, M, P, C, D
Vitellaria paradoxa Gaertn. f.	Sapotaceae	vipa	F, E, M, P, C, D
Ximenia americana L.	Olacaceae	xiam	F, E, M, P, C, D
Ziziphus mauritiana Lam.	Rhamnaceae	zima	F, M, D

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Résumé en Français (French Summary)

Durant la dernière décennie les formations forestières des régions tropicales et boisées marquée par un taux particulièrement élevé de conversion en zone agricoles et en pâturage, à quelques exceptions près. Les études réalisées dans la présente thèse visent à soutenir la prise de décision en matière de gestion. La démarche adoptée, qui combine approche spatiale, données de terrain et méthode participative, à consister à appréhender la dynamique complexe de l'occupation des terres, à travers l'analyse des facteurs socio-économiques et biophysiques dans région de la Sissili, au sud de Burkina Faso. Les résultats montrent qu'un un changement rapide s'est opéré dans l'occupation des terres sur une période de 16 ans. L'immigration rurale et l'évolution des systèmes de productions agricoles, et les extractions forestières, sont les principaux moteurs de cette dynamique dans la zone. Une étude de la flore ligneuse en relation avec la protection et la pression humaine a été réalisée. Au total de 69 espèces ligneuses, comprenant 52 genres et 26 familles ont été identifiées, la flore des formations naturelles non-protégées était plus riches avec 58 espèces contre 45 à l'intérieur des forêts protégées. Sur les deux sites d'étude choisis, le site ayant une forte population humaine avait une densité d'arbre et une surface terrière plus importantes que le site moins peuplé. Au niveau de la diversité floristique, l'indice de diversité de Shannon et celui de Fisher étaient plus élevés dans le site à faible densité humaine et dans les formations forestières non-protégées. Le résultat de l'étude de la régénération n'a révélé aucune différence significative entre les formations protégées et non-protégés pour la densité des rejets, bien que la densité moyenne était légèrement plus élevée dans les formations non-protégées du site à densités humaines contrastées. La distribution spatiale des rejets montrait une distribution groupée pour la quasi-totalité des espèces

indiquant une prévalence de la multiplication végétative dans les sites. L'étude ethnobotanique sur les utilisations des espèces ligneuse et la perception des populations locales a confirmé leur vision d'une tendance générale de la dégradation des forêts; elle a aussi révélé la forte dépendance des communautés locales des forêts. Celles-ci les considèrent comme leur grenier, leur pharmacie, leur pâturage et source de bois d'énergie et de construction. Approximativement 82 espèces de plante ligneuses sont exploitées pour d'usages multiples par les populations locales, illustrant de ce fait, le rôle important des forêts dans la réduction de la pauvreté, comme source de revenu et de survie, surtout pendant les périodes de pénuries alimentaires.

Mots clé : Occupation du sol, Migration, Biodiversité, Forêts protégées, Régéneration, Densité humaine, Connaissance locale, Utilisation duable