LOCAL KNOWLEDGE OF NATURAL REGENERATION AND TREE MANAGEMENT IN SAHELIAN PARKLANDS NORTH OF TOMINIAN, MALI

Project submitted in partial fulfilment of the requirements for the degree of *Master of Science* (Masters) in Agroforestry
Bangor University

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ABSTRACT

This research was conducted between June and August 2010 in 4 village communities in the north of the district of Tominian, Mali. Using a system-based approach and collecting data mainly through semi-structured interviews in the fields I explored local knowledge about natural regeneration and the management of woody vegetation in parkland systems. The aim was to identify and analyse some of the constraints and opportunities farmers may have in adopting agroforestry innovations such as farmer managed natural regeneration or other practices to increase trees in the agricultural landscape.

The research suggests that farmers have an extensive knowledge of natural regeneration processes and the complex interactions between human and ecological factors affecting different tree resources. Knowledge of indigenous tree management on the other hand is practically non-existent mainly due to the restrictive forest legislation and a past of resource abundance. Although numerous trees and their final products are central to local livelihoods and their decline of particular concern to all villagers, in cultivated fields, trees generally represent a nuisance because they complicate animal traction, compete with crops and attract birds, bees, snakes and harvesters. The lack of tradition in managing indigenous trees, the slow growth and vulnerability of indigenous fruit tree seedlings remains a major factor discouraging farmers from fencing and protecting them.

Faidherbia albida is the only commonly regenerating species which farmers have started protecting for its role in soil fertility and fodder value and reveals the increasing role played by livestock in the local livelihood. Gaining a better understanding of the local potential of tree fodder is a topic which deserves particular attention as there is a clear need for improved feed resources and feed management strategies. A major topic of concern villagers expressed was the impact of deforestation on the degradation of the “bas-fonds” (lowland riparian zones). Sedimentation, flooding of fields, lower and shorter water retention of temporary watercourses and loss of key biodiversity are having severe repercussions on local livelihoods and implications throughout the landscape scale which suggest intervention and further research is needed to explore re-foresting opportunities for the rehabilitation of these zones.

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LIST OF ABBREVIATIONS

APU: Agricultural Production Unit

AKT: Agro ecological Knowledge Toolkit

CMDT: Compagnie Malienne pour le Développement du Textile

FMNR : Farmer Managed Natural Regeneration

FL: Farmer leader

FVE: Forest Village Enterprise

KB: Knowledge base

ICRAF World Agroforestry Centre

NTFP: Non Timber Forest products

NGO: Non-governmental Organisation

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1. LITERATURE REVIEW

1.1. Background to Agroforestry Parklands

Agroforestry parklands are the most common land use systems in semi-arid zones of West African Sahel where the majority of a predominantly rural population are subsistence farmers. Parklands are often associated with 'savannah' vegetation type ecosystem but are generally defined as anthropogenic landscapes in which scattered multipurpose trees occur in fields or fallow as a result of farmer selection and protection (Boffa, 1999). Parkland indigenous trees play a fundamental role in rural livelihoods by securing a variety of staple products such as food, medicine, fodder for livestock, fuel wood and many other essential non-wood products contributing to rural income and food security. They also play essential ecological functions such as improving soil fertility, combating erosion, providing shade and at the heart of social and cultural values (Kalinganire et al. 2007). Many products derived from indigenous parkland trees such as *Vitellaria paradoxa*, *Parkia biglobosa*, *Adansonia digitata* and *Sclerocarya birrea*, provide the most frequently consumed staple food, fruits and drinks (Gustad et al, 2004).

In Mali, parkland systems cover some 90% of agricultural land but the integration of trees-crops-livestock is subject to different spatial and temporal dynamics where trees can occupy very different productive niches on the farmland (Kalinganire et al., 2007). Agricultural productivity centred on subsistence cereal crops such as millet and sorghum and livestock production remains very low (*ibid*). The majority of farmers live below the poverty line and face the challenge of sustaining their existence from scarce resources and marginal land under unfavourable and unpredictable semi-arid climatic conditions (Boffa, 1999).

In the last 50 years, parkland systems have been subject to profound climatic and human-driven shocks which have resulted in widespread deforestation, severe land degradation and desertification further marginalising farming communities into chronic food insecurity and poverty (Kandji et al. 2006). The causes of decline in parklands are numerous and often interconnected but can be broadly explained by detrimental climatic conditions (history of severe drought, a general unpredictability and scarcity of rainfall) combined with unsustainable exploitation of limited and fragile natural resources by a fast growing

population trying to meet its basic needs for food, fuel and water (Boffa, 1999). Conventional agricultural policy and intervention favouring mono-cropping, mechanisation and traction as well poorly integrated and conflicting as land use activities (agricultural land encroachment on pastures, pastoralism with change in migratory routes, incidence of bush fires) also had large impacts on the degradation of woody resources (Yossi and Kouyate, 2001).

Furthermore, the political and institutional context in most West African notably the restrictive state forest legislation inherited from colonial past has severely limited the integration of trees in smallholder systems (Toure and Kanouté 2006). In Mali, state ownership of trees and their protected status, strictly regulated by a permit and fine system and appropriation of long term fallow has significantly affected tree management practices (Yatich et al. 2008). Today, although a decentralisation is a process underway to recognise local conventions for the management of natural resources, the status of trees in cultivated land still remains ambiguous (*ibid*).

Agroforestry parklands are mostly based on the dominance of one or a few multiple purpose tree species, and the most commonly found species are *Vitellaria paradoxa, Parkia biglobosa* or *Faidherbia albida* which is used for soil fertility management and for fodder (Boffa, 1999). However they are often be associated with a diversity of other tree and shrubs such as including exotic species ((Larwanou and Saadou, 2005). Despite the lack of accurate quantitative and qualitative data to analyse the trends and evolution of parklands, there is evidence that many parkland systems have been degraded in terms of tree density with an ageing of the population, lack of regeneration and a loss of genetic diversity occurring in many parts of the Sahel (Teklehaimanot, 2004; Wezel and Lykke, 2006).

1.2 Parklands and climate change

The Sahel is a vulnerable zone of the dryland which raises particular concern as regards climate change. Although there are many uncertainties associated with models and predictions for climate change, the Sahel is known to be drought prone and predictions lead to believe that this trend is likely to worsen (Mortimore, 2009; (Kandji et al, 2006).

Recent studies (Gonzalez, 2001; Maranz, 2009) suggest that, although human factors (deforestation, overgrazing, shortening fallow period) may be substantially contributing to the decline of parklands, distinct change in climate towards expanding aridity is undermining the recruitment of young trees and giving way to the adaptation of a new vegetation cover especially in the northern range of parkland species.

As aridity and the variability of rain increases, agricultural production potential declines and diversification of rural livelihood becomes an imperative for many small holders of rain-fed agricultural zones (Mortimore et al., 2009) . This can lead to migration, off-farm employment and to an increasing reliance on livestock Parkland agroforestry systems are characterised by their inherent diversity, complexity and dynamism at both the micro-scale and broader regional scale. Farming practices do not obey conventional agronomic or orchard management research and it is also often difficult to assess the contribution of trees to the profitability of the system (Boffa, 2000).

The role of improved livestock-crop-trees systems is being increasingly recognised as fundamental to address the need for diversification in dryland (Mortimore et al, 2009). Evidence from Niger has shown that with the adaptive ecosystem management by smallholders, high population density and increase in livestock could be compatible with the rehabilitation of land through an increase in trees (Mortimore and Turner, 2005).

1.3 Agroforestry innovations in the Sahel

Although in the general decline of trees and vegetation cover and accelerated soil erosion is expanding in drought prone Sahelian parkland systems, over the last decades, there has been a variety of successful ‘re-greening the Sahel’ grassroots projects in different West African countries where in some areas tree cover has been considerably increased (Botoni and Reij, 2009). Along with soil and water conservation methods, farmers have adopted simple field management techniques to improve natural regeneration of tree species on agricultural land. Farmers are encouraged to identify, stimulate and protect naturally regenerating trees and shrubs in fields and fallows (Lykke et al., 2004b).

This technique, known as Farmer Managed Natural Regeneration (FMNR), is low cost, does not require any particular input and often based on the exploitation of shoots and

stems sprouting from living tree roots and stumps of felled trees (Cunningham and Abase, 2005) Although a corresponding clement period in rainfall may have influenced the success, evidence from research in areas of Niger, Burkina Faso and northern Mali suggest that after a period of two decade of FMNR practices, changes in the micro-environment where noticeable with rehabilitated land, increased crop productivity and significant improvements in local people's livelihoods (Reij et al., 2009). FMNR is emerging as a leading paradigm in agroforestry interventions in the Sahel; by making use of the opportunities occurring within fields, faster tree recovery can be achieved at minimum external cost (*ibid*).

Increasing trees and enhancing their delivery of ecosystem services in agroforestry parkland systems to combat desertification and poverty is being increasingly advocated through rural development interventions, with a growing co-operation between international organisations, research institutions, governmental bodies and NGO's programs (Lykke et al., 2004b).

Although parkland indigenous trees have received increasing attention recently, they still remain highly understudied to this date. Known as the 'Cinderella species,' many of the central species to parkland systems are indigenous fruit tree species which remain undomesticated or semi-domesticated and which have, until recently, been largely ignored by research and development (Leakey and Newton, 1993). Many aspects of their management and reproduction including genetic diversity are still unknown (Teklaimananot, 2004).

1.4 Local knowledge and participatory research

In rain-fed agriculture systems, the biophysical interactions between trees and crops strongly influences tree management practices and their structural and spatial assemblage (Boffa, 1999). Farmers manage the different trade-offs and synergies between the different components of the agroforestry system and if the benefits of trees to the overall agriculture system is the main driving force to the maintenance and reproduction of parkland, economic incentives largely influence the choices and the changes farmers make about which resources they will invest on (*ibid*).

Integrating local knowledge about natural resource management in both agroforestry research and development is increasingly seen as essential in forging solutions appropriate to local conditions and optimising the integration of trees in the agricultural landscape based on resource users' priorities (Mortimore 2009).

Local knowledge in agroforestry research is defined as the general explanatory ecological knowledge encompassing all the practical skills, know-how and wisdom developed through the understanding of observations, experience and experimentation held by a person or a community in a particular environment (Walker and Sinclair, 1998). Farmers and rural people who secure their livelihoods directly from the use of land or natural resources have a very intimate knowledge of their environment. Through daily observations, experimentation, experience and perceptions they build an understanding of ecological processes and change (Brook & McLachlan 2008).

The important contribution local knowledge can make to scientific knowledge has been increasingly recognised as useful in providing a deeper insight into the interdisciplinary and site-specific characteristics of land use and natural resource management and the understanding of the interaction between agroecological systems and humans (Warburton & Martin 1999). Local knowledge can provide valuable information that can feed back synergistically to channel the direction of conventional science to meet the needs of local people (Sinclair and Joshi, 2001). In many circumstances, interventions that build on local practice to improve land management practices management will be more readily accepted by farmers than new technology (*ibid*).

Eliciting the different perceptions and knowledge farmers may have about tree management is a key component of participatory research aiming to identify local people's priorities for managing trees and their natural regeneration and understand how these may differ or concur with agroforestry intervention objectives.

2. RATIONALE AND OBJECTIVES OF THE RESEARCH

2.1 Organisational setting

This research project was conducted with the support of the World Agroforestry Centre (ICRAF) in the framework of the 'Re-greening the Sahel Initiative' program initiated in 2009 by Sahel Eco, a Malian NGO, with the inter-village Farmers' Cooperative Farakunna in the district of Tominian in the region of Ségou, Mali.

The objective of the 'Re-greening the Sahel Initiative' in Mali is to increase the number of trees in the agricultural landscape to mitigate the impact of desertification, land degradation and depletion of natural resources on the livelihoods of rural and urban communities The program recently initiated in Tominian aims to scale up from long-running and successful FMNR experiences in Bankass in the region of Mopti (Sahel Eco undated). It focuses mainly on the provision of training through farmer leaders and agroforestry promotion groups, and on capacity building of local institutions to improve the management of natural resources through good agroforestry practices such as FMNR.

2.2 Rationale

The success of extension programs promoting agroforestry techniques to enhance natural regeneration of trees and increase their numbers in agricultural land is highly dependent on local farmers' perceptions of trees and the trade-offs which may exist when integrating new tree-systems or new approaches to management in existing land use systems (Lykke et al, 2004). The adoption of FMNR in the intervention area will be heavily influenced by the availability of reproductive and vegetative regeneration in the field, by local knowledge informing natural resource management and the perceptions of opportunities and constraints that different farmers associate with trees and natural regeneration. The aim of this research was to explore local knowledge about natural regeneration and management of woody vegetation in parkland systems by conducting interviews within different village communities in the north of Tominian in Mali.

2.3 Research objectives

The main objectives of the research were:

- Collect and collate local knowledge held by farmers on the ecological and anthropogenic factors influencing natural regeneration and tree resources and about the management of tree features in the agricultural landscape
- Gather qualitative information from the farming community on the perceptions of trees in the livelihood and land-use systems to analyse the opportunities and constraints associated with increasing tree cover through management of natural regeneration or other re-foresting activities

2.4 Broad research questions:

- What are the local perceptions about change in woody vegetation and natural regeneration in the agricultural landscape? What are the drivers of change and their impact?
- What are the different perceptions of trees utilities in the livelihood and land use systems? How are they spatially characterised?
- What is regenerating in farmers' field? What influences the management?
- What are where do farmers see the opportunities to increase trees?
- What are the main constraints to increasing trees in fields?

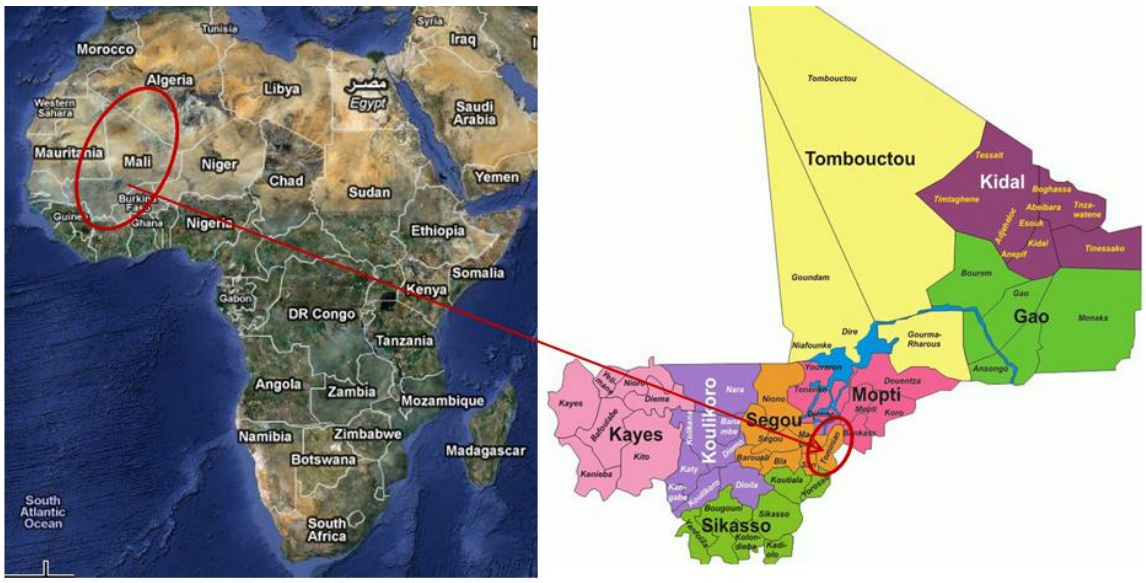
3. RESEARCH AREA

Although there are numerous NGO reports, previous scientific research on the area is very limited. Because of the little availability of written material on the research area and the importance of providing an overview of the social and environmental background to a qualitative research on local knowledge and perceptions, I decided to provide a more detailed description of the area compiled from documents collected, information given in interviews and my own personal observations.

3.1 Location of the research area

The research was conducted in the district of Tominian, located in the northern extremity of the Ségou region in central Mali, bordering Burkina Faso. The district of Tominian with a population of 175 146 inhabitants in 2001 covers an area of 6513 Km2 and population density is estimated at around 27 inhabitants/ Km2 (Sahel Eco, 2007).

Figure 1 Visualisation of the research area Tominian, Central Mali in West Africa



The research focused on 4 villages (Bambara, Siradié, Pakan Bobo and Tieblenikuy) in the districts of Koula and Lanfiela located in the northern part of the district of Tominian on the northern latitude of 13.5°. The villages are bordering a natural forest area of 6000 ha

called Duwa and is home to diverse ethnic groups Bwa, Dogon, Dafing and sedentary Fulani though the Bwa dominate in that part of Mali, known as the 'Bwa-tun' or the 'Pays-Bwa'.

3.2 Human context

Table 3.1 presents some updated demographic information about the area compiled from participatory surveys conducted in 2009 by Sahel Eco (unpublished data). It is unofficial data but indicative of the poverty and food security issues.

Table 1 Demographic information about the research area in 2009

Village	Population	APU	better off	poorer
Bambara	507	29	12	17
Tieblenikuy	408	61	30	31
Pakan Bobo	538	33	17	16
Siradie	712	58	23	35
Total	2165	181	82	99

Criteria used to determine indicative resource level: (Sahel Eco, 2005)

Better off ("nantis") Cattle for traction (between 6-20 head), Agricultural equipment , self sufficiency in food, between 10-45 small ruminants, labour availability (+ 5 persons working)

Poorer ("démunis"): self sufficient in food for 6-9 months , horse/donkey plough or hand cultivation, livestock (0-5 head) less than 2 persons working

In common with large parts of West Africa, social and land organisation is based on a the concept of the extended family where nuclear family groups share the same compound, work the same fields and eat from the same pot. This is referred to as the Agricultural Production Unit (APU). The rupture of traditional large family compounds is the contemporary reality in the research area, agricultural production units are increasingly household units, altering the size of fields and shaping the labour dynamics of families. Although there are no demographic data for precise analysis, villagers in Bambara for example explained that there are now 29 APU compared to 11 in the early 1990s.

Newcomers and population growth may have affected this trend but villagers explain it is largely the result of increased division within APU. A system of casts is still operating with different groups having specific social functions. In the villagers studied both "griots" and "forgerons" casts were present.

The main religion is Christian, followed by Animism and Islam though animist beliefs still dominate area (Coulibaly, 2003). Deprived of road access, the villages are very isolated. The main forms of transport mainly developed since the 1960s are horse/donkey carts and bicycles and on a small, but increasing scale, motorbikes. There is no electricity and television. Increasing migration, extension work and the co-existence of multiple ethnic groups contribute to the dynamism of knowledge, skills and ideas. Despite recent alphabetisation programs, and the increasing enrolment of children in school, illiteracy levels are still very high especially for women.

3.3 Climatic and topographic features

The district of Tominian is typical of semi-arid climatic conditions of the sudano-sahelian zone, characterised by one rainy season lasting from 3 months, and a long dry season which included a cold and a hot period where temperatures frequently average 40º C. Annual rainfall in the district is estimated between 400 and 800 mm but there are strong variations along the northern gradient and inter-annual variations (SOS Sahel GB, 2004). The research area is located in the northern part of the district and although there is a lack of precise data, rainfall is thought to be averaging between 400 and 500ml/year (Coulibaly, 2003), (Sahel Eco, 2006). A local seasonal and agricultural calendar is presented in Appendix I. During interviews villagers talked frequently about rain starting later and ending earlier and the decrease in rainfall in general. In addition important local variations were also observed. This year, a village north east of the Duwa forest had started cultivation nearly one month after villages south of the Duwa forest (18 km distance), due to insufficient rain.

The topography of the area consists of plains that are broken by rocky and lateric elevations extending from the Bandiagara cliffs. Soils are mainly ferruginous loamy-sand, though gravel and clay soils are also important in certain villages. In general soils are heavily vulnerable to erosion from heavy rains and Harmattan wind (Sahel Eco, 2007) and abandoned crusted land is commonly seen. Zai cultivation practices and other soil and

water conservation methods are widely used in the area though labour or status ('richer farmers plough') can be limiting factors. There are no permanent watercourses in the area but a temporary watercourse (marigot) runs through villages south-east of the Duwa forest. Temporary streams run through the area in the rainy season and supply occasional ponds.

Plate 1 Overview of the parkland from the cliffs of Siradié . Photograph taken on the 25/08/2010

3.4 Characterisation of land use and livelihood system

There is no concept of 'farm' in the area but rather a concept of 'fields'. These vary greatly in size and given the trends in divisions of compounds it is difficult to gain an understanding of average size. In a farmer group meeting it was estimated that for a small APU of one or two nuclear family 3 ha was the minimum for subsistence. Farmers interviewed all had very dispersed fields, with a distance separating them sometimes exceeding 3 or 4 kilometres.

The agricultural zone is organised circularly around the village or hamlet and typically comprises:

- The settlement where poultry and pigs are reared and other animals kept during the cultivation period. Small fenced gardens for maize, combo production can also be found. The settlement area is the only zone where trees are planted (*A. digitata* and exotic species)

- Village fields ("fiyo" in bomu) usually owned by the lineage headman family in the vicinity of the settlement, almost exclusively cultivated by UPA of the headman lineage. These are the oldest fields, permanently cultivated for millet/sorghum, hosting the least abundance of trees and dominated by *Faidherbia albida*. These fields benefit from manure deposit from roaming livestock spending the night close to the settlement.

- Bush fields ("muwan" in bomu) where rotational cropping of subsistence crops sorghum, millet (intercropped with leguminous niebe (*Vigna unguiculata)*), fonio (*Digitaria exilis)* and da (*Hibiscus sabdariffa*). Cash crops such as ground-nut, *Vigna subterranean* and sesame are also cultivated in bush fields and *Vigna unguiculata* can be cultivated on its won for fodder.

- The bush ("ouwin" in bomu) which usually refers to fallow (short fallows), pasture areas and hills ("boo"). It represents the wider environment but excludes cultivated land. It is dominated by shrubby savannah type vegetation but hosts a wide variety of multipurpose trees.

- Riparian galleries fields (bas-fonds) where soil fertility is higher and land better irrigated are increasingly cultivated. Fenced gardens for off-season vegetable is present on a small scale.

- The Duwa forest on a rocky elevation is a source of pasture, fuel-wood, timber, game and NTFP also used in the rainy season by transhumant herders.

Hunting and subsistence agriculture based on rain-fed crops traditionally dominated land use systems. However livestock is increasingly becoming central to livelihood, both as a form of investment, to minimise risk from crop failure and to meet an increasing need for manure in fields (Coulibaly, 2003). NTFPs occupy an important place in the rural livelihood, mainly harvested and traded by women. Income diversification search is also an important trend and is dominated by increasing migration especially in young men and women which is more and more permanent. A diagrammatic representation of livelihoods and land use system for both a large and small Bwa APU are included in Appendix II-a and II-b respectively.

3.5 Customary access to land and trees

3.5.1 Land ownership

Traditionally, land is not individually owned because it is considered a legacy from ancestors and its function is to ensure the subsistence, sovereignty and cohesion of the social group (Coulibaly, 2003). Customary land rights are usually secured through first occupancy of the village and the older men of the lineage is the customary headman. Land acquired by inheritance through patriarchal lineage, can be donated or lent. There is no monetisation of land and all agreements are made orally. There seems to be various 'degrees' (ways) of lending and associated security which are difficult to elicit but indicate that, with an increase in the duration of cultivation of a field, land security increases (though not in all instances). The Bwa tradition is known for its open and free access to land. The customs of the Bwa of granting a field to a newcomer ("bienvenu") to feed his family although still prevailing is becoming threatened in the area due to the decreasing availability of land. Women do not have land rights or inheritance right but they can be allocated a field for her needs. Administrative claims to land are emerging though it is not well considered within village communities.

3.5.2 Parkland trees and customary rules

The parkland surrounding the Duwa forest is composed of a large diversity of indigenous mature trees dominated by *Vitellaria paradoxa, Parkia biglobosa, Tamarindus indica, Sclerocarya birrea, Lannea microcarpa* which are protected by customary by-laws since people in the village could remember. It also has 8 of the protected species by the Malian Forestry Code and 15 species have been recently included in the local convention. (See Appendix III for the lists of trees protected by different institutions) Trees are spatially differentiated by topographic and edaphic features occurring in the landscape and affected by the duration and intensity of cultivation. There are sacred wood present in the area and ancestral sacred trees such as *Terminalia macroptera, Ceiba pentandra, Adansonia digitata* present around the villages.

The customary headman rules the opening of the harvest for certain key fruits such as *Parkia biglobosa* and *Tamarindus indica* which are picked directly from the tree as well as the harvest of *Adansonia digitata* leaves for drying purposes/commercialisation purposes. This is a form of protecting the communal interest by discouraging immature fruit picking and ensuring the supply of vegetable leaves in the hunger period. *Vitellaria paradoxa* and *Sclerocarya birrea* are collected under trees and picking from the tree is not allowed. *Adansonia digitata* is increasingly a privately owned tree. The access right to trees varies in different village for different species especially economically important species. In Bambara and Siradié, morning picking of *V. paradoxa* under trees is reserved to the women of the APU owning/cultivating the field but the rest of the day is opened to all. *Parkia biglobosa* and *Tamarindus indica* can only be picked by women of the APU owning/cultivating the field. In Pakan Bobo access is still free in all fields and for all fruits. All other NTFP harvest and fuel-wood collection are open without field ownership restrictions.

3.6 The influence of extension in the area

Extension work in this area has long standing roots; from CMDT which introduced plough in the 60s to soil and water conservation programs and support for decentralisation and natural resources management conducted by SOS Sahel GB since 1998 and transferred to Sahel Eco a local NGO in 2004. The main focus is on capacity building to aid the transfer of management to local authorities through the creation of an inter-village cooperative (Farakunna) with legal and institutional support, provision of training, information and material to promote the adoption of good forest and agroforestry management practices. The villages belong to the 6 Forest Village Enterprises initiated in program to increase the production, transformation and commercialisation of NTFP such as shea butter, honey and tamarind initiated in funded by TreeAid Through village enterprise groups, agroforestry promotion groups have been established since 2009 as part of the Re-greening the Sahel Initiative (Sahel Eco 2006).

4. METHODS

The focus of the research was the exploration of farmers' ecological knowledge about trees in agroforestry systems, their natural regeneration and management practices. It is qualitative and purposive in nature. The main approach used for knowledge acquisition, formal representation and analysis is derived from the Agroecological Knowledge Tookit (AKT), a method grounded in knowledge-based systems developed by Bangor University[1] and used in combination with other participatory social research techniques.

4.1 AKT – a systematic methodology for knowledge acquisition

4.1.1 Introductory note on AKT

AKT is based on the assumption that knowledge of agro-ecological processes can be isolated from supra-natural explanations of phenomena and expressed using explicit statements and a simple definite clause grammar. It offers a systematic approach and a computer software designed to create formalised but flexible knowledge bases from multiple sources on specific agro-ecological topics (Dixon et al, 2001).

It provides a comprehensible environment and standardised structure to synthesise and thematically organise knowledge collated from different sources (e.g. the representation of qualitative knowledge held by farmers or scientific knowledge) and in different forms (e.g. interviews, written documents or illustrations). This in turn enables the comparison and analysis of different knowledge across disciplines which can be useful in broadening the understanding of complex agro-ecosystems (Walker and Sinclair, 1998).

Knowledge acquisition according to the methodology laid out by the AKT manual (Dixon et al, 2001) can be divided into four main stages: 1. Scoping, 2. Definition, 3. Compilation and 4. Generalisation[2] described in the following sections. It must be noted that given the short duration of the study there is some overlap between the stages.

[1] Information on AKT methodologies and its applications can be viewed on Bangor University Website http://akt.bangor.ac.uk/

[2] The generalisation stage which involves testing the representativeness of the knowledge through a questionnaire based survey does not apply to the short duration of the Master dissertation.

4.1.2 Scoping

The scoping stage is the introductory phase of the field work used to refine the knowledge acquisition strategy by getting acquainted with the research area, local people and the various stakeholders. Purposive snowballing meetings and discussions with knowledgeable and informed members of the community were conducted to identity key informants willing to take part in the knowledge base during the compilation stage. This period was also used to refine the objectives, the research questions and to determine some of the site specific variables in the community that were likely to influence the variation in knowledge held by different groups of persons.

4.1.3 Definition

The definition stage served to establish the preliminary boundaries of knowledge base domain and the topics it would cover through an exploration of the major areas of knowledge of relevance to the management of trees on farms and the natural regeneration of trees. Key sources of knowledge were purposely sought in the community, these including long discussions with Sahel Eco's partners, Farmer champions and local documents were obtained. I also used this time to acquire local terminology and names for trees and farming practice. In this period, the objectives and methods were clearly explained to the translator.

4.1.4 Compilation

The compilation stage is the actual creation of the knowledge base through an iterative cycle of SSI with key informants, formal representation and exploration of knowledge. Formal representation is done through processing knowledge articulated by informants from interviews and other sources and recording the information in the software. The information extracted from the discourse is semantically interpreted before being broken down into single clauses (unitary statements) using natural language and formal grammar

rules. The information is systematically related to the its source and contextual information about the 'pieces' of knowledge can be linked to the software environment.

The process of representing knowledge in the software is designed to act as a tool particularly useful to inflict rigour into the elicitation process of detailed knowledge often tacit and implicit to farmers. It forces the researcher to channel reflection on the information collected, helps identify possible ambiguities which need to be clarified. This often triggers new questions required to deepen the understanding of the knowledge communicated. Immediately processing the interviews is therefore of importance to organise additional interviews necessary to complement the information by seeking clarification or probing further on certain relevant topics.

4.2 Data collection and research tools

The field work took place during a 6 week period between the 21st June of the 2nd August 2010. Knowledge acquisition was the primary focus of the research and information was collected mainly through semi-structured interviews, depth interviews and informal discussions with villagers mostly conducted in the field. Interviews are adapted techniques to gain an understanding of different people's views and experience especially when working with a small sample (Laws et al 2008). Semi structured and depth interviews are important in allowing open questions to lead the discussion and enables interviewees to express what he or she feels is important to discuss. They are also flexible to being conducted in the field when walking and discussing features is an important part in knowledge elicitation of agro-ecological processes. Other research tools which were applied to triangulate information were observations and transect walks, causeries (informal discussion) and feed-back sessions.

4.2.1 Ethical considerations

An ethical review was conducted prior to starting the research but it was important to reflect on the ethical implication of the research methods all along the field work. In working with illiterate and remote communities it is difficult to judge how many people fully grasp the concept of university research purposes. It was important no one build any expectations from the research project or misunderstood my presence in the field. The

purpose and scope of the research were explained as clearly as possible to all interviewees and respondents. Farmers or interviewees participated in interviews from their free will. Consent from each interviewee was obtained about taking notes, which would be used in the research and about recording their names and details. Though only the researcher and her supervisors would have access to the KB where details are stored.

It was also important for the research not to disturb the interviewees' schedules and priorities especially at a critical time of cultivation work. Care was taken so that farmers chose the time of interviews at their convenience. Interviews were closed down by summarising the important information that had been elicited and obtaining confirmation from the interviewee that the information was accurate.

4.2.2 Sampling strategy

The aim was to interview 20-25 farmers, with repeated in-depth interviews, preferably conducted in the field. The methodology calls for 5 informants per strata (Dixton et al 2001).
In total 36 interviews were conducted; 26 first interviews mainly with a single respondent but sometimes ending with a neighbour or family member joining in the discussion. 10 second interviews were conducted 4 of which were conducted with FL.

The stratification used and associated numbers of interviewees are as follow:

1. Farmer leaders (FL) who have been trained in FMNR and other agroforestry practices (5) second interview (4)
2. Men members of a FVE groups and 'volunteers' for the re-greening program (7) second interview (2)
3. Women members of a FVE groups and 'volunteers' for the re-greening program (5) second interviews (2)
4. Men non-affiliated to FVE groups (7), second interview (2)
5. Women non-affiliated to FVE groups (2)[3]

[3] As I will explain in the variations of knowledge section 5., women are not field owners and it was found that questions about trees in fields and opportunities for change were limited so a greater majority of men were interviewed.

I used a combination of non-random sampling methods to conduct interviews which was flexible enough to be adapted to the short period of research and the time of year when farmers are most busy or rain impairs travelling or even being outside. These were purposive when I wanted to meet farmers because of specific features in their land or some distinct management practice, or when they could express themselves in French and communicating was easier (important for triangulation), it was snowballing when a farmer or farmer leader recommended another farmer. Convenience sampling applied to days when distances could not be covered or when an interview had been cancelled. Some interviewers asked to be interviewed and were therefore self-selected.

As the research progressed, I wished to complement the original stratification by looking into issues of land tenure security as this was an issue particularly relevant. I therefore made a purpose to interview farmers with little land security as well as those with secured access. Ethnic variations in knowledge were also important to note because they had some specialised knowledge associated with certain trees.

4.2.1 Semi-Structured Interviews (SSI) and depth interviews

The majority of interviews were conducted in the fields because discussing natural regeneration and tree features with observation is important in bringing out information which would not be generated from sitting in the homestead (see plate 2 for a photograph of an interview). Fields were often dispersed but when the flow of conversation was good and the farmer interested and available some long walks were made into different zones of the landscape to visit fallows or fields the farmer wanted to point out.

The questions and answers were usually interpreted by the translator as the conversation went along. Because the villages are very remote and deprived of technology recording interviews was seen as inappropriate and unsuitable to the informal and relaxed conversation style that interviews required to be dynamic and enjoyable for all. Sometimes notes were taken in the course of the interview but in general the least obtrusive method to record interviews was to take numerous pictures and go over the interview with the translator as early on as possible. This allowed farmers to feel more at ease and less interrogated during the visits.

Questions were kept simple and unambiguous and avoided sensitive issues. Due to the ethnic diversity in the area many of the interviews were conducted in Bambara language

which was neither the translator nor the interviewee's mother tongue. This sometimes made communication slower and more difficult. The French translation was sometimes difficult to understand despite all the good will of the translator. Triangulating information with French speaking villagers and second interviews to clarify and complement information elicited in the first interview proved useful in many instances.

Plate 2 Photograph taken during an interview in the village nursery in Bambara on 18/07/2010

4.2.2 Other research tools and triangulation of information

Tree identification and vernacular names

Identifying trees and the local names of trees was an important part of the initial work and it was very important that I gained a rapid understanding of the names and the features themselves. J.M. Coulibaly, Saheleco's facilitator in the area, was very helpful in identifying local Bomu and corresponding scientific names. Another tool that I used in the identification of tree species was the graphical identification tool V.1.0 Ligneux du Sahel[4]. The scientific names of 6 additional species were identified by the Forest Engineer of the Forestry Department in Tominian. Early on in the research I started compiling a table of corresponding vernacular names of trees in the different local languages based on trees that were discussed and observed in the landscape. I completed and obtained consensus on the local uses of names in the different local languages in a farmer leaders meeting with the help of a herbarium I had made. The table is included in Appendix IV. This table was very

[4] Bonnet P, Arbonnier, Grard,P (2008) Graphical identification tool V.1.0 Ligneux du Sahel CIRAD, édition QUAE, CTA

useful in all field work and particularly in interviews. It helped gain time as the interviewees could express themselves about the tree species in their native language. It enabled me to ask specific questions based on the local tree name and the farmer would know which tree we would be talking about. This considerably eased the conversation flow, the contact with farmers and the work of the translator. In addition it enabled me to pick up precious information on many species and their utilities throughout my study.

"Causeries" (informal discussions)

Causeries are an important part of Malian culture; they basically entail getting together, drinking tea and exchanging ideas. Being immersed in the village life, I had plenty of opportunities for causeries, many of them were very informal but 3 particular occasions where discussions took place with a group of 4 to 6 farmers were very useful in providing a lot of information on particular topics, such as the management of livestock and free roaming and the problems of the temporary water course and water issues, the problems with the rupture of large families. One causerie took place in French and in the absence of the translator. It was very useful because some farmers were discussing more freely issues of land tenure which were otherwise difficult because the translator was also the local headman's nephew and some farmers did not speak as openly in front of him.

Transect walks

A part from transects that were walked with farmers in visiting fields, other transect walks were conducted, 2 with women collecting shea-nuts, one with children herding livestock and one with the member of the local village forest surveillance committee.
Transect walks were very useful in gaining an understanding of the landscape features and spatial characterisation of tree features.

Feed-back session

One feed-back session was organised in the headquarters of Farakunna Cooperative and took place on the 2nd August 2010 (plate 3). 5 of the farmer leaders interviewed, 13 other farmers including 3 women and 3 members of Sahel Eco's staff were present. The first part of the feed-back session was to summarise the main findings that I had obtained in the

course of the research and check that farmers agreed with the information I presented back. Some details were added. The later part was used to discuss the current main constraints in the adoption of new agroforestry practices that had come out of the research (See appendix V for the poster highlighting the main constraints). This triggered a dynamic discussion which lasted for over 3 hours, though large fragments of the discussion were primarily animated by FL.

Plate 3 Photograph of the feed-back session held at the Farakunna headquarters in Bambara on the 02.08.2010 (taken by A. Tangara)

4.3 Analysis of results

AKT software offers a range of analytical tools for exploring the knowledge base. It facilitates the organisation of local classification for processes and object components of agro-ecosystems which can shed light on how local farmers view different ecological processes. Furthermore, a diagrammatic interface where the relationship between concepts can be established and cause and effect relationships visualised facilitates analysis and comparison of knowledge. It helps gain an understanding of the variations, wealth or gaps in certain domains. The content of the knowledge base and other information elicited is analysed in the light of the objectives and relevant current literature.

4.4 Usefulness and limitations of the methodology

Despite the brief scope of the research, by using a systematic approach, combining different methods and remaining flexible, a lot of detailed information about parkland tree management and the role of different trees in livelihood and land use systems was elicited about an area which is considerably understudied. This research was conducted during the rainy season which corresponds to the 3 months of vegetation growth. Due to the focus on natural regeneration and its management of the research, the period had significant advantages in terms of being able to observe and discuss with farmers what vegetation was regenerating and growing and the interaction it was having with cultivation work. This generated important material for this dissertation.

One the other hand the small geographical scope and sample size make it difficult to make definite conclusions and generalisation about a broader area in general. The villages where the interviews took place are all under intervention programs and may not reflect the reality of other villages. Furthermore given the time limitations and the poor conditions of road travel more interviews and "causeries" were conducted in Bambara and Siradié. These areas are more fertile than other villages and have better water resources. With more time it would have been useful to interview a greater proportion of farmers in villages with different conditions.

Although I fully recognise the importance and opportunities of the AKT software gives in organising agroecological knowledge and obtaining a deep and robust understanding of processes, knowledge representation and KB management is extremely laborious, and the program not the most user friendly, especially at the beginning. The methodology relies on updating the knowledge base regularly to guide the elicitation process. This often proved difficult for a number of reasons ranging from lack of sunlight to run my solar panel, some technical problems and a general lack of privacy in the village. At night, my computer being the only source of light in a wide perimeter I seemed to attract all the flying creatures of the vicinity. And although this would have been useful in providing a data set of insect diversity of the area, as dung beetles crashing in my hair would synchronise with the AKT program repetitive crashing, I was often wondering if there were no other easier way to go about this project.

5. RESULTS

5.1 Knowledge boundaries

5.1.1 Agro-ecological topics and statements in the KB

The development of the KB supported the general organisation of information collected in the interviews and field visits. It also helped to extract and represent agro-ecological knowledge which guided the following interviews and enabled to confirm or complement information elicited. It facilitated the representation of local taxonomies and helped classify information about tree species. Topics in the KB are mainly associated with ecological factors affecting reproduction (dispersal, germination) and the behaviour of woody vegetation to external drivers such as human practices or livestock. Other topics include trees and environmental services and tree management. 455 statement of the 526 statements represented in the knowledge base were causal statements and helped to capture some of the multi-level interactions between human action and natural processes.

5.1.2 Sources and derivations of agro-ecological knowledge

There are 34 sources represented in the KB. 24 villagers were interviewed once and 10 a second time (5 of which were with farmer leaders). 6 interviews were conducted with women, 4 of which were conducted with two women interviewees and 2 second interviews with women. The majority of interviews were conducted within the Bwa community (14 interviewees), and 8 Dogons, 2 Fulani families were also interviewed. Knowledge derived from observation was a significant part of knowledge elicited. There was not much knowledge derived from practice because natural regeneration or tree management are emerging practices. There was a lot of extension knowledge on soil and water conservation which was not represented in the KB because the focus was on trees management. FLs stood out more knowledgeable about tree management than the rest of farmers as a result of attending numerous training organised by SahelEco in the last year. The inter-village exchange visit to Bankass in 2009 was also commonly mentioned by FL as a reference point to managing natural regeneration and to realising its opportunities.

5.1.3 Variations in knowledge elicited and further considerations

The stratification I had proposed at the end of the scoping stage was to include from FVE and women which did not belong to FVE since FVE members are the ‘agroforestry promotion

group'. However, women although primary stakeholders in NTFP, have no decision power in field management. Knowledge about trees was very useful in identifying some of the priorities women may have but information about trees and field management elicited quickly became exhausted. The availability of women for interviews was also limited due to an overburden of work which in itself was revealing of the extent to which women can actively participate in re-foresting initiatives. Interviewing men farmers was more appropriate to understand where opportunities for change may be or where the constraints lied in the fields.

Ethnicity and specialised knowledge

In the interviews conducted it became clear that there were specialised knowledge associated with different ethnic communities in the area transfer of knowledge between different groups seem to occur. For example, Bwa women prepare traditional alcoholic drinks from *Sclerocarya birrea* and *Lannea microcarpa* so have a deeper interest in these species and knowledge of these species. On the other hand, the Dogons have an extensive knowledge of cultivation of *Borassus aethiopium*. Through practicing different germination techniques to develop various eatable parts of the fruits, most Dogon farmers have an improved knowledge of seedling development. Although only 2 Fulani farming families were interviewed, it appeared clear that they possessed a different and more extensive knowledge of tree fodder. Indications suggest that there are transfers of knowledge between different ethnic groups. Fulani sedentary herder/farmers are called in by the Bwa if an animal is sick for example.

5.1.4 Other knowledge representation

Other relevant information collected about tree utilities, land and tree tenure, social organisation and local institutions which are relevant to the scope of this research and complement ecological knowledge in the AKT are also presented in the results.

5.2 Functionality of trees in livelihood and land use systems

5.2.1 Legacy of the parkland: perceptions and knowledge of declining woody vegetation

This section briefly highlights some of the major points that came out of interviews and causeries about local perception of changes in the woody vegetation. Common illustrative sentences of the decline in parkland I heard on many occasions were “the trees are gone”, “the trees are finished”, and “all trees are old”. The older farmers (above 45 years) often pointed out to field areas which they could remember were like a dense forest. As children, they would be scared to enter for they feared wildlife, which, except for snakes, no longer exists in the area (e.g. lions, hyenas, monkeys). All farmers underline population growth and the increasing need for crop land as causing ‘the bush to be continuously pushed back’. Cultivatable bush land yet to be cleared is rare, fallows are shortened or abandoned and fields increasingly cultivated on a permanent basis. The ageing of trees and the lack of natural regeneration was confirmed by all interviewees.

Table 4.2.1 shows a list of trees mentioned by farmers when probing information on which trees had disappeared most. It also gives the protected status of trees which was often mentioned and the causes identified by farmers. The first species which all farmers first identified were *V. paradoxa* and *P. biglobosa.* . These were systematically followed by *T. indica* and *B. costatum* which were also identified by all farmers as having severely diminished. Other species which were mentioned by more than 10 farmers were often expressed as they remembered them and the table does not reflect a particular ranking of magnitude nor importance.

Table 2 List of tree species mentioned by villagers as having most declined

Latin name	Causes	Protected status	Final product
Vitellaria paradoxa	old age, drought, pests,wind	*Cbl* /F.C./Fk	Fo/Med/In
Parkia biglobosa	old age, uprooted by wind or water,drought, termites	Cbl /F.C/ / Fk	Fo/Med/In
Tamarindus indica	old age, drought,wind	Cbl/Fk	Fo/Med/In
Bombax costatum	abusive felling	*Cbl* F.C/Fk	Fo/Fw/Sw/In/Md
Khaya senegalensis	old age,abusive felling, bark removal	F.C	Fd/Md/Fw
Prosopis africana	old age, abusive coppice/felling		Sw/Fw/Md/Fd/Inc
Pterocarpus erinaceus	old age, abusive felling	F.C.	Fd/Fw/Sw
Anogeissus leiocarpus	old age abusive felling	F.C.	Fw/Sw/Md
Borassus aethiopium	wind and abusive felling	F.C.	Fo/Sw/Md/in
Faidherbia albida	old age, uprooted by wind or water, pests	F.C.	Fd
Lannea microcarpa	old age, drought	*Cbl*./Fk	Fo/Md
Sclerocarya birrea	old age, felling of male trees	*Cbl*./Fk	Fo/Fd/Sw/Md/In
Abbreviations	*F.C Malian Forestry Code*	Fo:food	*Fw:fuel-wood*
	Cbl: Customary by-laws	*Fd:fodder*	*Sw:service or construction wood*
	Fk: Farakunna Convention (2009)	*Med:medicine*	*In:income*

5.2.2 Trees and the provision of final goods

Preferential ranking of tree attributes and a quantitative assessment of tree utilities was not the purpose of this research, but because farmers' decision to retain or to plant a tree is ultimately linked to the perception of its utility, it was important to classify certain trees according to the main utilities they represented for different farmers interviewed.

For the purpose of this research, ecosystem services obtained from trees are classified in two categories; one related to the provision of final goods, and the second relating to environmental services which can be regulating and supporting services.

The most salient feature brought out from interviews and causeries with both men and women was that all villagers mentioned that if they were to have more trees they would want more fruit trees in their fields and the main reason was for the importance these trees played in providing staple food products. Income was the second attribute mentioned systematically by women and by farmer members of FVE who wanted to plant mango trees and/or recognised the importance of indigenous fruit trees as a sources of income

(secured by women) to the household or to the FVE. Other attributes such as tree fodder, medicine, fuel-wood and construction wood were also mentioned for specific species.

Food

Table 3 lists the 10 key trees for nutrition of the family and some of the reasons given by interviewees for their importance. Most trees were said to be diminishing. It also includes details of the final goods consumed and harvest period.

Plate 4 shows a typical daily scene of preparing food from trees.

Plate 4 Food products from trees: recently harvested leaves of Adansonia digitata and fruits of Borassus aethiopium

Table 3 List of 10 key trees mentioned by men and women as very important for family nutrition

Scientific name	Harvest period	Product	Importance
Adansonia digitata	May-December	**leaves (consumed daily) fresh in rainy season and dried for the rest of the year**	**main source of green vegetable**
	November-January	fruits (seeds, dried pulp to make juice)	fruits available in the dry season
*Bombax costatum***	December-January	flowers	enhance the palatability of dishes
*Borassus aethiopium**	June-July (fruits) July-October (germinated parts)	fruits, germinated seed and roots	sweet fruit with a lot of flesh, culturally important for the Dogon
*Lannea microcarpa**	June	fruits, alcohol, leaves in porridge	energy to work in the fields and cultural importance of its drink, important fruit for children
Parkia Biglobosa **	**May-June**	**seeds (pounded for soumbala)**	**enhance the palatability of dishes culturally important**
*Saba senegalensis**	June-July	fresh fruits, juice	energy to work in the fields ,fruits for children
*Sclerocarya birrea**	May	fruits, kernels and alcohol	cultural importance (pre-cultivation animist rituals)
*Tamarindus indica***	October-December	dried fruits all year round (fruits and leaves used in porridge) fruits used to make juice	cultural importance in diet, enhance the palatability of porridge
Vitellaria paradoxa **	**July-August**	**fresh fruits, kernels: butter**	**energy to work in the fields, alleviates feeling of hunger, dominant source of fat in cooking**
Ziziphus mauritania	December-February	fruits	Good fruit to have in the cold season

The tree species highlighted in bold show the trees identified by all interviewees as being very important and the * symbol denotes it has diminished and the ** symbol it has significantly diminished.

Income

Table 4 shows some of some important sources of income from parkland tree products, the tree names highlighted in bold reflect the importance that was mentioned by all interviewees. The table shows clearly that women are the major beneficiaries of NTFP trade as illustrated in plate 5 below. However important resource users such as 'forgerons' (blacksmith cast) and farmers developing honey as a FVE product must be noted. One category of income not reflected is the trade in medicinal goods and for which little information is available.

Plate 5 Women trading in NTFP

Women selling soumbala transformed from P. Biglobosa

Extraction of kernel from Sclerocarya birrea nut

Table 4 List of key parkland tree products commercialised locally and their beneficiaries

Tree name	Product	Who
Adansonia digitata	Dried leaves / Fruit	Women (bwa)
Banalites aegeptiaca	Nuts (boiled)	Women
Borassus aethiopium	**Fresh fruit / germinated seed/root**	**Women (dogon)**
Lannea microcarpa	Alcohol (traditional ceremonies)	Women (bwa)
Parkia Bigolobosa	**Soumbala (spice)**	**Women**
Saba senegalensis	Fruits	Women/Children
Sclerocarya birrea	Alcohol (unle Gna)	Women (bwa)
Sclerocarya birrea	Kernel	Old women (bwa)
Tamarindus indica	**Dried fruits/Juice**	**Women**
Vitellaria paradoxa	**Nuts/Butter**	**Women**
Ziziphus mauritania	Dried fruits/cake	Women
	Honey	**Men (over 40)**
	NON FOOD	
Prosopis africana	mortars, construction,	Forgerons
Borassus aethiopium	Beds, chair	Forgerons
Sclerocarya birrea	Tools, stools, doors	Forgerons

Tree fodder

Although there is a clear distinction between trees that are lopped for fodder and those that are browsed by livestock, it was difficult to elicit which trees were palatable to livestock because farmers mentioned that a hungry animal can eat just about anything it finds green. For example new shoots of Lannea microcarpa are browsed but as soon as the grass grows livestock will stop eating them. Most fruit trees seedlings are palatable to livestock especially at the beginning of the rainy season when animals is still roaming.

Table 5 lists some of the trees which farmers mentioned they valued most as fodder sources and which leaves were lopped or pods fed to animals.

Table 5 List of trees commonly used as fodder described by farmers

Scientific name	Importance mentioned	Niche	Trend
Pterocarpus lucens	Leaves available at the beginning of rainy season (May)	Duwa forest	diminishing, no seed germination
Pterocarpus erinaceus	leaves available at the beginning of rainy season (May)	Duwa forest , forest galleries	disappearing
Sterculia tomentosa (?)	evergreen nutritious leaves, important in the beginning of the rainy season (calving)	Duwa forest, bush, fields	stable , no regeneration observed
Khaya senegalensis	Nutritious leaves available at the beginning of dry season (march)	Fields	disappearing (abusive lopping prevents fructification)
Ficus exasperata	Evergreen	Fields, Forest galleries	decreasing but evidence of seed germination and natural regeneration
Celtis intergrifolia	**evergreen highly nutritious leaves (compared to cotton seed cake) evergreen important fodder in dry season also has veterinary uses**[5]	**Forest galleries**	**disappearing (abusive lopping prevents fructification)**
Faidherbia albida	nutritious leaves in the dry season (nutritious pods)	Fields, deeper soil	increasing number of natural regeneration in fields
Balanites aegyptiaca	evergreen fodder for goats	Fields, Bush, degraded land	abundant but heavily lopped

[5] Only mentioned by Fulani herders

Medicine

Most trees play a role in traditional pharmacopeia and reviewing all their uses is beyond the scope of this research. There are some species which are commonly known and used by the villagers in traditional medicine but there is a wide variety of other species known by traditional healers, usually older men in villages. *Vitellaria paradoxa* and *Parkia Biglobosa* were mentioned by all women because of its importance for paediatric uses and gynaecology.

Many tree species highly valued for medicinal purposes mentioned are commonly found in riparian galleries and have severely diminished. *Ximenia Americana, Vitex doniana, Saba senegalensis* are some examples. Another important medical tree also in decline is *Khaya senegalensis.*

Fuel-wood

Women are responsible for the provision of fuel-wood for cooking and heating water for daily washes. In addition, large amount of fuel-wood are used for the preparation of 'Gna', the local sorghum beer which is boiled for over 18 hours and prepared often weekly by each married woman in Bwa families. Much fuel-wood is also used in the preparation of shea-nut butter.

The distances are longer because fallows are diminishing rapidly. The main source of dry wood comes from the Duwa forest. Women mentioned they used to spend an hour collecting enough to fill a horse cart, but today they have to spend nearly a whole day because wood is becoming scarce. Some valued species which are particularly diminishing are: *Combretum aculeatum, Pterocarpus erinaceus, Combretum ghazalense. W*omen say they have to use increasing amount of *Prosopis Africana* whereas before there were better wood was available. Women observed there was no natural regeneration of these species.

Dying mature trees in fields and fallows continue to provide a source of fuel-wood and many dead trees can be observed lying in fields. The lack of equipment, time and labour prevents women from utilising this resource. Women mentioned valuing *Guiera senegalensis* burning quality though the small size of its branches limits its use to meal preparation on small stoves.

Service wood and construction wood

Service wood such as *Prosopis Africana, Sclerocarya birrea, Banalites aegyptiaca, Lannea acida* and *Dyspiros mesiliformis* are also used in the community for important tools and equipment, they are mainly transformed by 'Forgerons' or 'griots' (casts members). Apart from *Prosopis africana* all the other species mentioned are protected by the Farakunna Convention since 2007. Only harvesting of fruits or leaves is permitted because of the importance of their role in nutrition or medicine. By protecting these resources some other stakeholders are affected by the lack of access to important resources. It would be useful to gain a further understanding of the impact this may have on these resource users and to explore the alternative options they could have to access these particular resources.

Men frequently expressed concern with the lack of wood and the cost of wood for construction. Younger farmers frequently mentioned they wanted to build a house near their bush-fields but lacked the means. Suitable woods such as *Pterocarpus erinaceus, Anogeisus leiocarpus* or *Borassus aethiopium* are rare and can only be obtained with a permit from the Forestry Department at a prohibitive cost. Farmers valued eucalyptus spp. an alternative quick growing timber source but the lack of water was as the restrictive factor. The alternative is increasingly purchasing tin plates.

Rarefaction of key resources

The results mentioned in the above section illustrate the dimension trees play in providing the community with key products. The decline in tree, the ageing of trees and the lack of fructification has made villagers aware of the importance of many fruit tree species. Rarefaction of essential products appears to be a driver for farmer leaders and FVE members' motivation to increase indigenous fruit tree species in their fields. The slow growth and maturation and difficulties involved in managing and increasing indigenous tree species will be presented at length in later sections.

5.2.3 Local perceptions of trees and environmental services

Along with the importance of trees for the delivery of provisioning services, farmers are aware of the importance of trees for environmental services in both their fields but also the broader landscape. They often mentioned that it was because trees had gone that they now understood how important they were. This section presents some of the main environmental services that were discussed with farmers in relation to trees.

Water erosion control

Water erosion control was one of the key environmental services delivered by trees and expressed by farmers. All farmers mentioned that the general decrease in trees has resulted in increasing erosion from water during the rainy season. Damage was felt in most fields but predominantly on slopes, on the foot hills and in riparian galleries. As trees are uprooted by water, the flow of water increases and so does the vulnerability of other remaining trees being uprooted. In fields new gullies are formed, soil and manure are lost; seeds and crops risk being washed away by the flow of water.

Soil and water conservation techniques are widely developed in the area; many farmers are using zai, stone bunds and live-fences as methods they learnt with SOS Sahel in the 1990s. However, it appears that this is a combat on many fronts. Most farmers are improvising their own water control somewhere in the field such as blocking gullies with branches of removed woody vegetation (commonly *Piliostigma reticulatum*), using logs from dead mature trees present in the field. Although live-fences planted with exotic species are present in the landscape, the number of unsuccessful attempts at planting live-fences is striking.

I observed and discussed with many farmers their problem in establishing and maintaining live-fences. *Euphorbia balsamifera* seedlings are browsed by goats or seedlings which have to be planted in the rainy season are washed away before the roots can fully establish. The problem of maintaining live-fences on the banks of the marigot or near temporary watercourse due to the increasing flow of water and the riparian bed changing location was frequently mentioned. During my interviews, I had several discussions with farmers about the available vegetation that could be used to supplement and strengthen live-fences near waterways, *Borassus aethiopium*, S*arcocephalus latifolius, Acacia macrostasya* and

agaves were mentioned and observed as good and fast rooting species which can be used to reinforce live-fences.

Soil fertility

The general impact of trees and the decomposition of litter in maintaining soil fertility is recognised by all farmers. They often mention the communal role played by all trees during a fallow phase in improving the soil. However when it comes down to trees in their fields, the fertilising effect of standing trees is offset by the fact that farmers do not grow crops under the crown area of the tree because of the negative impact of shading on crops. The most acknowledged tree for improving soil fertility is *F. albida*. With its reverse phenological cycle, *F. albida* is thought by farmers to have no negative interference on crop cultivation. This is the most common 'protected' natural regeneration found in fields. The majority of farmers expressed that animal manure was the best solution to maintain soil fertility and they also added that chemical fertiliser could not be an option because they did not have the means to purchase it..

There was a striking difference between farmer leaders and other farmers in the practices of managing natural regeneration occurring from root stock. One of the main reasons farmer leaders were managing trees naturally regenerating from rootstock in their fields (*Combretum* spp., *Piliostigma reticulatum, Guiera senegalensis*) was for the mulch they provide. For most farmers, these are eliminated in the field because the area had to be cleared and 'swept' (balayé) for good tillage and crop growth. Most farmers accumulate residues and burn it on the side of the field but I also observed some practice of burning rootstocks. One farmer leader was leaving the remains of his shrubs pruning to be decomposed by termites in the field and explained this was adding organic matter quickly to the soil. It must be noted that his eldest son in his early twenties present at the time was laughing at him and the farmer leader explained to me he was thinking he had gone crazy ever since he had seen the fields in Bankass (FMNR program).

Farmers also identify the fertilising role of different trees based on their observation of cultivating the soil where a 'departed' tree used to be. Although farmers say that wherever a tree has been, crops need less manure, there are certain trees which certain farmers acknowledged as particularly good. *P. biglobosa* was by far the best identified. *V. Paradoxa* and *Acacia nilotica* were also mentioned frequently.

Trees and wind

The main cause of indigenous trees mortality was wind. The impact of trees protecting each other was raised by many farmers. The women were also particularly worried about the impact of wind on flowering of fruit trees and subsequent lack of fructification. Men farmers involved in bee keeping were similarly concerned with the impact of flower loss. The loss of top soil and manure from severe wind storms is a problem severely felt in the area. Live-fences acting as wind shields are valued in the area but the extent to which these can be adopted is largely based on land ownership and labour availability and the species successful establishment.

Trees and rain

A reason that was mentioned frequently by farmers for wanting more trees was the common belief that if trees would increase in the environment then the rains would improve. Discussions indicate that this is a source of motivation for local villagers to promote trees. This was sometimes derived from hearsay but some farmers mentioned that the elders were concluding that 'before there were more trees and there was more rain, but now that the trees have gone the rains were becoming shorter.'

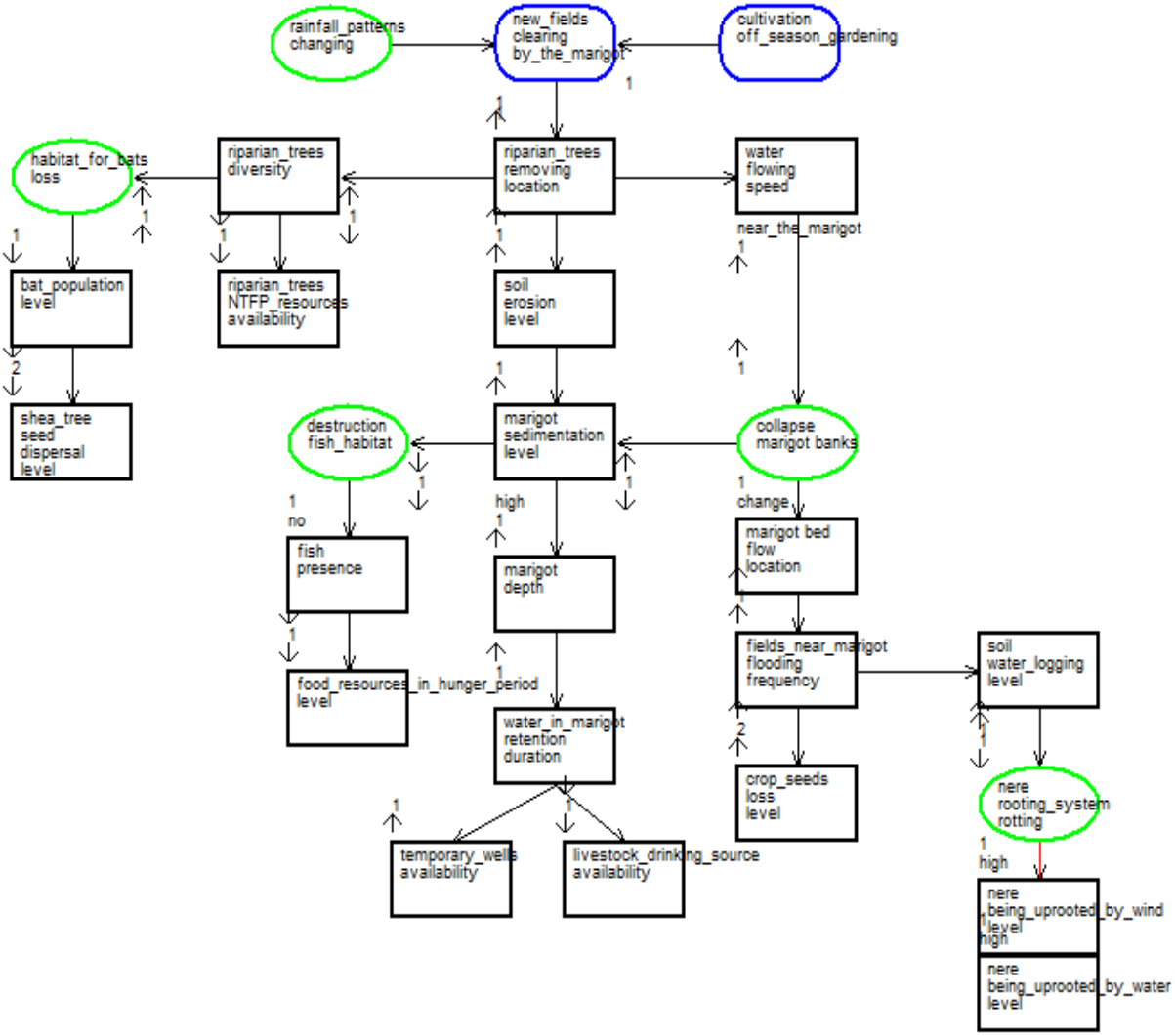
Trees, lowland valleys and riparian galleries

One very important trend described by farmers is the increasing exploitation of inland valleys and riparian galleries for cultivation. As a result of decreasing rainfall and the development of small scale gardens, many new fields have been created and intensified in these lower valleys which capture more soil moisture due to topographic characteristics. The degradation of "marigots" (temporary watercourse) was a subject extensively discussed with several farmers and in numerous 'causeries'. Plate 5 illustrates an example of "marigot" decline with previously fertile fields inundated by the changing course of watercourse. Figure 3 is an AKT diagrammatic representation extracted from farmers' statements in the KB, of the of the complex features of the degradation of the 'marigot' and some of its multiple impacts. The impact of tree clearing on the riparian zones is a concern to many farmers who have fields near the marigot but also to villagers in general as the services delivered by the watercourse benefit the village community as a whole. This

was particularly prevailing in Bambara but Siradié and Pakan Bobo which are located near the same watercourse are experiencing similar trends.

Plate 6 View of the "marigot" in Bambara, taken on the 30/07/2010

Figure 2 AKT causal diagram depicting local knowledge about the multiple impacts of tree clearing and land use intensification in the Bas-fonds (lowland riparian zones)



Legend: Nodes represent human actions (boxes with rounded corners) or attributes of objects, processes or actions (boxes with straight edges). Arrows connecting nodes denote the direction of causal influence. The first small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the second arrow on a link refers to an increase (↑) or decrease (↓) in the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case ↑A causing ↓B also implies ↓A causing ↑B, or one-way (1), which indicates that this reversibility does not apply. Words instead of small arrows denote a value of the node other than increase or decrease

5.2.4 Spatial characterisation of trees in the landscape

As illustrated in the livelihood and land use diagrams (see Appendix II), the livelihood land use system of farming households is structured not only around cultivated areas and fallows but also neighbouring areas such as Duwa Forest and bush land unsuitable for

cultivation such as hills or rocky soils. These non-cultivated zones provide villagers with grazing areas and tree resources used for fodder, fuel-wood, timber and a number of NTFP such as fruits, medicine, honey and game.

Trees only occurring in fields

There are certain key species such as *V. paradoxa, P. biglobosa, T. indica, K. Senegalensis. B. Aethiopium, F. albida* which farmers identify as only occur in fertile areas. It is, however, where permanently cultivated fields tend to be located and where natural regeneration is practically inexistent or where the survival of seedlings is under threat. Most of the farmers identified that where fields had been cultivated for the longest period and often on a permanent basis, typically in the compound fields, the density of mature trees was the lowest and their age older. Farmers explained this was attributed to the repetitive use of the plough and the intensity of livestock presence in the free roaming period.

Trees occurring in fallows.

5 transect walks were done with farmers in fallows. The longest fallow duration was 5 years. 2 farmers had land in fallow for 3 years and were cultivating it this year. The dominant regenerating species were *Piliostigma reticulatum, Guiera senegalensis and Combretum micranthum.* There were some regeneration of fruit trees observed in *P. reticulatum* and *G. Senegalensis*. Noticeable young trees were *Grewia bicolour, Cassia siberiana* frequently noticed in the fallows.

'Widely available trees'

Some species occurring in fields also occur in the bush, in hilly areas or the Duwa. The most commonly found species, viewed as invasive in the field is *Piliostigma reticulatum*, despite its many recognised utility. *Sclerocarya birrea* and *Lannea microcarpa* were also mentioned to occur outside fields so farmers had little motivation to encourage those in the field. In general, species spontaneously occurring in fields and resistant to livestock or cultivation pressure are commonly abundant in the wider landscape and regarded as invasive in their fields unless they are occurring in water paths and protect field from water erosion. These are often thorny and render field work difficult (*Balanites aegeptiaca, Ziziphus mauritania, Acacia macrostasya, Acacia nilotica*).

Trees in riparian zones

There is diversity in tree specific to riparian zones, important species mentioned were *Ximenia americana, Vitex doniana, Saba senegalensis, Celtis intergrifolia* which are threatened by changes in the valley environment and lack of natural regeneration. I was told by a farmer from Tieblenikuy that people used to travel 12 km to collect fruits or medicine from trees along the marigot south of the Duwa forest. It would be useful to further research these 'hot' spots of tree diversity in riparian zones and the extent to which these may be important for neighbouring communities.

Trees in the settlement

Most tree species that are planted are located in the settlement area and are usually exotic species. Details of the species will be presented in later sections of the results.

Trees in the Duwa forests

The most commonly mentioned trees occurring predominantly in the Duwa forest were *Pterocarpus lucens, Pterocarpus erinaceus, and Combretum ghazalense* valued for their wood and fodder.

5.3. Natural regeneration and tree management: practices and local ecological knowledge

Because I was conducting this research in the period of vegetation growth and field preparation, I was able to observe a lot of the regeneration taking place in the fields and what was happening to it. Much of the discussions in the interviews stemmed from observations of the vegetation occurring in the field and the results presented here are indicative of the main current trends.

Table 6 illustrates some of the trends frequently observed and discussed about the management of woody vegetation commonly regenerating in fields. The most abundant regeneration seen in fields was *F. albida* which existed in various class ages and which is resistant to browsing. All farmers said they were retaining *F. albida* in their fields since extension work had made them 'aware' of the importance of these trees for fodder and soil

fertility. However, it was often seen unprotected and without any tutor. Juvenile trees were commonly damaged by crude lopping and their development slower. *A. digitata* was regenerating in fields and is the most commonly protected species in the landscape. It is frequently transplanted to the settlement areas where exclusive harvesting can be secured and where I can easily be protected from livestock. It is only tree along with mango trees that is frequently protected with a purchased wooded fenced cage. *B. Costatum* was also transplanted from the bush to the settlement areas. *B. aethiopium* cannot be transplanted but were often observed protected with thorny branches or planted in riparian gardens

Interference with ploughing activities was also a major cause of the removal of woody vegetation regenerating from root-stuck in fields. Cultivation involving animal traction was also generally identified as the primary cause of seedling mortality in trees regenerating from seeds. Those that are spared from the plough are mostly vulnerable to grazing and trampling by an increasing number of livestock freely roaming during half of the year. The reduction or absence of fallows was also commonly mentioned as a major factor in the recruitment of younger trees.

Table 6 List of commonly regenerating species in fields discussed with farmers

Scientific name	Reproduction type	Management	Occurrence
Piliostigma reticulatum	V and R	cut back as seen as invasive - abundant in the bush retained in some fields by FL	bush fields, fallows, bush
Guiera senegalensis	V and R		bush-fields, fallow, bush, forest
Combretum micranthum	V and R		bush-fields, fallow, bush, forest
Ziziphus mauritania	V and R		bush-fields, fallow, bush, forest
Vinue (unidentified)	V and R		bush fields, fallows, bush
Covanro (unidentified)	V and R		bush fields, fallows, bush
Acacia nilotica	V and R		bush-fields, fallow, bush, forest
Balanites aegeptiaca	R	thorns make field work difficult but regeneration is common though young trees are heavily lopped sometimes through crude coppicing	bush-fields, bush, poor soil
Lannea microcarpa	R	frequent seed germination, grazed in early rainy season, low seedlings survival (ploughing) , perception of negative crop interference	bush fields, fallows, bush
Sclerocarya birrea	R	frequent seed germination , low seedling survival (ploughing). Young trees recruitment from fallow retained, often observed with signs of damage (human/livestock)	bush fields, fallows, bush
Adansonia digitata	**V and T**	**frequent germination but low seedling survival due to grazing, some protected (fenced cage) many transplanted to settlement area**	bush fields, compound fields, settlement
Faidherbia albida	**R**	**frequent germination, protected from the plough, different age class categories, abundance of seedlings. Browsing and crude coppicing often limit its growth**	Compound fields, bush fields
Borassus aethiopium	**R**	**frequent germination Seedlings threatened by children digging or by grazing (often protected in the field)**	Compound fields, bush fields, settlement
Bombax costatum	**R**	**some seed germination , seedlings and sapling resist some browsing level. Often damaged by wind, children or cattle (transplantation near settlement)**	bush fields, bush, settlement

There is a wide difference between farmer leaders and most farmers' management of naturally regenerating vegetation. Table 7 illustrates some of the contrasting perceptions of different tree utility in the fields between the majority of farmers interviewed (reasons to cut) and farmer leaders (reasons to keep) and Plate 7 illustrates the practical aspect of managing some regenerating woody vegetation. Figure 3 is a AKT diagrammatic representation of the causal links between managing naturally regenerating trees and the benefits to farmers identified by FLs. FLs said it was their trip to Bankass last year that had made them aware that the fields did not like to be 'clean' (i.e. swept of woody vegetation) that trees and crops could be compatible with multiple benefits.

Table 7 Illustration of the differences in reasons informing the management of regeneration

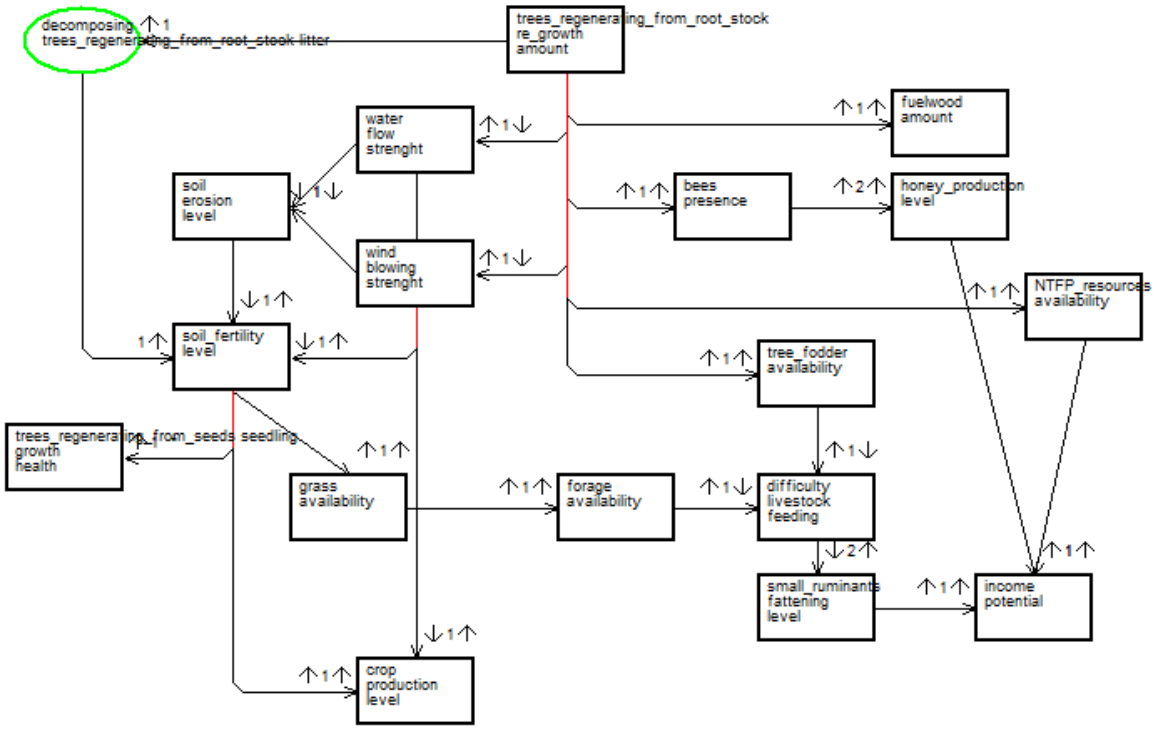
	Reasons to cut	**Reasons to keep (FL)**
P. reticulatum	Invasive, plenty in the wider landscape, compete for space with crops	Pods are used for fodder, seeds are burnt to extract honey from bee hives, good fibre used as rope, mulch, wind-break, hosting natural regeneration
G. senegalensis	Invasive, plenty in the wider landscape, compete for space with crops, attracts bees	Good source of fuel-wood, good source of pollen for honey, various medicinal use (disinfectant), mulch, windbreak
C. micranthum	Invasive, plenty in the wider landscape, compete for space with crops, attracts bees	Good source of fibre, mulch, wind protection, fuel-wood, mulch
Z. mauritania	Thorny, plenty in the landscape	Fruits, good source of thorny fencing material, mulch, fodder

Plate 7 Photographs illustrating two different management techniques of *Piliostigma reticulatum* vegetative regeneration

Managing *P. reticulatum* for tree development

Eliminating through burning

Figure 3 AKT diagrammatic representation of the causal links between managing naturally regenerating trees and the benefits to farmers identified by FLs



See figure 2 for the legend of the diagram

Table 8 lists some of the trees which are more rarely regenerating or for which no regeneration was observed by farmers.

Farmers identified the decline in seed stock (due to high mortality of parent trees, overharvesting of pods and fruits by humans, habitat change and drought) as a major factor in explain the low level of seed reproduction. This was particularly the case for trees which have severely declined and with fructification levels dropping continuously such as *Parkia biglobosa*, *Vitellaria paradoxa*, *Tamarindus indica*. Diagrammatic representations of farmers' local knowledge about factors affecting *Parkia biglobosa, Vitellaria paradoxa and Tamarindus indica* are included are included in Annex VI. In some other trees mentioned lopping for fodder or wood extraction were accounted responsible for the lack of fruit development (*Khaya senegalensis).*

Table 8 List of tree species which have a low or absence of regeneration observed and discussed with farmers

Latin name	Reproduction type	Frequency	Occurrence	Seedling survival /Juvenile trees
Vitellaria paradoxa	R and V*	Rare due to lack of seed (overharvesting and decline in parent tree)	under parent tree / shrubby vegetation / rare in field	none observed threat : plough, grazing, trampling
Parkia bigolobosa	R	Rare due to overharvesting of fruits and parrots increasingly feeding on immature seeds	under parent tree / shrubby vegetation / live fences	rare only in shrub or live-fence / Threat : plough, grazing, ,trampling
Tamarindus indica	R	Very rare , overharvesting of fruits	bush fields	none observed
Prosopis africana	R	none observed, decrease in parent tree, over lopping of foliage, lack of seed		none observed
Combretum ghazalense	R	none observed, decrease in parent tree, over-lopping of foliage, no seed available		none observed
Khaya senegalensis	R	none observed, decrease in parent tree, over lopping of foliage, no seed available		none observed
Celtis intergrifolia		none observed, decrease in parent tree, over-lopping of foliage, no seed available		none observed

*Note: root sucklers were identified on a couple of occasions but farmers never mentioned transplanting them

5.3.1 Natural vegetation used as hosting sites for desired species

Vegetation features present in or around fields such as planted live-fence or naturally regenerating shrubs have been identified by farmers as important niches for natural regeneration of indigenous fruit trees. Seed germination (dispersed by birds or water) and seedling development benefit from shelter against livestock and wind, as well as higher levels of nutrient and moisture available in these micro-systems. In well established life-fences, often protected by a dead-fence, farmers had observed a wide variety of species regenerating including *P. biglobosa*. Based on their observations, farmers have started planting desired seedlings in these vegetation features. Some farmer leaders are experimenting in directly sowing *V. Paradoxa* seeds or transplanting seedlings obtained from the village nursery inside the shrubby formation of *P. reticulatum* or *G. senegalensis*. Well established live-fences (*Euphorbia* and *Jatropha* spp.) were also areas where farmers have recently planted *P. biglobosa* and *V. paradoxa* seeds or seedlings. Live-fences act in the same way as shrubby vegetation in protecting the seedlings. They also have the advantage of being on the edge of the field which was the desired location farmers preferred because that is where the crop shading negative interaction can be minimised.

5.3.2 Opportunities in zai fields

In zai fields, which are cultivated manually with the use of the hoe, identifying and avoiding regenerating seedlings was seen by farmers as easier. Three farmers interviewed mentioned that by digging a small circular trench around these seedlings, water retention was increased and the growth of these trees was healthier and faster. I observed some of the tallest juvenile *Faidherbia albida* in these fields. Zai cultivation is a physically very demanding and done by farmers who do not own animals, whose fields have degraded or those who value the practice and have enough labour availability.

Plate 8 Photographs illustrating the role of vegetation in assisting natural regeneration of fruit trees

Parkia biglobosa regeneration in *Piliostigma reticulatum* (2006)

Parkia biglobosa regeneration in euphorbia live-fences(2007)

Parkia biglobosa planted in euphorbia live-fence (2009)

Vitellaria paradoxa planted in jatropha live-fence (2010)

5.3.3 Local knowledge of tree management

Management of trees such as pruning for better crop-tree interaction is practically non-existent. Pruning mature trees or managing saplings for better growth was also not a practice I encountered with the farmers I interviewed. Some trees are known by farmers to grow healthier if they are pruned ("coiffé" translating as hair dressed). *S. birrea* and *F. albida* were species mentioned by a couple of farmers. Most of the knowledge on tree management is extension knowledge which is held mainly by farmer leaders and derived from recent training supported by SahelEco. Pruning for rejuvenation, girdling for improved fructification grafting, for example, were techniques that were explained to farmer leaders earlier this year and no practical application had been done yet. Managing shrubby vegetation in fields was learnt mainly from the trip to Bankass. Knowledge of the impact of crude coppicing and pollarding, over-looping of leaves or fruits are known to some extent by farmers but appear unavoidable to them due to the diversity and number of resource users.

Table 9 presents the main planted species in the research area. Amongst indigenous species *A. digitata* is the most commonly planted species. *V. paradoxa*, *P. biglobosa* and *T. indica* are being grown in the village nurseries established in 2009 and the start of a domestication process is just emerging. Women did not appear involved in the selection of species nor parent trees for the nursery. At least 2 seedlings of each were due to be transplanted in August in the fields of all members of the FVE. Many farmers were unsure of how much they should be watering the seedlings and which were the best soils and conditions for the growth of seedlings.

The main planted species about which some farmers have practice in managing are exotic species which are highly valued for their faster growth (provided all conditions are met) and live-fences species..

Table 9 List of the main indigenous and exotic tree species planted in the research area

Indigenous trees	Growth characteristics	Requirement
A. digitata	Drought resistant, fast growing, early leaf harvest (2 years)	shelter from animals
B. aethiopium	Slow growing ,fruit harvest after 15-20 years, low maintenance	shelter from animals (in early years)
P. biglobosa	Slow maturation, fruit harvest after 12-15 years, slow juvenile growth (very vulnerable in early years)	shelter from animals, watering ? soil type and fertility requirement ?
V. paradoxa	Slow maturation, fruit harvest after 20 years, slow juvenile growth very vulnerable in early years	shelter from animals, watering ? soil type and fertility requirement ?
T. indica	Slow growing, fruit harvest after 20 years, very vulnerable in early years	shelter from animals, watering ? soil type and fertility requirement ?
Exotic species		
M. indica	fast maturing (fruit harvest after 6 years) (grown for income)	soil fertility, shelter from animals, termite control, watering
Eucalyptus spp.	fast growing (grown for timber)	shelter from animals (early years) watering
Azadirachta indica	fast growing, termite resistant, drought resistant, (grown for shade)	
Jatropha curcas	live-fences, fast multiplication	
Euphorbia spp.	live-fences, drought resistant	
Citrus spp.	slow growing	soil fertility, shelter from animals, watering

5.4 Main Constraints to increasing trees in fields

5.4.1 Field cultivation

The main constraint for land cultivation is undoubtedly the unpredictability and variability of rainfall, waiting for the rain, and most of all waiting for the right amount of rain. Most work has to be done immediately after the rain and farmers and all their available family members literally rush to the fields. Identifying and avoiding naturally regenerating seedlings is considered a major obstacle in conducting fieldwork. Farmers explained clearly that this involves deviating from the parallel furrow configuration, which is particularly difficult with a pair of oxen, but also difficult for a horse or donkey. This is a source of extra work and

constraints especially as the same furrows will have to be used in subsequent weeding and mounding field operations, which as farmers added had to be conducted in similar 'rushed' way. Trees are also associated with bees and snakes which most farmers fear, and attracting birds which damage crops. *Vitellaria paradoxa* fruits mature during crop development stages, many farmers recall the days when abundant trees in fields would be associated with the damage to crops around trees done by women hurrying to pick fruits. Trees are not manipulated and shading is the major constraints farmers associate with trees and particularly *Parlia. biglobosa, Acacia nilotica* and *Lannea microcarpa*

5.4.2 Difficulties in protecting trees from livestock

Due to the roaming of livestock for large parts of the year, farmers find it difficult to protect seedlings. Only dead wood from *Prosopis africana* is known to resist termites. Although thorny bush such as *Ziziphus mauritania* or *Acacia macrostasya* are used these often cannot resist strong wind. All farmers highlighted the lack of fencing material. The cost of fenced cage is considered very expensive, in the range of 500 to 750 CFA with limited life span. However, Plate 9 illustrates the care taken to protect *M. Indica* and *A. Digitata* in the settlement areas clearly show that if the farmers see the benefits he will deploy all his ingenuity to develop protection mechanisms. Tree management in bush-field is complicated by the distances. Hungry cattle are thought to be aggressively attacking the defence and goats frequently climb over any fencing material and maintenance of tree shelters in bush-fields have never been a practice. This task is more difficult for women who already have an over-burdened work calendar.

Plate 9 Photographs illustrating different types of fences protecting Adansonia digitata and Mangifera indica

5.4.3 Children and their mischievous behaviour

In all the interviews I conducted, there was at least one mention of children damage or impact on trees which usually followed some observation in the field. The types of damage that were mentioned frequently were:

- *Children train to cut trees or look for herding sticks destroy young trees (e.g. Sclerocarya birrea, Bombax costatum, Piliostigma reticulatum, Acacia nilotica)*
- *Children crude coppice trees for fodder (mainly Sclerocarya birrea and Balanites aegyptiaca)*
- *Children pull out seedlings for fun (any)*

- *Children hunt for rats and destroy euphorbia live-fences*
- *Children are scared to go far when herding livestock so there is overgrazing of fallows in the vicinity of village*

In the feed-back section, this was a vividly debated topic in which women, very quiet until then spoke out to confirm that children were a major source of damage. The debate went on for about 45 minutes where various suggestions were made by farmers. Amongst others such as awareness of the importance, involving the schools and teachers, developing a system of punishment and reward system for children, removing cutting objects from children.

5.4.4 Land tenure security

There are various ways in which land tenure security was raised as a constraint to planting or managing trees often for opposite reasons:

- The field is borrowed; if the cultivator starts encouraging natural regeneration he may 'spoil' the field and the owner may claim it back.

- The field is borrowed; if the cultivator starts encouraging natural regeneration he may 'improve' the field and the owner may claim it back for his own advantage.

- The field is borrowed; if the cultivator plants trees he may improve the land and the owner may take it back

- The field is lent; if the cultivator starts planting trees he may want to claim the land administratively and the owner may lose the land

- The land is securely owned but the large family is splitting and division of fields temporary , planting trees may be seen as an early claim to land which may cause family problems

- Women do not own fields and cannot plant trees without their husbands consent. The limitations of women inclusion in natural resource management are also raised by Monimart and Drame 2008).

6. DISCUSSION

6.1 Opportunities for provisioning services

The findings of this study confirm the importance played by a wide diversity of trees in the delivery of numerous ecosystem services that is increasingly reported about Malian parklands (Faye et al, 2010; Kalinganire et al., 2007, Gustad et al, 2004, Gosselin et al. 2007). The rarefaction of many tree resources and environmental degradation share similarities with those characterising in West African Sahelian parklands and the impact of woody vegetation change has a broad impact on the rural economy and welfare as a variety of provisioning services are declining (Wezel and Lykke, 2006). In a region where climatic and natural conditions permit little agricultural options and where conditions for land productivity are low, trees play a fundamental role in the provision of food diversity and food security (Kandji et al, 2006).

Ranking local needs and priorities is a tool increasingly used in participatory research. However as Gausset (2004) describes, ranking needs is a complicated matter which requires both an inter-disciplinary approach, significant time and resources and which often reflect only partial views. My objective was not to provide quantitative data on the preferential or priority trees or estimate of tree decline, however due to the extensive utilitarian knowledge held by farmers and elicited in the course of my research, some key points stood out which may be important to guide further research into understanding the contribution of different trees to ecosystem services.

6.1.1 Natural regeneration, tree diversity and food security

This research underlines the importance of edible trees in the village communities and the implication of the decline of important edible species such as *V. paradoxa*, *P. biglobosa*, *T. Indica.* These are of particular concern to villagers both because of its food value but also income potential. Understanding the overall and distinctive contribution of trees to food security is a particularly difficult subject because it is linked to the complex and integrated mechanisms for risk management of food scarcity within the community and within families (Mortimore et al, 2009) There are times when food is scarce and everyone has to cope by themselves ("se debrouiller"). I was explained that grain stock management differed widely from year to year and from a wide range of factors which make an identification of patterns difficult. However it is common practice in the event of

anticipated food shortages that the family headman close granaries temporarily and women or households have to cope. This is often the case towards the end of the dry season when family food stocks are reserved for the cultivation period when labour and strength is most needed. This can have significant implications for women as they are the ones 'coping' and have the responsibility to generate income and purchase grain. For example *P. biglobosa* bares its mature fruits in May and women who would have stored up for their own soumbala needs or for selling later in the season when the prices rise, may be forced to sell their production at the time when the price is at its lowest. So it is not only the final good provided by different trees but also their phenology which can be important in providing food or income at different time of the year. Other trees which are also in decline are *Detarium microcarpum, Ximenia Americana, Dyspiros mespiliformis* species mentioned as particularly important because children eat them. The information I obtained from interviews indicates that when food is scarce, parents rely on the availability of a wide range of products and tree habitats as an important source of nutrition for children who have to cope and find their own food such as fruits, bats and rats. Many of these species are disappearing or not regenerating. These findings suggest that the 'diversity of trees', their phenological characteristics and distribution would need to be addressed through a ethno-botanical survey to understand the implication of change and natural regeneration in the area for food security.

6.1.2 Income opportunities and implications

NTFP are traditionally known to be a source of income for the poorest requiring no cash investment (Boffa, 1999). However in the research area, this may have been the case when resources were abundant but today economically important trees (*V. paradoxa, P. biglobosa, T. Indica)* are becoming increasingly appropriated by field owners. It also appears that this process starts in the villages with highest population density and saturation of land (Bambara and Siradié). In the villages were access to these resources is restricted to the owner of the field, then household who have less trees in their fields have less access to these resources. Some of the farmers I interviewed had no *P. biglobosa* in their fields and their wives had to purchase all their soumbala. These were often the poorest farmers who have more marginal land. In general the vulnerability of *V. paradoxa* to drought and pests have been lower in more fertile soils and these tend to be mainly owned and cultivated by richer or headman family. Certain trees such as *Ziziphus mauritania, Bombax costatum* can provide income sources in the cold season when additional income is needed for paying taxes. In all the villages I noticed numerous old

women extracting *Sclerocarya birrea* seed kernels and was told this was a source of income for their own needs. Dogon women rely significantly on the trade of *Borassus aethiopium*. Other NTFP resource used by different user groups may have a conflicting uses that are not well reflected. *Sclerocarya birrea* and *Balanites aegyptiaca* are common examples as they are used for wood, medicine, fodder which is having an impact on the availability of fruits and regeneration. The results suggest that there is a wide variety of stakeholders that need to be addressed, understanding access to tree resources and different needs especially for the lowest income groups would be useful to gain a further insight into what diversification options exist and how these can be promoted.

6.1.3 Increasing fruit tree resources

The importance given to fruit tree species as a source of nutrition of income, the decline in resources combined with new knowledge and project support about tree management appear to be the source of motivation to engage in planting/protecting activities. The local Farakunna Cooperative convention supports the protection of natural regeneration. However in reality this is a difficult concept. There are opportunities for regeneration as some seed germination is occurring. However protecting these species is not a common practice in the area.

The establishment of the village nurseries is new concept and aims at supplementing natural regeneration with domestication of certain species are mainly *A. digitata, T. indica, P. biglobosa, V. paradoxa* as well as exotics. Some farmers (men and women from FVE groups) interviewed mentioned they would prefer to plant than protect natural regeneration because if they planted it then they would own the tree. All women expressed the wish to own their own V. paradoxa trees, the lack of trees is a major concern and source of quarrels between co-wives or other female relatives and the echoes I heard were that this was even an important reason for families splitting. Women want trees but as they will tell you, they do not own any fields and have to ask their husband's permission to plant. A permission which is not always granted, especially if there is more than one wife. Some farmers mentioned they were interested in planting trees because they could choose the location and the location is on the edge of the field. The experimentation of planting in live fences represents an opportunity for regeneration. However it is likely to be limited to farmers who have live-fences, which as a study conducted by Levasseur et al. (2004) underlined is farmers with a secured land ownership status and also wealthier status.

As the process of domestication starts it is very important to consider the implications for individualisation of land and tree ownership. Many of the poorer households may not have access to land that will permit them to plant trees. In many villages access to all NTFP is still opened to all, providing the harvest season is opened. In a conversation about planting *V. paradoxa* and the implications, with the doyen of the area and customary headman in a village (who is particularly interested in rejuvenation of the parkland), I asked him what would happen to this open rule when people will start planting, watering, protecting trees. Will the same rule apply? The answer was "of course not. Times are changing. Even the lazy ones will have to plant!" to which I asked what about those that do not own land? And "Well they will just have to cope (se debrouiller)!". Coping is a major strategy in the area and maybe illustrates why it is difficult for farmers to have a common long term vision. However without these coping mechanisms, subsistence may not have been possible.

The issue of land tenure is complex as mentioned in the result section. With individualisation it is likely that some farmers will invest more in the land but there are many villagers which will be excluded because land ownership as shown in the result section largely determines the extent to which you can plant a tree. The small scale domestication process is emerging for a few indigenous key trees which are in decline; however their slow growth is a factor constraining farmers. It is obviously difficult for farmers to engage labour and time to protect a seedling that will bear fruits in 20 years and any earlier growth development techniques are likely to be of importance in the area.

On the other hand if as Maranz, (2009) suggests that there is a shift in the suitability of certain species due to the southern shift of the rainfall isohyets, then it is difficult to predict if these protected species will survive the event of a drought. Because no one has been involved with protecting any seedling, there is no local knowledge about climatic or soil factors and the impact on seedling survival or juvenile tree establishment could be elicited. So it domestication appears to be an opportunity for planting indigenous trees, the success in tree establishment remains to be seen. This is a reason for focusing on the diversity of species in the landscape rather than individually targeting species. Maintaining biodiversity is critical in building the resilience of the system (Mortimore et al. 2009).

6.2 Issue of space, trade-offs and priorities

There is a fundamental difference between the recognised importance of a species and its value and the potential it may have to re-integrate the field. All farmers may value the shade of *Parkia biglobosa* to rest and recognise its positive soil fertility impact and, but its shading interference is such that there is only so many *P. biglobosa* farmers want in their fields. The fruits of *Vitellaria paradoxa* being mature during crop development stages, many farmers recall the damage to crops around trees done by women coming to pick fruits that were so abundant so the idea of having many *V. paradoxa* in their fields obviously doesn't sound good to them.

To say it simply tree resources benefit women (and the family) but trees are in men's field and the perception is that trees are a nuisance in the field. The main issue is space competition and the perception that trees in fields are an obstacle. The livelihood and land use system of farming households is structured not only around cultivated areas and fallows but also other areas such as Duwa Forest and bush land unsuitable for cultivation such as hills or rocky soils. This spatial resource endowment is important in explaining how farmers prioritise trees they would like to increase in their fields. Species naturally regenerating in fields and resistant to livestock or cultivation pressure are commonly abundant in the wider landscape (forest, bush land) and are known as invasive in the field even though they may have numerous utilities.

The potential of trees for ameliorating micro-climate (Boffa, 2000) are increasingly recognised and these are likely to play a key role in the event of droughts (Kandji, 2009). However eco-physiology of different trees is requires a deeper exploration to understand what the portfolio of trees in the area which are suitable to different terrains and to different needs is.

The success of FMNR in Niger for example was attributed amongst others to the need of the community in fuel-wood provision. In the research area this does not seem to be the case yet especially because of the Duwa forest. If women frequently refer to an increase in time spend collecting wood and a trend towards scarcity, farmers may not realise this urgency. Retaining trees for fuel-wood in fields is not a common practice in the area.

Farmers' main concern, as I reported in the result section, is the need to control water erosion. Improvements in life-fences or water barriers needs to be addressed further. *Jatropha curcas* cannot establish well as its roots don't survive the impact of water. In the course of the research some farmers identified local species which require further

investigation. The role of *Borassus aethiopium* could be important as its roots establish fast and retain water and knowledge about planting is available within Dogon communities.

The rehabilitation of the riparian zone is of ultimate importance to farmers. As Figure 2 shows the implications of the degradation of these zones are numerous. This is an area where both farmers owning the fields and the broader community could benefit from improvements through reforestation. Sedimentation is changing the bed of watercourses and increasingly flooding fields, the river bed is widening and the duration of water retention has significantly decreased. This in turn has reduced water availability for communities which rely on temporary wells dug along the watercourse and water availability for livestock. Furthermore this process is leading to loss of key biodiversity with loss of fish, caimans and key trees. Conservation of riparian tree species diversity has been raised by Wezel and Lykke (2006) as a very important issue in addressing local needs. The rehabilitation of the "marigot" beds has also been underlined in Coulibaly (2004) research in the area as being critically important for villagers. Indications show that other neighbouring communities without a temporary watercourse can travel significant distance to harvest fruits or medicine that are not present in their village area. The delivery of services of the watercourse occurs in the wider landscape.

6.3 Tree-crop-livestock integration

In Bwa villages, livestock integration is a very recent but galloping trend. However, traditionally they are not animal keepers (except women who raise pigs and poultry and men oxen for traction) and even have a very pejorative image of herding. This is mainly due to the numerous agro-pastoralist conflicts that have opposed farmer/herders in the area historically (Coulibaly, 2004).

Obtaining quantitative data on livestock heads from farmers is a sensitive issue and most farmers obviously avoid talking about how many animals they own for a variety of personal and social reasons. However, the reality is, according to some farmers interviewed, that 'some' farmers own more livestock now than the sedentary herders in the area and that a large share of the damage, experienced every year, to crops or fodder trees is internal to villages In the feed-back session the role of animals was extensively discussed and farmers added that 'without animals life wouldn't be possible anymore' (see plate 10 for an illustration of a herd size).

Plate 10 Child herding livestock in Bambara, picture taken on the 26/07/2010

The decrease in rainfall reported in the northern part of the Tominian district suggests that the annual rainfall may not be exceeding 500 mm in the last decades (Sahel Eco 2006). This trend could be illustrative of the study conducted by Mortimore and Turner (2005) where the threshold for livestock to be more productive than agriculture lies between 400mm to the 600mm/year precipitation. Encouraging and promoting mixed farming in the area is likely to improve income sources but there are significant constraints. Firstly a large knowledge gap in animal husbandry; indications are that feed management strategies are very poor, there is no veterinary knowledge, and farmers admit not vaccinating their animals because it is too expensive. There are no adequate keeping facilities and an increasing number of animals attached here and there to houses, granaries, wood logs during the rainy season. For the rest of the year animals are extensively kept and the prevailing strategy of leaving the animals cope by themselves ("se debrouiller") is an important pillar of management practices where supplemented fodder is used mainly for specific objectives such as fattening purposes, reproduction or in emergency. Although farmers are aware of the loss of manure that is involved in leaving the animals to roam freely, in the feed-back session I was explained that the lack of feed and water availability meant that livestock had to feed themselves and look for their own source of water. There wasn't enough water in the village to give to all animals.

Though it is difficult to make a generalisation from 2 interviews, it is not surprising to find that Fulani showed a significantly different knowledge of tree fodder resources available

locally. *Khaya senegalensis* was highly valued by the Fulani families interviewed. 3 Bwa farmers mentioned the milk was bitter and the kids wouldn't drink from their mothers if they had been fed the leaves of *K. senegalensis*. The Fulani farmers said both cattle and goats were used to it and the leaves gave them strength. *Celtis intergrifolia* was extremely valued by Fulani but many Bwa farmers ignored its use although one trader in livestock (newcomer to the village) was fattening his sheep and supplemented their diet with *Celtis intergrifolia*. Though *Celtis intergrifolia* is mentioned (Le Houerou 1980) as a fodder source, I found no scientific evidence that supports the value 2 Fulani herders mentioned 'as one of the most important species' because 'when you feed the leaves (in the dry season) to weakened cattle they find the 'strength' to stand up. It would be useful to explore if that knowledge was widely available and what are the implication for this riparian specie which is not regenerating and scarce.

Pterocarpus erinaceus which is highly valued as a nutritional source has considerably diminished and is also located primarily in the Duwa forest. Due to heavy lopping and felling for timber, farmers confirmed there was little regeneration. However this is a leguminous tree which has received much attention recently for its fodder value which is an important commodity in Mali (Faye et al. 2010). *P. erinaceus* potential in fodder bank has been investigated by (Franzel, 2007) who suggests the adoption is likely to be farmers interested primarily in fattening or who have fodder shortages primarily. Due to the high quality of its wood for construction and tools, the potential to increase *P. erinaceus* in the research area could have some benefits. However, given that it is a protected tree by the Malian Forestry Code this species may only interest farmers if they have the right to own the tree.

Livestock although associated with the lack of fruit seedling survival is a major dispersal agent of different species (e.g. *Balanites aegyptiaca, Faidherbia albida, Acacia seyal*) which is important in shaping new vegetation features which are themselves sources of fodder. *F. albida* is the most commonly integrated new regeneration in the area as it is perfectly suited to the tree-crop interaction with its reverse phenology. However, farmers identified it didn't grow everywhere (not on shallow soil nor gravelly) so there are spatial limitations to its distribution which concern farmers. Some key species were identified by farmers as not regenerating because of heavy lopping was preventing fructification. If a better integration of fodder and animal nutrition could make some improvements, the problem of water still remains a constraint to farmers maximising livestock potential of manure return and better animal health.

6.4 Beyond the 'clean field' cultivation ethos – FMNR

Agroforestry techniques such as FMNR and planting through the development of village nurseries are emerging practices. These extension and participatory intervention are developed amongst others through a farmer leader training network which disseminates information through village assemblies and personal communication within agroforestry promotion groups (roughly half of which are women) and any volunteers they recruit to re-green their villages. The practice is still at an early stage but FL are themselves innovating with FMNR techniques they have learnt in Bankass. Apart from farmer leaders who have been managing natural regeneration for tree growth of *P. reticulatum* and *G. senegalensis,* no farmer interviewed had taken up on the technique yet. FMNR has been translated in bomu language by local FLs as 'vewa ne hun', which literally means 'trees that you leave'. The etymology of this expression is very revealing of the concept of field management prevailing in the area which is to remove trees. A FL also reported anecdotally that his neighbour seeing all the stems he had purposely retained and pruned decided he had probably forgotten to cut them so he went in his field to help and cleared all regeneration. In general leaving woody vegetation is a sign of laziness or craziness to the Bwas who prides in being good cultivators. When I asked FLs how they thought the practice was going to scale up, FLs all seemed confident that when the other farmers would see the benefits to their land they would start doing the same. Because they, themselves, had learnt in Bankass that 'fields didn't like to be clean'.

Plate 1 Young Faidherbia albida seedling

7. CONLUSIONS AND RECOMMENDATIONS

This study illustrates that although many key indigenous tree species are declining, the tradition of planting or nurturing natural regeneration is not present in the area. Though farmers have an extensive knowledge of the human and ecological factors affecting natural regeneration, ideas to actively remedy the situation comes largely from the 'outside'. Farmer managed regeneration in the area has a potential in the sense that there is vegetative regeneration from both root-stock and seed dispersal for many species. However integrating these species spatially in the field remains problematic because most farmers see trees as nuisance in cultivation. The improvement of markets for shea butter and honey are encouraging farmers to enhance certain key tree resources. Women are the primary beneficiaries to NTFP and the vested interest in promoting and acquiring their 'own tree' however they have no access to land. With the commercialisation of the final goods developing, the appropriation by men of these resources must not be overlooked. Furthermore tenure security is a major factor restricting certain villager categories from tree planting.

The research has also highlighted that although the decline in certain key species are of particular concern, there are many species which are not regenerating at all due to lack of fructification. The loss of tree diversity in the broader scale is of particular importance and would need to be addressed through an ethnobotanical survey and comprehensive stakeholder analysis. The research suggests some categories but the scope and time spent in the research area are to minimal to make broader recommendations.

Livestock management is a key area where local farmers need technical knowledge. The increase in livestock and the potential for integrating trees-livestock and crops have been shown to improve smallholders in the semi-arid zones. The trend in the area suggest that the system is gradually moving towards mixed farming. However the promotion of livestock integration requires improved feeding strategies. Detailed information about tree fodder and their potential in improving animal productivity and health is needed in the area.

This research also confirms that the degradation of the "bas-fonds" is a serious issue with broad implications for the community and which requires urgent research and intervention.

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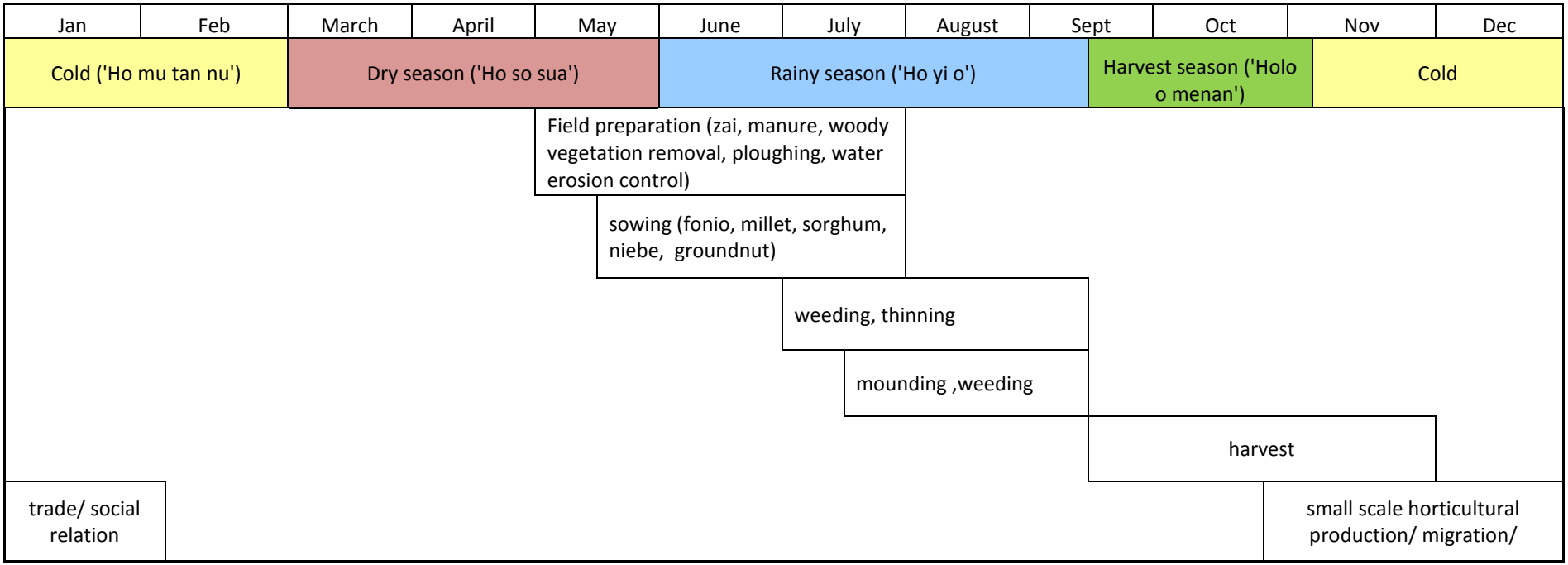
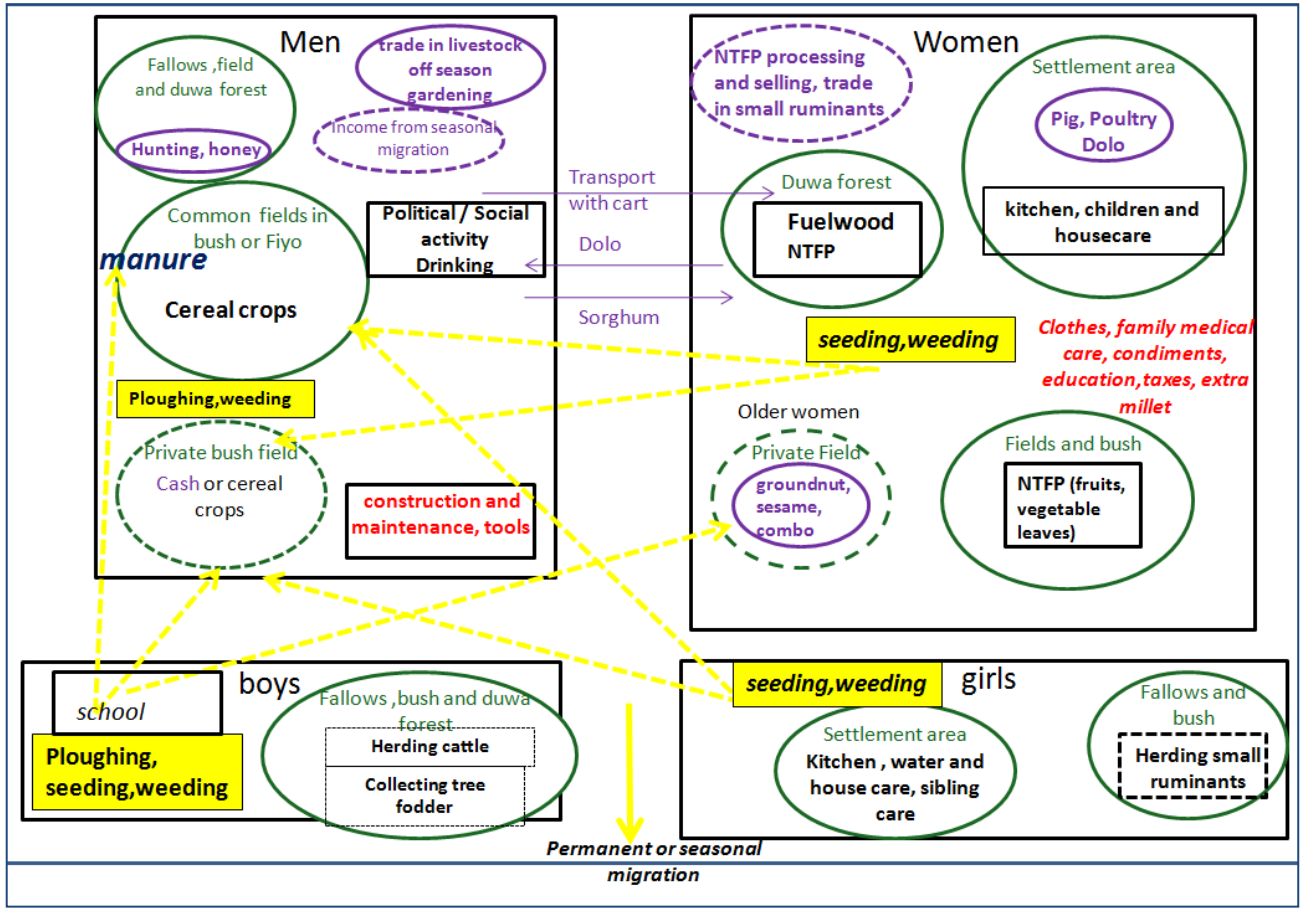
APPENDIX I Calendar of seasons and agricultural activities in villages bordering the Duwa forest in the district of Tominian, Mali



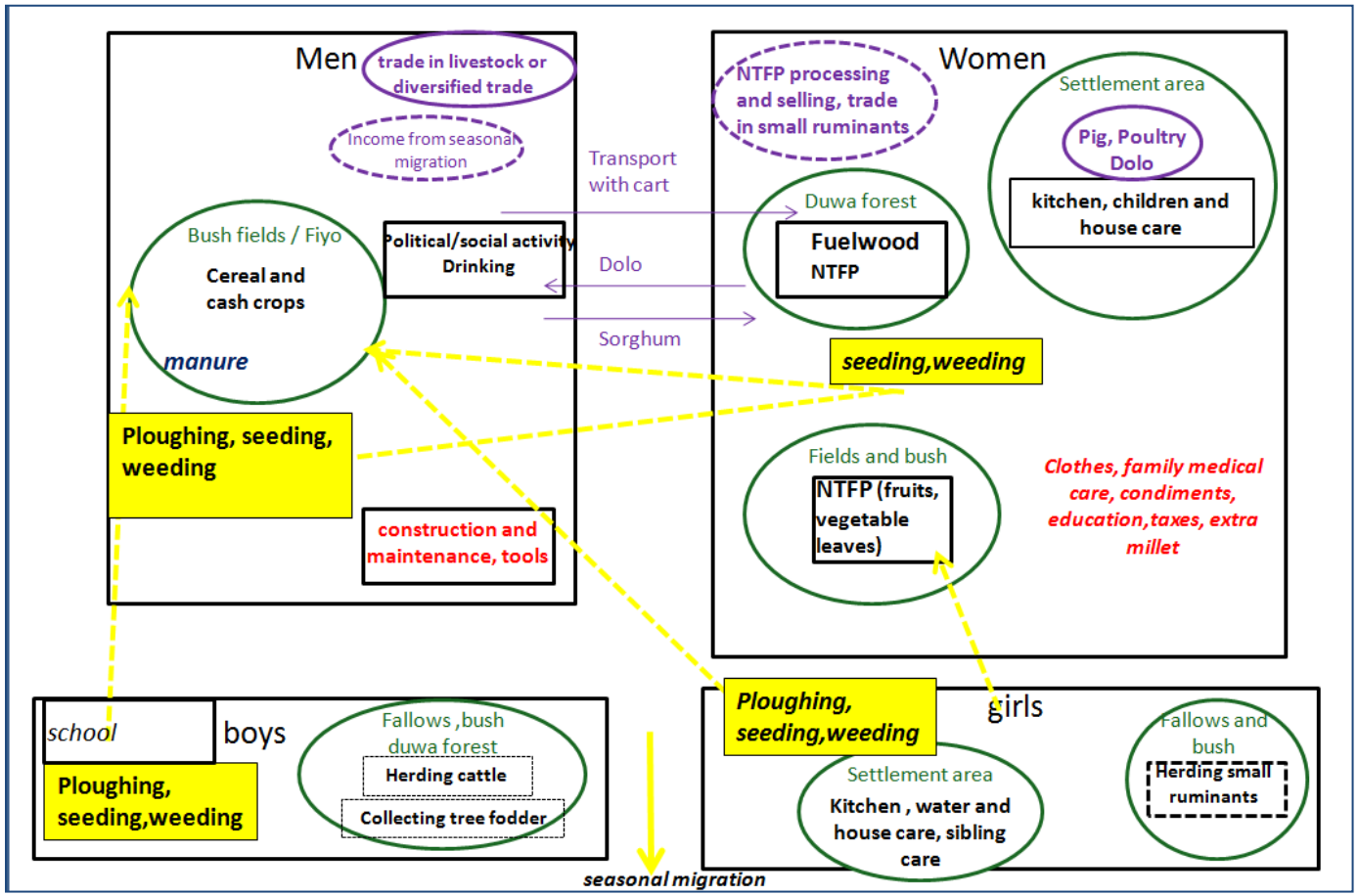
APPENDIX II Land use and Livelihood Diagrams

a) Land use and Livelihood Diagram - Large Agricultural Production Unit (family compound in Bwa villages)



LEGEND:
Green circle: land use type
Black boxes: activity
Yellow : labour
Red: expenditure
Purple: income

b) Land use and Livelihood Diagram Small Agricultural Production Unit (household compound in Bwa villages)



LEGEND:
Green circle: land use type
Black boxes: activity
Yellow : labour
Red: expenditure
Purple: income

APPENDIX III List of protected species in the area according to different legislation and rules

Customary by-laws[6]	Farakunna Convention 2009[7]	Malian Forestry Code[8]
Parkia biglobosa	***Parkia biglobosa***	***Parkia biglobosa***
Vitellaria paradoxa	***Vitellaria paradoxa***	***Vitellaria paradoxa***
Lannea microcarpa	***Lannea microcarpa***	*Anogeisus leiocarpus*
Sclerocarya birrea	***Sclerocarya birrea***	*Borassus aethiopium*
Tamarindus indica	***Tamarindus indica***	*Khaya senegalensis*
Adansonia digitata	***Adansonia digitata***	*Pterocarpus erinaceus*
	Saba senegalensis	*Faidherbia albida*
	Bombax costatum	***Bombax costatum***
	Banalites aegyptiaca	
	Lannea acida	
	Ziziphus mauritania	
	Detarium microcarpum	
	Ximenia americana	
	Dyspiros mesiliformis	
	Vitex doniana	

[6] From information elicited in the villages and from interviews with the president of Farakunna Cooperative

[7] Syndicat Intercommunal Sinignesigui (2009) Convention Intercommunale de gestion durable des ressources naturelles de la Foret du Duwa. Ministère de l'Administration Territoriale et des Collectivités locales, Région Ségou, Cercle Tominian.

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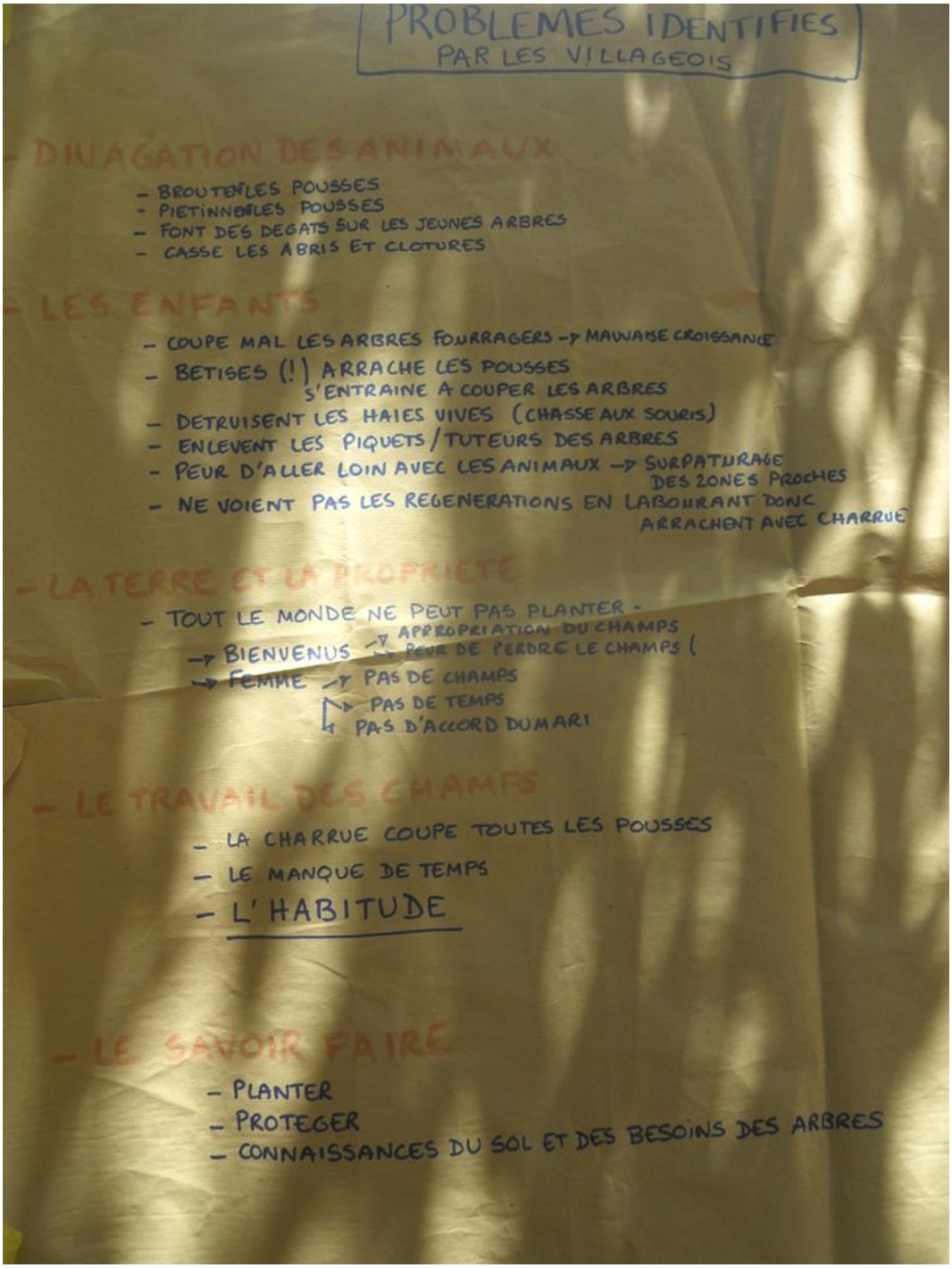
APPENDIX IV List of trees and their corresponding vernacular names in local languages

Scientific name	French	Local (Bomu)	Local (Bambara)	Local (Dogon)
Acacia macrostasya		Hibiru ouè ouè-nou	Donkori	Bagondo
Acacia nilotica	Arbre du griot	Amoro	Bana	Banga
Acacia seyal	Gommier	Hibiru Fonu	Uanidjema	Sangala pili
Adansonia digitata	Baobab	Inyan	Sira	Oro
Afrormosia laxiflora		Covanro		
Anogeisus leiocarpus	Bouleau d' afrique	Eminu	N'galoma	Uwin
Banalites aegyptiaca	Dattier sauvage	Bodyo	Zegene	Miyene
Bombax costatum	Kapokier	Do'oro	Bunbun	Tugele
Borassus aethiopium	Rônier	Oro	Sebe	Kongo
Cassia siberiana		Sinsan biru	Sisan Fin	Iribololu
Combretum aculeatum		Duwa	Don	
Combretum gazhalense		Maco	Cankala	Adanga
Combretum glutinosum		Maco ono		
Combretum micranthum		Bumaho		
Daniella oliveri		O'onu	Sana iri	Cadja
Detarium microcarpum	Detarium	0'o	Tabakumba	Hodu
Dyspiros mesiliformis	Ebenier de l'Africain	Boro Iwe	Sunsun	Kongo
Faidherbia albida	Cad/kad	Vigninu	Balanzan	Kuni
Feretia apodanthera		Vinue		
Ficus exasperata	Figuier	Cowono	Torontoge	
Grewia bicolor		Nono	Nogo'nogon	Djeyi
Guiera senegalensis		Suncave	Hundje	Boburu
Khaya senegalensis	Caïlcedrat	Penu	Yala	
Lannea acida	Raisinier acide	I'o	Bembe	Sasunru
Lannea microcarpa	Raisinier	Gninu	N'pegu	San
Parkia biglobosa	Néré	Dui	Nere	Yolo

Scientific name	French	Local (Bomu)	Local (Bambara)	Local (Dogon)
Prosopis africana		Aanu	Gwele	Kila
Pterocarpus erinaceus	Vène	Yeho	Gueni	Uin
Pterocarpus lucens		Daba'ara	Dabakala	Biyala
Saba senegalensis	Zaban	Gnanu	Zaban	Kembe
Sarcocephalus latifolius		Oho		
Sclerocaria birrea	Prunier	Unle	N'guna	Bin
Sterculia tomentosa ?		Pecua	Kongonsira	
Tamarindus indica	Tamarinier	Mugnu	Tomi	Umu
Terminalia macroptera		Huanu	Mununa	Suein
Vitellaria paradoxa	Karite	Va	Shi	Midji
Vitex doniana	Prunier noir	Orobiru	Koronifi	Muna
Ximenia americana	Prunier de mer	Conconyave	Tonke	N'pede
Ziziphus mauritania	Jujubier	Tobo	N'tomono	Wele

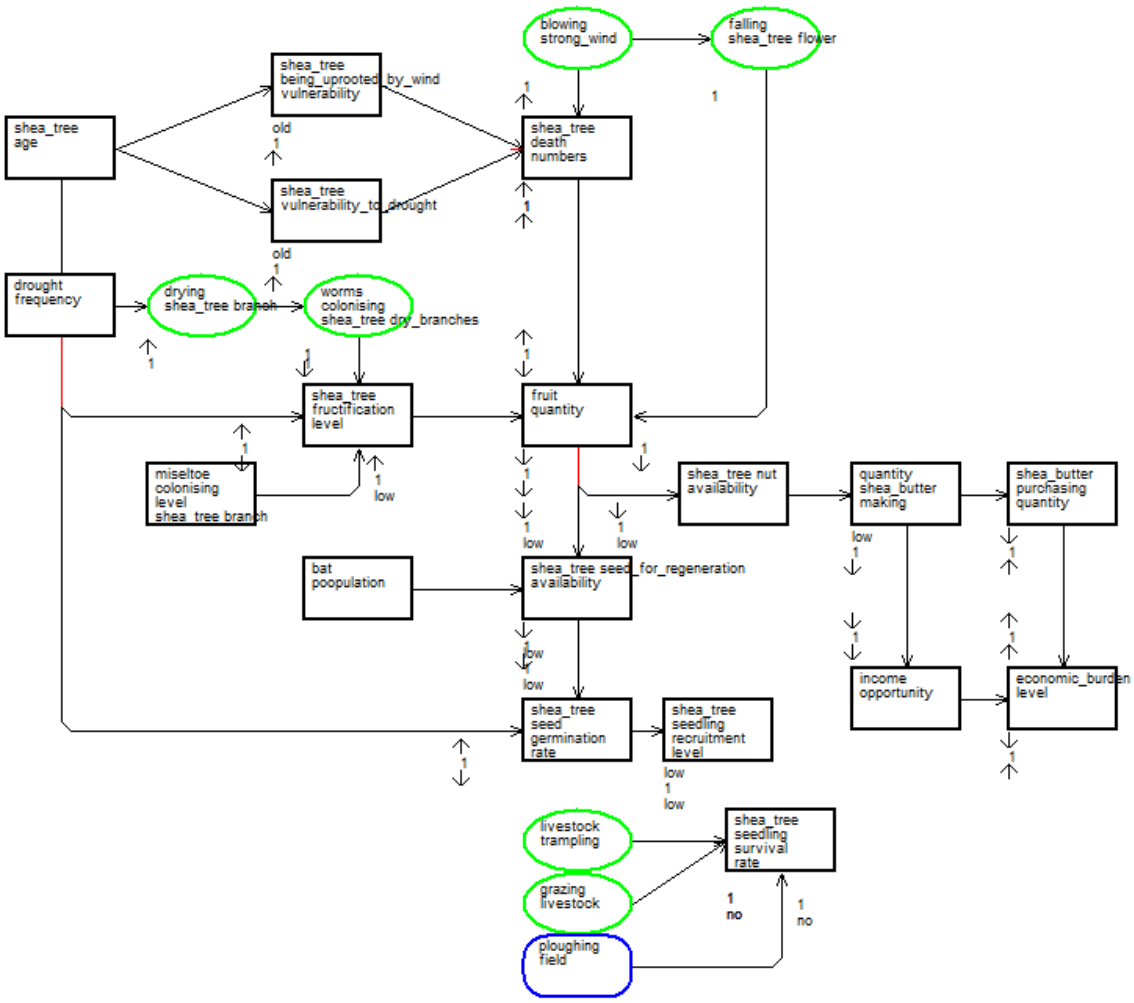
APPENDIX V Feed Back Session Poster

Photograph of the poster highlighting the main problems identified by villagers to increasing trees in fields and discussed in the feed-back session on the 02/08/2010



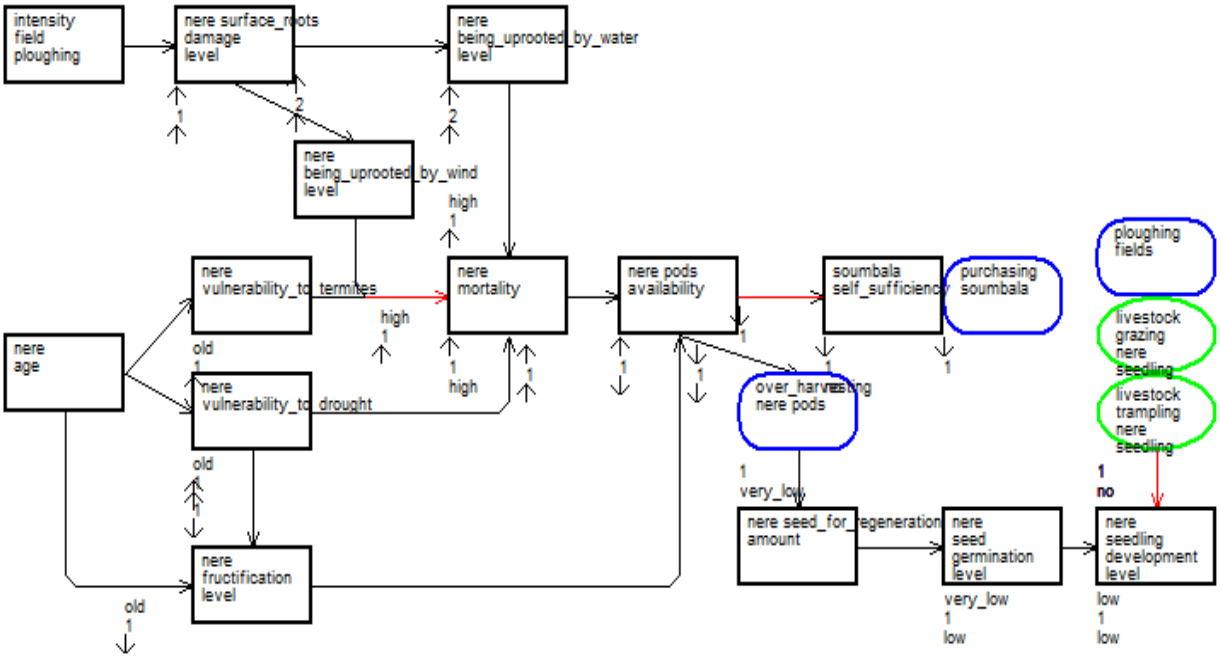
APPENDIX VI AKT diagrams on the regeneration of fruits trees

1. AKT Diagrammatic representation of the local knowledge about factors affecting Vitellaria paradoxa regeneration



Legend: Nodes represent human actions (boxes with rounded corners) or attributes of objects, processes or actions (boxes with straight edges). Arrows connecting nodes denote the direction of causal influence. The first small arrow on a link indicates either an increase (↑) or decrease (↓) in the causal node, and the second arrow on a link refers to an increase (↑) or decrease (↓) in the effect node. Numbers between small arrows indicate whether the relationship is two-way (2), in which case ↑A causing ↓B also implies ↓A causing ↑B, or one-way (1), which indicates that this reversibility does not apply. Words instead of small arrows denote a value of the node other than increase or decrease

2. AKT Diagrammatic representation of the local knowledge about factors affecting Parkia biglobosa regeneration



3. AKT Diagrammatic representation of the local knowledge about factors affecting Tamarindus indica regeneration