Trees for Livelihoods

Insights into Practice and Adoption of Agroforestry in Tiby, Mali

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LIST OF ABBREVIATIONS

AF	Agroforestry
AFS	Agroforestry System
ANR	Assisted Natural Regeneration
BBN	Bayesian Belief Network
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza – Tropical Agriculture Research and Education Center, Costa Rica
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement – Agricultural Research for Development, France
CPT	Conditional Probability Table
CSIC	Consejo superior de Investigaciones Cientificas – The Spanish National Research Council
FCFA	Franc de la Communauté Financière Africaine
FunciTree	Functional Diversity: An Ecological Framework for Sustainable and Adaptable Agro-forestry Systems in Landscapes of Semi-arid and Arid Ecoregions
GDP	Gross Domestic Product
HDI	Human Development Index
ICRAF	World Agroforestry Centre
IER	Institut d'Économie Rurale – the Institute of Rural Economy, Mali
ISRA	Institut Sénégalais de Recherches Agricoles – Institute for Agricultural Research, Senegal
LCD	Least Developed Country
MVP	Millennium Villages Project
MVRP	Millennium Villages Research Project

NINA	Stiftelsen Norsk Institutt for Naturforskning – the Norwegian Institute for Nature Research
OECD	Organisation for Economic Co-operation and Development
ORS	Office Riz Ségou
SL	Sustainable Livelihoods
SLA	Sustainable Livelihoods Approach
SLF	The Sustainable Livelihoods Framework
UNDP	United Nations Development Programme
UW	University of Wageningen, Netherlands

MAP OF MALI

Source: http://www.lib.utexas.edu/maps/africa/mali_pol94.jpg (retrieved 12 May 2011)

The fieldwork site in the Ségou region is marked:

1. INTRODUCTION AND BACKGROUND

During the 1960s and 1970s agricultural intensification was promoted via the introduction of improved crop varieties in Africa to eradicate hunger problems. The approach was based on the so-called ‘Green Revolution’ that had been a success in other parts of the developing world, in particular in Latin America and Asia. The adoption of new crops by African farmers was, however, very low. It proved to be more difficult than expected to apply the concept at another continent with tremendously different conditions without conducting intensive research beforehand (Evenson and Gollin 2003). Problems of poverty, hunger and environmental degradation remain prevalent in sub-Saharan Africa and issues like increasing population growth and the consequences of extreme weather events that come along with climate change pose additional threats – especially in very vulnerable areas like the Sahel. Along with these, market fluctuations make livelihoods of rural farmers particularly difficult. They find themselves confronted with various problems, risks and uncertainties that endanger their livelihoods.

The rise of the concept of agroforestry (AF) lifted up new hopes as it promises to provide sustainable solutions to problems of both food insecurity and environmental degradation:

> In the wake of the frustrations arising from the Green Revolution’s failure to benefit poor farmers, and from escalating land-management problems, such as tropical deforestation, fuel wood shortage, and soil degradation, the development community embraced this ‘new’ concept with unprecedented enthusiasm as a magical development vehicle, with a perceived relevance to ‘difficult’ or ‘fragile’ environments and resource-poor conditions. (Nair 1998: 224)

Scholars agree about the important role, agroforestry can play for improving farmers’ livelihoods. But a continuing dilemma is the contradiction between safeguarding rural livelihoods against the background of the mentioned problems via agricultural intensification and at the same time promoting the adoption of improved and sustainable natural resource management (see also: Barrett et al. 2002: 1).

This thesis aims at investigating the decision-making of farmers in a village cluster in rural Mali. A theoretical background is provided by results of previous research on agroforestry adoption and the Sustainable Livelihoods Framework. The focus lies on the context influencing farmers' choice of different livelihood strategies, and on diversification as a strategy to reduce risk and uncertainty at the farm level. It will be investigated if and how agroforestry can function in this framework. A particular focus lies on multifunctional agriculture that includes trees and how it can contribute to tackle risk, uncertainty and environmental problems in farm households. This study aims to contribute to the scientific debate about agroforestry adoption and improved natural resource management, which includes agroforestry.

1.1 Problem Statement and Case

Agroforestry can play an important role in the improvement of land use patterns in rural Mali. However, the "gap between advances in agroforestry science and the success of agroforestry-based development programs and projects" (Mercer 2004: 311) is a problem that needs to be tackled. Although research on agroforestry adoption has increased, there is still a lack of knowledge about decision-making processes at the farm household level. Various factors influence the behaviour of farmers, of which biophysical, resource factors and risk are among the most important ones (Pattanayak et al. 2003). To gain more knowledge about how existing agroforestry practices and adoption can be improved, it is necessary to learn more about farmer characteristics and what their own perceptions and preferences are. Moreover, it is of interest to find out more about how the adoption of agroforestry practices can contribute to making the livelihoods of farm households more sustainable.

This study is concerned with the reasons for adoption and non-adoption of agroforestry in rural households in Tiby, a village cluster located in the Ségou region of Mali. Although, traditional forms of agroforestry – especially parklands, live fences and home gardens – have for a long time been common in this area, there are a lot of issues that restrain AF adoption, practice, maintenance and innovation. Some of these are: The on-going cultivation of more and more land, deforestation, unfavourable ecological conditions, extreme climatic events and a slow regeneration of trees (FunciTree 2010). It is necessary to find out how these and other factors influence farmers' attitudes towards agroforestry.

The FunciTree project with which this master thesis is connected regards agroforestry practices that are adapted to local preferences and functional needs as a solution to biodiversity loss and rural poverty. This is why the project "proposes to work directly with farmers to identify the most pressing barriers to sustainable production" (FunciTree 2010: 7). The aim is to find out more about farmers' attitudes and the socio-economic settings that influence their decision-making in order to gain a deeper insight into the main challenges to adoption and maintenance of agroforestry practices. Thus, solutions and improvements to make them more efficient and better adapted to farmers' needs may be found.

1.2 Objectives and Research Questions

This thesis aims to contribute to finding out more about adoption and non-adoption of agroforestry in Tiby, Mali. It focuses on local farmers' perspectives in the context of their land use and tree management patterns and on identifying factors that influence their decision to integrate or not integrate agroforestry practices into their farm production systems. To define some of the various issues that possibly play a role in household decision-making and tree adoption behaviour, important aspects of main household characteristics and farm activities are being investigated. Thus, different groups of farmers with common traits and features can be identified. By figuring out major similarities of and differences between these groups, conclusions about which factors are most influential for adoption and non-adoption can be drawn. One goal is to provide information about which variables should be focused on in the future and how they have to alter so that the adoption rate of agroforestry practices can increase.

The objectives of this study can be divided into the following interrelated research questions:

- Which factors influence the decision of farmers to adopt or not adopt agroforestry practices? (**1**)
- What are farmers' perceptions of possible benefits related to multifunctional trees? (**2**)
- Which role do risk and uncertainty play in the adoption of trees in the farm system? (**3**)
- Which are the common characteristics of and differences between adopters and non-adopters? (**4**)

1.3 Contextual Background

For a better understanding of the subject this thesis focusses on, the contextual background will be presented in the following section. This includes information about Mali and the Ségou region, agroforestry, the projects the study is connected to and the fieldwork site.

1.3.1 Mali – Poverty and the need for sustainable land use

In the Human Development index (HDI) of the United Nations Development Programme (UNDP) of 2010, Mali is ranked 160 out of 169 and, thus, belongs to the world's poorest countries with a low human development (UNDP 2010). It is one of the world's Least Developed Countries (LDCs) (Colin de Verdière et al. 2009) and economically weakest states with a GDP per capita of 688 US dollars (UNDP 2010).

Mali has a population of circa 13.3 million inhabitants and an area of 1.240.000 km² (OECD 2009), of which most of the middle and Southern part belongs to the semi-arid Sahel region, a landscape, which is characterised by savannah woodlands, grassland, thorny bush (Mortimore 2001), and a low precipitation rate that lies by 100 to 600 millimetres of long-term annual rainfall (Benjaminsen and Lund 2001). As Benjaminsen and Lund (2001: 10) state: “The Sahel as the poorest region in the poorest continent of the world is the home of people who face tremendous challenges to their livelihoods.”

Due to a high variation in climate that is predominant in that zone, there are a lot of agronomic problems. In addition, effects of global climate change make the traditional agropastoral region even more fragile and prone to food crises and climate accidents (OECD 2009) than it has already been for a long time. In the beginning of the 1970s, major droughts happened, which led to debates on natural resource management and on the high population growth in the instable region (Mortimer 2001). Still today, West Africa has one of the highest population dynamics in the world, while at the same time; there are low life expectancy rates and high mortality rates, especially among children. Moreover, diseases like Malaria are predominant (OECD 2009).

At the same time as populations are growing, their livelihoods and well-being are to a large extent dependent on natural resources from functioning agricultural and ecosystems (Benjaminsen and Lund 2001). However, unpredictable rainfall makes agricultural and livestock management difficult as plant growth varies from year to year. The rising demand for food by a growing number of people causes that more and more of the land area is used for cultivation. Thus, herding land becomes scarce although pasture has traditionally been the dominant agricultural activity in the Sahel (UNEP 2002) and the demand for livestock production is rising as well. More than half of the Malian population live in rural areas and work in agriculture, livestock breeding and forestry (OECD 2009). Despite the important role of agricultural activity for livelihoods, 60 per cent of the inhabitants of Mali live on degraded land. (UNDP 2010)

The main part of the population belongs to the ethnic group of the Bambara, related or sub-ethnics that share an almost similar language and comparable traditions with the Bambara[1]. Mali's official language is French but de facto is Bambara[2] the national language which is spoken by huge parts of the population (OECD 2009: 64) although there are further important languages spoken by other ethnic groups, like Fulani, Songhai or Tamasheq.

Islam is the most common religion in Mali and is practised by circa 98 per cent of the population. There is nevertheless some influence remaining from traditional religions as well (Colin de Verdière et al. 2009: 60).

Politically, on the other hand, Mali is one of the most stable countries in West Africa and has a comparably high rate of decentralisation and participation (OECD 2009: 106). The country became independent from the former colonial power France in 1960 and has since then, like many other African countries, gone through a time of transition. In 1991, after 23 years of military rule, public uprising led to the establishment of a democratically elected government that has been stable ever since and led to many democratisation and decentralisation initiatives (Dehnbol 2001: 104). Instability and uproar are rare in Mali, but conflicts about natural resources tend to become more and more common, especially in places where pastoralism competes with crop cultures over land (Oksen 2001).

1.3.2 Agroforestry

"Agroforestry is a modern word for a concept that farmers in Africa and other tropical areas have practised for decades." (Jonsson 1995: 7). Indeed, the insight that integrating trees in the agricultural production system of a farm is not new and agroforestry has always been practised in one way or another. However, in the recent decades – especially in places where natural vegetation needed to make space for agriculture on a large scale[3] – it has been rediscovered as a way to sustain trees in spite of changes and modernisation.

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[1] All of those groups belong to the Madinka people.

[2] Or closely related Manding languages.

[3] In the 30 years after 1950 more land had been converted into cropland than between 1700 and 1850 (ICRAF 2008).

The term ‘agroforestry’ came up in the end of the 1970s when the awareness of the roles of forests and trees started rising due to growing environmental problems and food shortages in marginalised regions (Nair 1985). The pressure on agricultural land was increasing and droughts in the West African Sahel region caused that tree cover decline was recognised as a problem that needed to be tackled. From that period on, public and scientific interest in agroforestry advanced (Boffa 1999) and in 1978 “The International Council for Research in Agroforestry” (ICRAF) was founded. The organisation has since then played an important role in researching and promoting sustainable agroforestry in developing countries. Since 2002, ICRAF is called ‘the World Agroforestry Centre’ (ICRAF 2011b).

The following definition of agroforestry by Lundgren and Raintree (1983: 2) has been most widely agreed upon and quoted in diverse ICRAF – and other – publications:

> Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and / or animals, either on the same form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between different components.

The main characteristics of agroforestry systems are: There is always at least one woody perennial (a shrub or tree) involved; there are at least two outputs; the cycle is more than a year; and the most simple system is ecologically and economically more complex than a monocropping system. There is quite some variation in the components that an agroforestry system can have: While an agrisilvicultural system is a combination of crops and woody perennials, a silvopastoral system consists of an animal component and trees or shrubs. An agrosilvopastoral system, on the other hand, includes all three components, trees or shrubs, crops and animals[4]. In addition, there are various subsystems and other specialised agroforestry practices.

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[4] In this case, there are three outputs.

However, “agroforestry, as it is practiced, is very rarely a whole farm or forest system. It is much more common for trees to be used in various productive niches within a farm, which is increasingly how agroforestry is being viewed and defined.” (Sinclair 1999: 162). For this reason, it will normally be referred to the term ‘agroforestry practice’ and occasionally to the expression ‘agroforestry type’ in this thesis as long as there is no distinctive classification of an ‘agroforestry system’ given.

The most common traditional form of agroforestry in the Sahel region is agroforestry parklands. In those, several scattered trees are present in fields that are actually used for crop cultivation. Farmers cut down most trees for making space for crops, but leave single ones they consider most useful and valuable as they provide food, fodder or other services. The main goals of maintaining trees in the fields are to diversify farm production and to improve the ecological stability of the cropland. Other common AF practices are for example tree gardens, hedgerow intercropping, boundary planting, windbreaks and shelterbelts, live fences, home gardens and fodder banks (e.g. Nair 1985, Young 1989, Sinclair 1999).

A wide range of trees is used for different agroforestry practices, which offer an even wider range of functions: There are fertiliser trees that can contribute to land regeneration, soil stability and food security. There are fruit trees that provide nutrition for humans and fodder trees that can improve livestock production. Moreover, timber and fuel wood trees are being used for shelter and energy. Medicinal trees can help fighting diseases and there are trees producing gum and other products. As the World Agroforestry Centre (ICRAF 2011c) outlines it:

> Agroforestry provides many livelihood and environmental benefits, including: enriching the asset base of poor households with farm-grown trees; enhancing soil fertility and livestock productivity on farms; linking poor households to markets for high-value fruits, cash crops and medicines; balancing improved productivity with sustainable management of natural resources; Maintaining or enhancing the supply of environmental services in agricultural landscapes for water, soil health, carbon sequestration and biodiversity.

However, the degradation of traditional agroforestry parklands is an increasing problem due to various reasons: droughts; rising population pressure that leads to the shortening or complete abandonment of fallows; an increasing mechanisation and land use activities conflicting with agriculture, like extensive grazing and deforestation (Teklehaimanot 2004). Especially in the regions in the world that are at the same time suffering from extreme poverty and rapidly rising populations – mainly in East and South Asia, in Latin America and in Sub-Saharan Africa – the demand for food is growing steadily and agriculture plays a large role in reducing poverty, food insecurity and at the same time, maintaining environmental stability. The pressure on agriculture and ecosystems to provide food, fibre, fodder and energy is very strong and a lot is expected from agroforestry. There is a clear trend: The number of trees in the forests worldwide is decreasing while there are more and more trees on farms. It is important that modern agroforestry fulfils both roles, contributing to improving the incomes of poor rural households and stabilising agricultural systems by keeping ecosystems functioning (ICRAF 2008).

The role of agroforestry has already changed a lot during the last years but it still needs to adapt more to current challenges. One problem is that there is not a very high number of tree species used which would offer a larger range of functions. Also, many species are introduced from the outside and not very suitable for the ecosystem of the region where they are used (FunciTree 2008). While older AF practices mainly focused on improving agricultural productivity and livelihoods, improved practices also have to adapt to problems that come along with climate change and the continuing loss of biodiversity (ICRAF 2008).AF is also an accepted greenhouse gas mitigation strategy (Takimoto et al. 2008). Moreover, they have to contribute to improving the livelihoods of farmers in vulnerable areas. Prevailing problems, like land degradation, low market prices and institutional weakness require “a modernization of AFS that meet the specific requirements of local landowners, but whose capability to provide regionally and globally important ecosystem services is imbedded.” (FunciTree 2008: 5).

There are various traditional agroforestry practices that could be improved and combined to fulfil the manifold requirements mentioned above. Windbreaks and shelterbelts, trees on pasture lands, trees on fallow lands, trees on cropland and tree plantations in combination with crops, trees used for erosion control (Jonsson 1995) and live fences are examples for practices that can be further developed and adapted to current demands. An important aspect can be the establishment of more silvopastoral or agrosilvopastoral systems through the integration of animal breeding.

1.3.3 The project background

As this thesis is connected to different projects and institutions, it is important to take a closer look at the backgrounds of those.

The FunciTree project

The research for this study is connected to the 'FunciTree' project: 'Functional Diversity: An ecological framework for sustainable and adaptable agro-forestry systems in landscapes of semi-arid and arid ecoregions' of the European Commission. The research project, which is a collaboration between seven different European, African and Latin American research institutions[5], has started in 2009 and has a duration of four years. The coordinating institution is the Norwegian Institute for Nature Research (NINA). FunciTree has three different project sites, in Nicaragua, in Senegal, and in the Ségou region of Mali. While the fieldwork assistants and me took part in a methodological workshop at the site in Senegal prior to the field research, the actual research for this thesis was conducted in Mali. The institution cooperating with the FunciTree project there is the governmental "Institut d'Economie Rurale" (IER) (FunciTree 2008).

[5] The participating research institutions are The Norwegian Institute for Nature Research (NINA); The Tropical Agriculture Research and Education Center (CATIE), based in Costa Rica; the Dutch University of Wageningen (UW); the Spanish 'Consejo Superior de Investigaciones Cientificas' (CSIC); the French 'Centre de coopération internationale en recherche agronomique pour le développement' (CIRAD); the 'Institut Sénégalais de Recherches Agricoles' (ISRA) and the 'Institut d'Économie Rurale' (IER) based in Mali (FunciTree 2008).

The project's main goal is to find out more about the various functional traits of different agroforestry tree species and identify farmers' preferences and needs. It "proposes to work directly with farmers to identify the most pressing barriers to sustainable production" (FunciTree 2008: 7). Based on local knowledge, the project aims to figure out how to develop improved agroforestry practices that are better adapted to farmers' needs and thus contribute to increased AF adoption. FunciTree's overall goal is to help fighting rural poverty and food insecurity. Furthermore, the project aims to contribute to climate change mitigation and the fight against biodiversity loss.

A unique aspect of FunciTree is the use of a trait-based approach that focuses on the specific needs of farmers and which traits of trees they prefer concerning different aspects contributing to improving both farm productivity and environmental needs. Previous projects did, for example, promote the Eucalyptus (*Eucalyptus camaldulensis*) tree because of its rapid growth rate and good construction and fuel wood. These are in fact all characteristics that farmers prefer. However, farmers are not always informed about invisible costs and external impacts. The Eucalyptus tree has, in spite of its advantages, negative effects on ground water, soil conditions and biodiversity. FunciTree aims at taking such and similar aspects that affect the ecosystem into consideration, too.

The project does not only intend to find out more about factors of adoption and non-adoption of AF in the African and Central American project sites, it also aims to identify universal tree traits that farmers prefer and their decision-making processes in adopting and not adopting agroforestry. By comparing the findings of the three different project areas, one site is able to benefit from the knowledge from the other two sites. Although, this study does not include a cross-site comparison, its results can contribute to the project's overall goals. Those include to modernise existing agroforestry practices in a way, that there is a higher diversity of tree species with various functions, to improve land management strategies and use trees for erosion control and soil protection. Training and capacity building is intended to be ameliorated and new crop varieties introduced that can be combined with trees on the fields. Those strategies can contribute to sustainable development and mitigation of negative climate change effects (FunciTree 2008).

The Millennium Villages Project

One of the partner projects of the FunciTree project is the 'Millennium Villages Project' (MVP) of the 'Earth institute' of Columbia University, the NGO 'Millennium promise' and the United Nations Development Programme (UNDP). FunciTree's project sites in Senegal and Mali are two of the 13 designated Millennium villages in Africa in which the project is conducted.

The MVP was launched in 2006 and has been planned to be of ten years duration with the goal of "helping rural African communities lift themselves out of extreme poverty" (UNDP 2011) getting the villages closer to reaching the eight Millennium development goals to fight extreme poverty of the United Nations[6]. The focus lies on Africa because of the high poverty rate of the continent and the various challenges that this entails. The Millennium Villages Project aims to combine "fighting poverty at the village level through community-led development" with "new advances in science and technology […] like providing high-yield seeds, fertilizers, medicines, drinking wells, and materials to build school rooms and clinics." (The Earth Institute 2011). Among the technologies the project is promoting is also agroforestry: In the framework of the MVP, tree seedlings are planted and training provided for example in planting, harvesting and seed management (The Earth Institute 2010: 29).

The Millennium Villages Project's approach is to "work with villages to create and facilitate sustainable, community-led action plans that are tailored to the villages' specific needs and designed to achieve the Millennium Development Goals." (The Earth Institute 2011). To accomplish that approach, the MVP conducts detailed household surveys every three years to obtain updated

[6] The millennium development goals have been agreed upon in the year 2000 at the Millennium summit. The objective was that the goals should be reached by the year 2015.

representative information about the population of the respective village. The data provides a basis for project activities and evaluation. The MVP intends to tackle the main problems that are prevalent in the project sites. That implies food insecurity and poverty caused by factors like inconsistent rainfall, inefficient irrigation management and increasing soil degradation (Millennium promise 2010a).

1.3.4 Practice of agroforestry in the Ségou region

Due to the traditionally strong role of pastoralism and livestock breeding, there are various combinations of silvopastoralism and agrisilvopastoralism present in the Ségou area, where Tiby – the Malian project site – is located (FunciTree 2010). Some of the most relevant agroforestry practices and related activities in Mali, and especially in the Ségou region, are: Live fencing; food and fodder banks; improved management of parkland systems to maintain tree health, tree regeneration, species richness, soil conversation and soil fertility improvements (Ashley 2004). There are various non-wood and wood tree functions that contribute to farmer's incomes and some species are well-known, appreciated and also widely spread, like *Vitellaria paradoxa* (Karité / Shea), *Faidherbia albida* (Balanzan[7]) and *Adansonia digitata* (Baobab), the most common tree species in the Ségou region.

One of the most important functions of these and other tree species is to provide households with domestic energy which is the case for 90 per cent of the population in the Ségou region. Another important use of wood is the construction of houses and sheds, but also furniture and art are made from wood. However, not only the wood, also other tree products, like fruit, flowers, leaves and roots play an important role, especially for human and animal nutrition, but also for traditional medicines. Many products, like the butter of the Shea tree, the fruits of the tamarind tree and the dried or fresh leaves of the Baobab are

[7] Ségou is also called 'the city of Balanzans'.

commercialised and sold at local markets. Moreover, agroforestry does not only contribute to income diversification in Ségou but can also have positive environmental effects, like contributing to carbon sequestration.

Otherwise, the principal source of income for more than 50 per cent of the people in the Ségou region is agriculture, while about 30 per cent are selling livestock or livestock products. Seven per cent claim that they also get income from selling wood and ten per cent gain revenues from selling Manioc and Baobab leaves (FunciTree 2010).

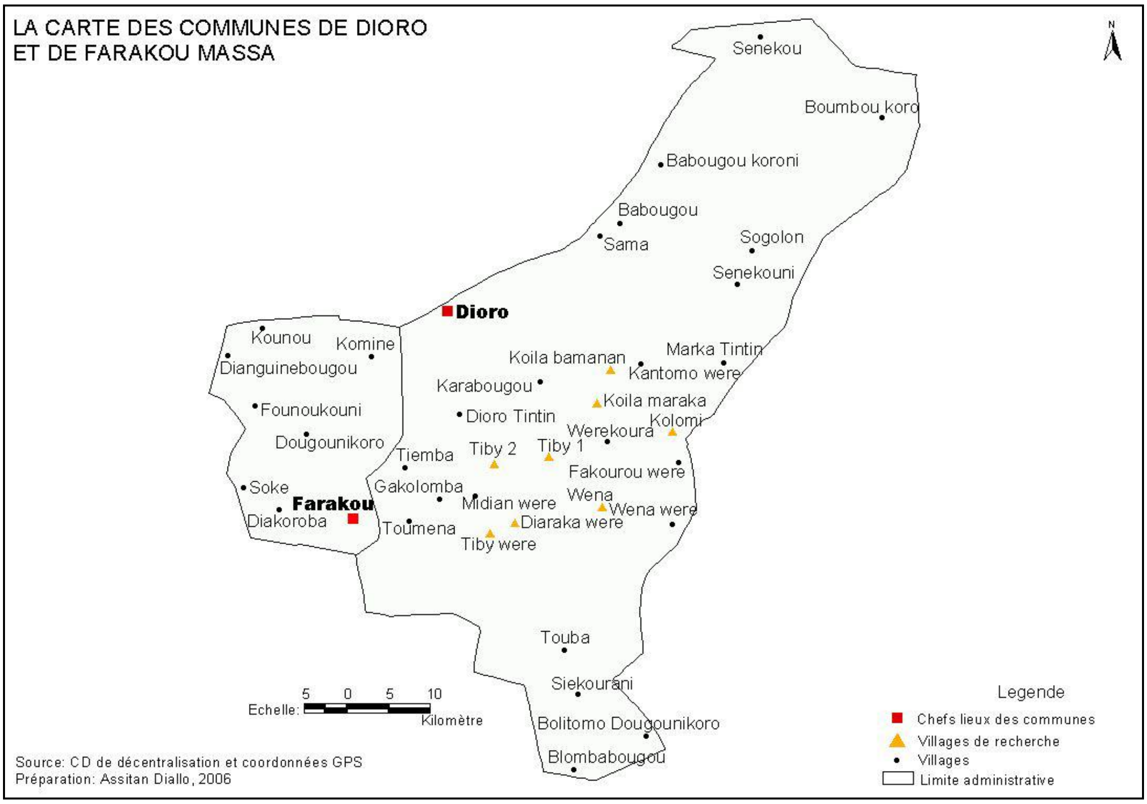
There are various problems with agroforestry resources present in the Ségou area that need to be resolved. As mentioned above, the on-going cultivation of more and more land plays a role. Then, deforestation for different purposes is a limitation to agroforestry. In addition, the regeneration rate in the fields is quite low, many species grow slowly and it takes a long time until they can provide products or services. Also, there are often unfavourable ecological conditions for the plants to grow and plantations are often insufficient in size and quality. Other continuing problems are extreme climatic events like droughts (FunciTree 2010).

1.4 The Fieldwork Site

As this master thesis is connected to the FunciTree project, fieldwork was conducted at the Malian site of the project in the so-called ‘Tiby village cluster’ which has been designated as one of the sites of the Millennium Villages Project that started in 2006 (Millennium promise 2010). The Tiby site has been chosen by the MVP because it fulfils three criteria: First, it is a place where hunger and food insecurity is still a widespread problem. Connected to this issue are, among others, problems with diseases like Malaria, a lack of medical and sanitation facilities and a lack of infrastructure and transportation. Second, Mali is a comparatively peaceful country with an accountable government. Third, there are local governmental and communal structures making cooperation with international non-governmental and governmental organisations possible (Millennium Villages 2010).

The cluster consists of 39 villages in the administrative municipalities of Dioro and Farakou-Massa, which are both located in the administrative 'circle' of Ségou in the southern Ségou region[8]. The eight villages Koïla Bamanan, Koïla Markala, Tiby I, Tiby II, Diaraka Wèrè, Wéna, Tiby Wère and Kolomi were chosen as the project's research villages in which detailed household surveys were to be conducted (The Earth Institute 2010).

Map 2:The Tiby village cluster in the municipalities of Dioro and Farakou Massa



Source: Millennium Villages Project 2006 (The designated research villages are marked: ▲)

The Malian capital, Bamako is located ca. 300 kilometres southwest of the village cluster and the nearest main town, Ségou, is about 70 kilometres away. The Dioro municipality is located at the bank of the Niger River. Due to the proximity to the water of the river and the nearby dam of Markala, the area

[8] Mali is administratively divided into 'régions', 'cercles' and 'communes'.

belongs to the field of intervention of the “Office riz Ségou” - the Ségou rice office (ORS). This regional branch of the governmental ‘Office du Niger’ – the Niger office – is responsible for the management and administration of rice irrigation under the auspices of the Malian ministry for agriculture (Office riz Ségou 2009). The Tiby village cluster covers an area of approximately 700 km² and has about 68.000 inhabitants (The Earth Institute 2010).

The climate in Tiby is typical for the Sahel region with a long nine-months-lasting dry season, variable rainfall and frequently occurring droughts. The landscape consists of uplands and plains that are flooded by water from the Niger River. About three thirds of the cluster population work in the agricultural sector which makes out 90 per cent of their incomes. The main crops that are cultivated are rainfed millet and Sorghum in the dry and sandy uplands, while rice is grown in the low areas with rather loamy soils under the governmental irrigation scheme[9]. While rice crops are often ‘cash crops’, millet, sorghum and other crops like beans or groundnuts are used for subsistence (The Earth Institute 2010). Furthermore, livestock production is a very important resource for investment and savings for many (Millennium promise 2010).

According to the Earth Institute (2010), the Tiby village cluster “is one of the poorest areas in Mali.” Agricultural production is not very high and the 75 per cent of the Tiby population who are farmers yield between 500 and 700 kilogram per hectare. Food insecurity is high due to factors like inconsistent rainfall, inefficient irrigation management and increasing soil degradation (Millennium promise 2010a). Not only the unreliable climatic conditions, also has the intensification of agriculture due to a continuously rising human and animal population contributed to the depletion of the soils. The prices for mineral fertiliser are high, organic fertiliser is lacking, too, and water access is not always provided. (FunciTree 2008: 10). Being about 25 kilometres away from the closest paved road, the Tiby cluster is not very easily accessible, especially during the

[9] The rice cultivation is under the management and control of the Office de riz since the construction of the dam of Markala in the 1930ies (Office du Niger 2009).

rainy season (The Earth Institute 2010). In addition, there is a lack of transport facilities and – apart from the weekly market in Dioro – there are not many markets, either (FunciTree 2008: 10).

Since the launch of the project in Tiby, the MVP has already contributed to improving some of these mentioned issues. In 2009, a new road was constructed that connected the Tiby village cluster with the town of Markala and thus, improved access to markets and health facilities (Aviles Lopes 2009). New schools, health facilities and improved water facilities have been built in the village cluster (Millennium promise 2010b). Nevertheless, many of the existing problems prevail and the project is continuing its work.

1.5 Structure of the Thesis

In the introductory chapter, the objectives and rationale of the thesis, background about agroforestry, the projects, the country and the fieldwork site were presented. The second chapter is concerned with the methodological approach. It describes the different methods of data acquisition and it is reflected upon the difficulties that came up during the field research. The third chapter focuses on the theoretical framework of the thesis. One theoretical approach is referring to meta-analyses of previous studies about agroforestry adoption. Another focus lies on sustainable livelihoods and the role diversification plays. In part four of the thesis, the methods used for analysis and the basic concepts of Bayesian belief networks are presented. In the fifth chapter, the main findings of the fieldwork in Mali are depicted. Important terms concerning the different prevailing agroforestry practices are defined and general information about agroforestry adoption, farm and household activities at the site is given. The sixth chapter is mainly concerned with data analysis via the comparison of different farmer groups and possible adoption factors with the help of Bayesian belief networks. In addition, the findings and analysis will be set into relation to the theoretical framework of the third chapter and recommendations for future research provided. The final chapter is conclusion of the thesis and summarises the results.

2. METHODOLOGY

The following methodology chapter will give an overview of the different methods of data collection used. Moreover, the strategy of the field research is described in detail. At the end of the chapter, the challenges and difficulties of data acquiring are presented.

2.1 Methods of Data Collection

There are several methods and materials that are used for answering the research questions that were raised in the introductory part of this thesis. The research strategy is an interdisciplinary one, which includes fieldwork conducted in Tiby, Mali consisting of a representative household survey and a few in-depth follow-up interviews with selected household heads. Findings from observations and non-recorded informal conversations also contribute to the fieldwork data. Furthermore, the FunciTree project and the Millennium Villages Project provided background material and, to some extent, aggregated survey data. More background information could be drawn from existing literature and studies on agroforestry and agroforestry adoption. Cundill et al. (2011: 75) proposes that such a ‘multi-source approach’, which includes primary and secondary data, can contribute a lot to understanding a specific problem in its local context.

During the fieldwork, both quantitative and qualitative methods were applied because the various kinds of data that are thus obtained can be used to answer the different research questions asked (Bryman 2008). The qualitative data achieved through semi-structured interviews, informal conversations and observations can contribute to corroborating, facilitating and complementing quantitative research findings and vice versa as Bryman (2008: 607) points out by referring to Hammersley’s (2006) classification of approaches to mixed methods research. Moreover, secondary data from projects and literature on agroforestry adoption can provide useful background information and underpin the various findings from the fieldwork. This approach of combining of diverse research methods used in different disciplinary approaches is also called 'triangulation' (Bryman 2008). As Hardy and Bryman (2004: 1) put it:

> Discipline boundaries too often act as intellectual fences beyond which we rarely venture, as if our own field of research is so well defined and so much ours that we can learn nothing from other disciplines that can possibly be of use.

2.1.1 Representative household survey using structured interviews

The main part of the field research in the Tiby village cluster consisted of a representative household survey that was conducted in the time between the beginning of October and the middle of November 2010. Field research makes it easier to understand the economic and social setting of a study area and thus, contributes to solving specific problems and questions (Reyes-García and Sunderlin 2011). Previous research in the field of agroforestry revealed that on-farm research is central to gain insights into the "richness of farmer knowledge" (Scherr 1991: 95).

The method of the household survey as a main research strategy was chosen to get primary data which can be used to generalise and analyse the material situation, the attitudes, opinions and decision-making processes of a population. Data, which is acquired with the help of standardised, structured questionnaires, is easy to quantify and aggregate (Fowler 2002). Furthermore, it is possible to find patterns and relationships by using statistical analysis (May 1993). By interviewing a representative sample of a population one is able to make some generalisations about the population as a whole (Bryman 2008). With data from structured interviews with standardised questionnaires, hypothesis testing is possible. This is useful for data analysis with the help of statistical techniques such as multivariate regression and Bayesian belief networks, which will be explained in detail in chapter four.

Conducting face-to-face interviews was chosen as the best solution to get household level information in the Tiby village cluster. As many people in rural

Mali cannot read or write (very well), a high response rate can only be guaranteed by direct contact. Another advantage is that non-verbal interaction and gestures become visible as well. Moreover, there is a high rate of control of the interview situation. Disadvantages are that face-to-face interviews require quite some time and can be cost intensive (May 1993). Other problematic issues will be explained in more detail later.

The three main activities of a social survey are, according to Fowler (2002: 4) the sampling, the designing of questions and the collection of data.

The sample

The prerequisite for the choice of the sampling strategy for this study was that the Millennium Villages Project had already conducted detailed household questionnaires in the Tiby village cluster with a focus on socio-economic issues and health, when the project was launched in 2006. As those were to be repeated every three years, the data was last updated in the beginning of 2010 (The Earth Institute / MVRP 2011). Following the goal of the Paris Declaration on Aid Effectiveness of “eliminating duplication of efforts and rationalizing donor activities to make them as cost-effective as possible” (OECD 2005: 1), it was a sensitive decision to reduce the survey questionnaire so that it would only include questions that had not been covered before and combine the data that would be acquired during the fieldwork with the already existing data of the MVP. For this purpose, it was necessary to interview only households that also had been covered by the MVP surveys and thus, use (part of) the same sample.

Another reason for choosing this approach is that with Bayesian methods, which are used for data analysis, it is possible to combine prior knowledge with new data (McCarthy 2007). During the planning process we did not know, yet, that the MVP would not share their data with the FunciTree project after all. The problems that came up due to this will be discussed further later.

The survey that the Millennium Villages Project had implemented in the project site covered a wealth-stratified and random sample (The Earth Institute 2010) of 300 of the 1048 existing households in the eight villages chosen as 'research villages'. In total, about 5500 households[10] are under the auspices of the Millennium Villages Project, but only the 1048 households in the eight designated research villages are part of the sample frame being surveyed. The MVP had assigned codes to all the villages and households in the project area, which made it easy to choose exactly those, that had been covered by the project's household survey before. The staff of the local MVP office in Ségou provided us with the household and village codes of 100 households in the villages of Koïla Bamanan, Koïla Markala, Tiby I, Tiby II, Diaraka Wèrè, Wéna, Tiby Wère and Kolomi. Those were randomly picked out of the about 300[11] households that had been interviewed in the household surveys of the MVP. The decision to interview about 100 households was based on availability of time and resources for the fieldwork.

Table 1: The research villages, numbers of households and inhabitants

Villages	Number of households	Population	Number of households interviewed	Percentage of households interviewed
Koïla Bamanan	349	4858	30	8,6 %
Koïla Markala	179	2348	24	13,4 %
Tiby I	178	3197	15	8,4 %
Tiby II	50	783	3	6,0 %
Diaraka Wèrè	44	767	2	4,5 %
Wéna	135	2347	13	9,6 %
Tiby Wèrè	50	703	6	12,0 %
Kolomi	63	794	1	1,6 %
TOTAL Research villages	**1048**	**15797**	***94***	***9,0 %***

Source: Millennium Villages Project 2010

The table shows that the populations of the eight villages and the number of households that were interviewed per village vary. As mentioned earlier, all the villages belong to the same administrative municipality (Dioro), which is one of the reasons why it is useful to define the different MVP research villages as one sample frame. Also, all of the eight villages lie relatively close to each other, have quite similar biophysical and socio-economic conditions and are culturally

[10] This includes the villages Soke and Komine in the neighboring municipality Farakou Massa and Senenkou, Babougou and the municipality's capital Dioro that lie outside the original Tiby village cluster.

[11] De facto, 296 households were interviewed by the MVP, probably due to non-response.

and religiously homogeneous (The Earth Institute 2010). A main difference is that half of the villages, Tiby Wèrè, Diaraka Wèrè, Wéna and Kolomi, are less easily accessible from Dioro than others, especially in the rainy season (FunciTree / IER 2010). On the other hand, there are also variations in accessibility within single villages as some of the interviewees live in hamlets outside the principal villages. Shively (2011: 55) emphasises that the analysis of household survey data requires some variation across the villages, too.

Due to non-response, the final dataset of the survey included 94 instead of 100 households. Six persons who were in the sample could not be interviewed for different reasons, ranging from illness to migration.[12] The 94 respondents make up about nine per cent of the sample frame, which is a number that gets very close to the ten per cent, which is often regarded as an adequate sample size for reducing sampling errors and variation to an acceptable extent (Fowler 2002: 34). This rule of thumb, however, does not necessarily apply to all survey research. The most important aspect is that the sample is as representative as possible, so that generalisations to the larger population can be drawn. It depends a lot on the tools and methods that are used for data analysis and on the extent of variation measured in a sample how important its size is. Furthermore, issues of time, cost and availability have to be taken into consideration (Bryman 2008, Shively 2011). Shively (2011: 51) argues that "many important research questions can be investigated with small samples provided the samples are drawn with care and their strengths and weaknesses are well understood." A smaller sample can, for instance, even provide more accurate information, because there is generally more time available per interview (May 1993). The use of Bayesian belief networks for data analysis is very useful in this context, as they allow analysing small and large data sets and such with missing variables.

[12] There were also a few households in which the household head, who was interviewed in the previous MVP surveys had died and his son had overtaken his role.

In this survey, usually the household head is interviewed due to his important role for all household management decisions. He is normally male[13] and the official owner of the land, the house and most household goods. He is responsible for finances and commerce and often, important household decisions have to be taken by him or in accordance with him.[14] Thus, it makes sense to conduct interviews with the household head to gain general household data and information on agricultural and tree management. Moreover, his position as the household's decision-maker makes it an act of courtesy to interview him, or at least, talk to him first before interviewing another household member, like his son or wife. Furthermore, "limiting interviews to a single adult has the advantage of reducing the time and expense of household surveys" (Fisher et al. 2009: 971).

The questionnaire

Angelsen and Friis Lund (2011: 108) define four types of questions that are part of a typical household questionnaire: The first group of questions is usually concerned with household composition and characteristics. The second one inquires about assets owned by the household and the third one about the household's income. Then, there is a fourth group of questions that has a focus on the particular topic of the respective research project. In this study, the focal point lies on agroforestry and tree preferences of the farmers as this is relevant to answering the research questions posed.

First of all, I prepared a questionnaire that only included the first three groups of questions. The initial plan was to add specific agroforestry questions during the FunciTree workshop "Training in Bayesian belief network modelling of AFS implementation & design workshop for representative farm survey" in Dakar, Senegal which I participated in before starting the fieldwork in Mali. However, in Senegal, we learned, that the first three groups of questions had already been covered by the household surveys of the MVP and that we would

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[13] According to the Earth Institute (2010: 8), there are just 1.4 % female-headed households.

[14] To what extent women actually are participate in and decide about AF is debated by some researchers (e.g. Kiptot and Franzel 2011). However, the topic would expand the scope of the research for this thesis.

receive socio-economic and household data from the project. This is why the survey questionnaire – which was developed in collaboration with the FunciTree staff during the workshop – was reduced to the fourth group of questions about agroforestry, while general questions about household characteristics and socio-economic aspects were almost completely left out. In appendix F, a box with FunciTree's request for the MVP household survey data and the different types of data asked for can be seen.

Concerning the structure of the questionnaire Scheyvens and Storey (2003: 39) state: "questionnaires should begin with the basic and least intrusive questions and progress to the more complex and sensitive questions. All questions should be simple to understand and unambiguous." For this reason, the first few questions of the survey questionnaire inquired about a few socio-economic aspects, like immigration to the village cluster, association membership and development projects or organisations that are present.

The remaining questions were concerned with issues related to agroforestry. The questions asked, for example, about land ownership, the use of fertiliser, animal nutrition and about the various problems that farmers have with agriculture and livestock breeding. Naturally, the latter are relevant to tree management as they are relevant to general farm management. The largest part of the survey was concerned with trees and agroforestry: It was asked about tree species present, preferred tree species, problems and benefits, and of course about the different aspects of AF practices farmers had adopted (Appendix B and C include the complete French questionnaire and an English translation).

The questions were mainly 'factual questions' (Bryman 2008) that were to a certain extent personal, as they concerned aspects about the interviewee's daily life, problems and choices he made. Most of the questions, however, were asking about the household as a whole, so they also included information about other people besides the household head. A large share of the questions were closed format, some of them simple yes- or no-questions, others providing different possible answers to choose from. While some of them were left open on purpose and the different answers had to be coded afterwards, also the closed questions with pre-coded answer choices were often left open to that extent that an ‘other’ option to respond was possible. Thus, the questionnaire enabled the respondents to answer more freely and mention all the different aspects that came to their minds (See also: May 1993, Bryman 2008). However, the questions were closed insofar that answers can be formulated and used for statistical analysis. Many questions had the form of tables so that a large amount of aspects related to the use of the different tree species could be collected.

Survey implementation

Before starting to interview the sample of households that had been assigned to us by the MVP, it was necessary to conduct a pilot survey to test the questionnaire. The aim was to avoid common questionnaire problems, like too specific or complicated questions, leading questions or questions that simply do not deliver any useful or relevant information that might contribute to answering the research questions (see also: May 1993). To be able to start with this, it was first of all necessary to get in touch with the local head – ‘chef de zone’ - of the Office riz Ségou in Dioro. This was possible with the authorisation and communication efforts of the MVP coordinator in Ségou. The responsible people of the ORS chose two farmers in the Tiby village cluster for the pilot survey. By interviewing them it was possible to erase some rather irrelevant questions and questions that were too long or repeated topics. Thus, the survey could become more functional.

As most people in the Tiby village cluster do not speak French (to an adequate extent), the survey and the answers needed to be interpreted into and from the Bambara language. For this purpose, two assistants were assigned with this task. They were permanently employed by the FunciTree project in Mali to implement surveys in the Tiby village cluster and to assist with data analysis in the framework of the tasks of the Malian project partner, Institut d’Economie Rurale (IER). Both of them came from the region of Ségou and had studied in Bamako. They had already conducted surveys for the project in the Tiby village cluster before and knew the region very well. The communication between me and them was in French. However, I tried to at least use the little Bambara I had learned in the weeks before to exchange greetings and the traditional 'Plaisantéries'[15] with the farmers we interviewed, because "knowing a few local proverbs can help break the ice with respondents" (Jagger et al. 2011a: 152).

Before starting the interviews in a certain village, it was obligatory to go and see the village chief and inform him about the project. Then he normally asked someone to get the farmers to come to his house or to accompany us to the households; a time-consuming progress that was nevertheless necessary to show respect and that often helped to find the different households and farmers. Shively (2001: 64) also recommends that "in some cases, it may be important to include the local leaders, such as the headman or village chief to ensure his cooperation and also to facilitate cooperation from those selected."

Another aspect that made the implementation of the interviews easier and faster was the fact, that there were two fieldwork assistants: We often split up and I was conducting a survey with a farmer with one of the assistants while the other one conducted an interview alone. However, the first seven surveys were implemented by all three of us to figure out the various aspects and difficulties that might come up in the interview situation and to ensure that both translators would ask the questions in a similar way and thus, avoid bias.

2.1.2 Qualitative data

Even if the main part of the fieldwork comprised a representative household survey, the experience of being in the field alone provides a lot of additional qualitative information from observation and informal conversations in between the 'official' interviews. According to Bryman (2002: 15) qualitative data derives from "seeing the social world from the point of view of the actor" and leads to better understanding behaviour in the context of a society's meaning system. For

[15] The 'parenté à plaisanteries' is a sort of 'joking relationship' between members of different families or tribes.

this reason, the research strategy also includes several semi-structured in-depth interviews that were conducted subsequently to the household survey.

Semi-structured follow-up interviews

To learn more about factors influencing the agroforestry adoption behaviour of farmers in Tiby several in-depth interviews were conducted. Those would contribute with another kind of data that adds up to the data collected in the representative surveys with the goal to gain a deeper understanding of the farmers' points of view, their experiences and attitudes. The initial focus was mainly on people's perceptions about risk and uncertainty.

An important advantage of in-depth interviews is that they are more flexible than household surveys. The questions being asked can be adapted and improved during the implementation of interviews and the interviewer is able to react to unexpected findings (Bryman 2002). Moreover, the respondent is freer in his answers and misunderstandings as well as possible translation problems can be clarified during conversation. Qualitative data can be used to complement, corroborate and explain findings from the household survey (Bryman 2008). Kvale and Brinkmann (2009: 117) emphasise the role that qualitative interviews can play as an auxiliary method to test and compare the quality of a different kind of research conducted in the same field. Follow-up interviews can provide additional insights into issues not asked about in the survey.

According to Shively (2011: 52), sampling is equally important for qualitative as for quantitative research. However, the implementation of follow-up interviews was as restricted by costs and availability of the respondents as the household survey. Therefore, only a few in-depth interviews were conducted and it was important that the interviewees were as representative as possible (see also: Kvale and Brinkmann 2009). Several potential respondents were chosen by convenience sampling, that is, farmers who had given the impression to be most available and willing to be interviewed once again were picked out. This way of sampling is, on the one hand, inherently biased, but on the other hand, quite practical and reasonable (See also: Shively 2011). The notes from the fieldwork diary, which was kept during the field research, were used to find about ten to fifteen farmers from the sample that seemed particularly interesting, either because they had been very open and talkative during the previous interviews, they had some unique characteristics or they had important positions in the village and could thus, function as 'key informants' (Cundill et al. 2011). Another important aspect was to interview both, farmers who relied a lot on agroforestry and such who did not. Thus, the final list of potential interviewees was a mix of a purposeful and a convenience sample (Scheyvens and Storey 2003). The five farmers who eventually were interviewed were selected by availability after the pre-selection. The table below shows the main characteristics that played a role in choosing the interviewees. Farmer types that would have been interesting to interview but are not present in the sample are: Someone who is younger and someone who is active in many associations.

Table 2: Sample of farmers interviewed in the follow-up interviews

Interview No.	Estimated Age	Agroforestry	Special characteristics	Estimated wealth level	Village
1	Old	Parklands, Eucalyptus forest	Very open, only one wife, wife is educated	Relatively poor	Tiby I
2	Middle aged	Parklands	Very open and talkative	Poor	Tiby I
3	Old	Parklands, Eucalyptus forest, small home garden (few trees)	Influential position in the village, illegal tree cut in the fields of the village	Relatively rich	Tiby II
4	Middle aged /older	Parklands (large fields, different crops)	Very open, village tailor, influential position in the village	Relatively rich	Koïla Markala
5	Old	Parklands (few trees)	Lives in hamlet	Very poor	Koïla Bamanan

It was intended to use semi-structured interviews that are to some extent open but follow a certain order (Kvale and Brinkmann 2009). For that reason, it was useful to have an interview guide (See appendix D and E: Complete French interview guide and English translation) covering all possible issues that the interviews were supposed to touch. The guide covered topics not being asked about in the surveys relative to risk, uncertainty and decision-making. It included questions on education and schooling, on different sources of income, on the household and land size, lacks and needs, food security and energy access, vulnerability and shocks, the financial situation, savings and credits. In addition, some questions on tree management and agroforestry were asked even though this was already the topic of the household survey. The intention was to find out if people would give differing explanations and additional information in a more open interview situation about their choices to adopt or non-adopt trees and problems of tree management. Another goal was to fill gaps that had arisen during the implementation of the household surveys.

However, the interview guide turned out to be too long, due to the vast amount of factors connected to people's attitudes and their AF adoption behaviour. Interviews would have been very restricted, controlled and had taken much time. I decided not use it at all, but instead to conduct more open interviews, keep the main issues that might be relevant in connection to the research questions in mind and inquire about them, when it was most convenient. While talking to the respondents about their lives and livelihoods we naturally ended up focussing on many of the topics mentioned above. People had the chance to tell the stories they wanted to tell, more questions about particularly interesting topics that came up could be asked and the conversations did not last too long. As Kvale and Brinkmann (2009: 31) point out, it is "up to the subject to bring forth the dimensions he or she finds important in the theme of inquiry."

It took only a few days to conduct the five in-depth interviews. Therefore, and also to have a more private interview situation, only one of the two assistants worked as an interpreter during the field trip. First of all, he gave an explanation of why we were implementing the additional interviews and asked the people if we could use a voice recorder. For different reasons, all but one of the interviewees, refused to have the conversation recorded, so everything had to be written down. This proved to be not that difficult as breaks naturally occurred when the conversation was translated from French to Bambara, and vice versa.

Field observations, informal conversations and field notes

> If you want to study people's behaviour and their interaction with their environment, the observations and informal conversations of field studies will usually give more valid knowledge than merely asking subjects about their behaviour. (Kvale and Brinkmann 2009: 115).

Although participant observation was not an intended part of the research strategy during the fieldwork in Tiby, the experience of staying in the rural villages for several weeks provided a lot of informal findings and insights into different aspects of farmers' lives that can be relevant for answering some of the research questions. Participant observation means that the researcher is immersed into the social setting that is being studied to observe behaviour "and to elicit the meanings they attribute to their environment and behaviour" (Bryman 2008: 257). There is, however, a lot of variation in how much the researcher actually participates in the respective social setting. In the case of our research, it included participating in meals, engaging in informal chats and occasionally – even spending the night in the village. Thus, it is valid to say, that we gained some useful insights into people's daily lives. As Reyes-García and Sunderlin (2011: 17) formulate it, it is useful to include

> observation of events as they occur in natural settings sometimes expanded by means of a contextual inquiry. Observation can be naturalistic or participant, when the researcher engages in the observed activities.

Moreover, much of the information from the household surveys could be verified by our own observations in the field. The two assistants who had already conducted fieldwork in the region before and had both grown up in the Ségou region could contribute with their knowledge and expertise. In addition, I kept a fieldwork diary and took notes about observations that were particularly interesting and relevant for the research goals. It was for example useful to look around and pay attention what sorts of trees and how many of them there actually were to be seen in the fields, to watch the harvest work and to find out if livestock is in the fields or rather at the farms. Also, by observing how and what women cook, we learned more about the role of agroforestry in the daily life of the households in Tiby. “Observing the local reality often tells you things that cannot be observed through national census or survey data.” (Reyes-García and Sunderlin 2011: 21).

2.1.3 Project data from the MVP and FunciTree

After a few months of fruitless communication between responsible people of FunciTree and the MVP, it turned out that it was impossible to get hold of the household level data from the MVP and to combine their dataset with the one from the household survey conducted for this thesis. The responsibility for acquiring the data was completely out of my sphere of influence.

There were formal reasons for the failed data exchange. Nevertheless, the exact reasons for why cooperation between two projects that share both, personnel and project sites and which could, due to the more research based focus of FunciTree and the MVP’s focus on practical implementation, complement each other perfectly, will remain difficult to understand. A quote from Reyes-García and Sunderlin (2011: 29) describes the dilemma of the lacking cooperation concerning data exchange:

> Researchers conducting field research assume they have full ownership of the primary data being collected. (...) The matter of relinquishing control of research data enters into the realm of ethics that researchers seldom think about beforehand.

In any case, this unfortunate development made the research strategy of the fieldwork incomplete and almost obsolete.

After the field research in Mali, I corresponded a lot with staff from the MVP via email and phone. They provided some aggregated average household data from the survey that was finished in the beginning of 2010, which was useful to support and verify the available data. The aggregate data received covered topics like employment, food security, education, gender equality, land tenure and some general household demographics (The Earth Institute / MVRP 2011). This could at least to some extent fill the gap of socio-economic data, although it cannot be used for data analysis.

The FunciTree project provided all project data that had been acquired in Tiby and the other project sites in Senegal and Nicaragua. A survey had been conducted on behalf of the Malian collaborating institute IER in early 2010 by the same two assistants who also helped implementing the household survey for this thesis. They had conducted surveys in 302 randomly selected households in 15 villages in the project area. As the sample of the IER's survey for FunciTree did not only cover households in the Tiby research villages but also some in neighbouring villages[16] (FunciTree / IER 2010), a direct comparison of the data is not possible. Nevertheless, the resemblance of the villages in the whole area makes it possible to at least compare some of the findings with each other. Other useful material provided by FunciTree included maps and (background) reports. Furthermore, the FunciTree workshop in Dakar, Senegal provided useful knowledge about the project and how it operates in one of its other sites. Moreover, I got an introduction into Bayesian belief networks as a tool to develop graphical probabilistic models that can be useful for data analysis.

2.1.4 Literature

Literature from previous studies about agroforestry adoption is used in the theory chapter and other parts of the thesis to verify and back up data collected during fieldwork. It provides information and knowledge when data is insufficient and can be used to compare previous results with the findings of this thesis.

2.2 Practical Issues and Dilemmas

"Criticism is not a means to an end: it is a means to the collective discovery of truths, or at least to the elimination of errors." (Hammersley 2011: 79).

[16] The survey had been conducted in the municipalities of Farakou and Dioro.

2.2.1 General issues

There are several problems and dilemmas that are quite common during the implementation of field research. The most relevant difficulties that came up during the field research for this thesis were related to the following issues:

- Time, costs and availability
- Living and travelling conditions
- Translation and communication
- Collaboration with the assistants
- Interview implementation

The most usual problems that came up during the research in Tiby were connected to time and money available and practical issues at the site. The organisation of field trips including communication with the responsible authorities turned out to be very time-consuming and quite unpredictable.

Another part of the fieldwork that was often difficult, were rather harsh travelling and living conditions. The daily-motorcycle-rides from Dioro to the villages were exhausting: In the end of the rainy season the roads were often flooded and in the dry and windy season that followed, the sandy roads were not easy to pass, neither. Moreover, it was almost impossible to avoid eating and drinking at the villages – for practical reasons and because refusing offered food and drinks might have offended people and negatively influenced our relationship to the respondents (see also: Scheyvens and Storey 2003, Jagger et al. 2011a).

As most people in the research area do not speak French, it was necessary that the research assistants worked as interpreters from and to Bambara, which “has the disadvantage of (...) receiving information second-hand.” (Scheyvens and Storey 2003: 133). As Jagger et al. (2011a: 152) point out; an interpreter is a sub-optimal solution. There is a risk that he does not pose questions correctly and writes down his own interpretations of what informants tell.

Collaboration with the assistants in general was not always easy. The fact that I was a European female, who was younger than them, had not yet finished her master's degree and was not an expert on agroforestry whatsoever, made it difficult to be taken seriously as the person who is in charge. The assistants, on the other hand, were both male, experienced with field research at the site and permanent employees of the project. Not only the cultural differences between the researcher and the respondents (see also: Bryman 2008, Jagger et al 2011a) also those between the researcher and research assistants can cause difficulties.

Another problem connected to power relations and authority structures in Mali was that the concept of random sampling is often not understood by the respondents. As Shively (2011: 64) points out "Notables in the village may feel offended at not being included. Others may suspect that households have been selected based on favouritism (or for other more mysterious reasons)."

A related issue is that it was almost impossible to always stick to the goal of interviewing one person privately and out of reach of others (Scheyvens and Storey 2003, Reyes-García and Sunderlin 2011). Often, children, wives, grandparents, brothers and neighbours sat down next to us during the interviews and contributed with comments and corrections of what the interviewee said. However, the input of people who had a connection to the respondents was often enriching and specifying the answers. Thus, the interviews occasionally became comparable to focus groups, in which several people challenge each other's points of view (See also: Bryman 2008) and also females could participate.

This is another issue of bias: The interviewees were predominantly male, although females often have important roles in the management of the farm households, while the household head is not always aware of all household activities. For example, some women in the Tiby cluster grow vegetables in home gardens in cooperation with each other (The Earth Institute 2010).

2.2.2 Specific issues with the household survey

There are two main areas in which difficulties occurred during the implementation of the household surveys and in connection to acquiring data:

- Difficulties in the survey implementation

- Incomplete questionnaire due to false premises

One problem that turned up in connection to the questionnaire was that some of its weaknesses did not become visible during the pilot surveys, yet, and could not be changed anymore afterwards. Many questions were interpreted quite differently by the respondents (see also: Jagger et al. 2011b): For instance, the question on how many trees people had on their farm led to a very large range of answers. It seems that some respondents counted all the species they had, also little trees or shrubs that grow more abundantly, while others only mentioned full-grown trees. Especially questions that required quantification were answered in very different ways and it was necessary to repeat and explain them to get valid responses (See also: Bryman 2008). This was, however, not always done by the assistants. Although we conducted the first interviews together, it was not possible to avoid that the two assistants asked questions differently and received contradictory or incomplete answers. There is, for example, only data about field sizes available for about half of the sample, as only one of them asked about it in connection to the number of trees in the fields.

As mentioned before, the problem was that the questionnaire used for the household survey was incomplete. As we did not receive household level data from the MVP after all, it was not possible to combine the two datasets as it was planned. This resulted in a serious lack of very important variables that would have been useful to answer the research questions. The fieldwork data turned out to be incomplete and fragmented: There is, for example, data available on what animals on the farm eat, but not on how many and what sorts of animals there are. Similarly, the questionnaire we used asked about fertiliser use and the number of trees in the field, while it did not inquire about field sizes and the kind of crops being grown. As there is only average data and information from literature available on most of the lacking issues, data analysis is difficult and some variables turned out to simply being useless as data to compare them with is missing. However, as Babigumira (2011: 197) states: “what is important is that the end-user knows why data are missing and this requires that one is able to distinguish between different types of missing data."

2.2.3 Specific issues with the semi-structured interviews

The specific problems that turned up during the follow-up interviews concern:

- Information loss
- Translation problems

As all but one of the respondents being interviewed in the open-ended semi-structured interviews refused the use of a voice recorder, the transcription of the interviews was impossible and a certain extent of information loss could not be avoided. A very high degree of concentration, sensitivity and listening skills was required, which was very exhausting for the interpreter and me.

Another problem was that the assistant was not quite familiar with the concept of open interviews and explaining it to him was not easy. Moreover, he sometimes rather reinterpreted than translated what was said by the farmers and it was necessary to be very attentive and make clear that "the role of the interpreter is to assist, and not to take over the role of the interviewer or the interviewee." (Kvale and Brinkmann 2009: 144).

2.2.4 Ethical dilemmas

> Who likes to have strangers ask personal questions concerning your level of education, the number of chickens on your farm, possibly illegal uses of the forest and the amount of remittance income you got from your daughter who lives abroad? (Reyes-García and Sunderlin 2011: 18).

The three main ethical issues that apply to our fieldwork are the following:

- Unequal power relations
- Informed consent
- Intentions of the project

It occurred quite often that people interrupted their work so that they could be interviewed for about 30[17] minutes; at times this included long walks from the field in the bush to the compounds. On the other hand, if the farmers were too busy, especially during the harvest season[18], they would sometimes just not turn up and we would wait in vain for a long time. Still, many of them felt obliged to participate in the survey, especially as the village chiefs were informed about and had agreed to it. As Reyes-García and Sunderlin (2011: 28) point out “even if researchers ask village or town leaders for permission to conduct research, there is often no latitude for the leaders to say no.”

Another issue is that “prospective respondents have to be provided with a credible rationale for the research in which they are being asked to participate and for giving up their valuable time.” (Bryman 2008: 200). This so-called ‘informed consent’ (Kvale and Brinkmann 2009, Reyes-García and Sunderlin 2011) was of course a prerequisite for the survey and follow-up interviews: People were informed that their participation is not mandatory and the promise was given to treat the information confidentially.

It was explained to each respondent that FunciTree is a research project and not an aid project that gives credits, builds facilities or the like. Nevertheless, many respondents thought the research was a part of the Millennium Villages Project as the farmers we interviewed were part of the sample that had been covered by the MVP’s surveys. This also contributed to a certain ‘interview-tiredness’ of some of the ‘over-researched’ (Scheyvens and Storey 2003: 104) respondents. Furthermore, it sometimes occurred that people expected help with a specific problem, which we were not able to provide. There is always a certain imbalance when people offer their knowledge and time without getting anything back in exchange (see also: Scheyvens and Storey 2003).

[17] The interview time actually varied and one questionnaire took us between 20 minutes and longer than one hour.

[18] When the interviews began, it was the season for beans and peanuts, later the millet and the rice harvests began.

3. THEORETICAL APPROACHES

There is not one distinct elaborated theory about agroforestry adoption. But in the previous decades, there were a lot of publications based on empirical research. Their focus lies, however, often on practical implications and technological improvements. So one of the two theoretical approaches of this thesis is concerned with the meta-analyses of existing studies and how the findings from those can provide a framework for new studies.

The second approach is rather a theoretical framework: The sustainable livelihoods framework (SLF) can be used for explaining diversification at the farm-level. Following the SLF, agroforestry adoption can be explained as a part of the livelihood strategies farmers choose to overcome risk and uncertainty. The ability to diversify with agroforestry is regarded as dependent on household assets, a broader context of vulnerability and institutional factors.

Another theoretical approach that might have been relevant in connection to decision-making strategies and behaviour on the individual scale is rational choice theory. Although it can be useful relative to model building and data analysis with BBN, the use of a third theoretical approach would go beyond the scope of this study. Moreover, there are a lot of critical aspects to rational choice theory, for example concerning the limitation of its focus to the individual and its inadequate description of reality (e.g. Zey 1992: 2).

3.1 Previous Studies and Research on Agroforestry Adoption

For more than three decades "agroforestry has been heralded and actively promoted as a practical and beneficial land-use system for smallholders in developing countries" (Denning 2001: 407). This development entailed increasing scientific research about the topic and thus, continuous innovations and technological improvements. At the same time, it led to the emergence of a discrepancy between the large amount of available knowledge about agroforestry and the actual success of AF practices. This includes both, the continuation of traditional practices, and the adoption of new or improved ones.

> In any applied science – be it medicine, engineering, or agriculture – scientific progress cannot be attained unless there is a strong and rigorously developed theoretical foundation. Because of its development-driven agenda, agroforestry research, unfortunately, had little emphasis on building such foundation (Nair 1998: 224).

Nair (1998) defines the two main goals of agroforestry research: One is to develop better land management solutions and the second is to advance the science of agroforestry. Early agroforestry research was primarily based on descriptive knowledge to gain basic information about the most common trees and AF practices used (Scherr 1991, Nair 1998). Since 1991, when ICRAF became a research centre, empirical and applied research and the 'science' of agroforestry grew in importance. General concepts were identified to get closer to developing a "sound conceptual framework" and transforming agroforestry research into "a rigorous scientific activity" (Nair 1998: 225, 223). Scientific understanding is an important prerequisite to improve technology, to make agroforestry projects more successful and to attain sustainable adoption.

"Agroforestry rural development projects have experienced uneven success rates in many parts of the world due to inadequate adoption rates and / or abandonment soon after adoption." (Pattanayak et al. 2003: 137). To gain better insights into research about agroforestry adoption, it is first of all, useful to define what the term 'adoption' signifies. For Mercer (2004: 312) adoption means that "farmers reduce uncertainty over time by acquiring experience, modifying the innovation and becoming more efficient in its application" (Mercer 2004: 312). It is important that farmers do not only use agroforestry practices when they are introduced from the outside and / or supported by a project, but accept them as part of their land-use system and continue them. In the optimal case, they decide themselves to start or maintain an agroforestry practice because they have sufficient knowledge, motivation and the resources to do so. Franzel et al. (2001:

38) argue that "adoption potential is defined as the likelihood of uptake of a new technology or practice when required information and material are made available to the farmer." So, it is the goal of researchers to find out the factors that influence farmers' attitudes towards agroforestry.

A critical aspect that has to be taken into consideration is that it is not always simple to make a distinction between introduced and traditional practices. Traditional agroforestry parklands, for instance, are 'adopted' by a very high percentage of farmers. Adoption studies are thus often concerned with the adoption of AF practices that farmers use in addition to parklands, e.g. live fences. Research on agroforestry adoption is concerned with both, the success of introducing new types of agroforestry and the improvement of any existing agroforestry practice.

3.1.1 Factors influencing agroforestry adoption

In the past, studies often "have failed to link the empirical analysis to underlying theory and typically have not examined the full range of potential factors that may influence agroforestry adoption." (Mercer 2004: 319). Or as McGint et al. (2008: 100) put it: "Agroforestry development programs have seen varied success (...). Therefore, a clear understanding of the influential factors in farmer decision-making regarding the adoption of agroforestry is important."

To improve research it is fundamental to achieve an overview of the various factors that might influence agroforestry adoption behaviour. As most studies just highlight the results of one single empirical study at one particular point of time Pattanayak et al. (2003) provide a meta-analysis of previous[19] empirical studies about AF adoption behaviour of smallholders in tropical areas. By reviewing those with the help of several quantitative methods, they attempt to figure out and categorise the most important determinants playing a role in adoption and non-adoption of agroforestry practices. The five main categories

[19] The studies have been published during the decade before the article was published, so they are from about 1993 until 2003 (Pattanayak et al. 2003: 137).

they define are: Preferences (1), resource endowments (2), market incentives (3), biophysical factors (4) and risk and uncertainty (5) (Pattanayak et al. 2003: 137). Those categories of determinants entail different sorts of explanatory variables that were listed and catalogued according to how often they have been included in research and to what extent they influence agroforestry adoption. Pattanayak et al. (2003: 142) found risk and uncertainty to have the highest statistical correlation to adoption behaviour. Moreover, their meta-analysis showed the importance of market incentives, biophysical factors and resource endowments – in this order. Preferences were found to be less influential.

Such or a similar kind of categorisation of groups of determinants can be useful to figure out which variables are most important to analyse in this study and contribute to providing a general framework of possibly relevant factors in agroforestry adoption. Pattanayak et al. (2003: 147 and 148) argue that their "five determinants provide a useful organizing framework for conceptual and empirical evaluations of agroforestry adoption" and a "generalized model of adoption".

By and large, other researchers who also reviewed previous studies about adoption have come up with rather similar conclusions about influential factors. One example is provided by Franzel et al. (2001). Although their focus is rather on giving an overview about different types of farm-trials and methods of data collection and analysis, they come up with some determinants of agroforestry adoption as well. Their main categories of factors are biophysical performance, profitability and acceptability (Franzel et al. 2001: 37). Most authors agree on the importance of social, biophysical, economic and risk factors. Some emphasize the importance of markets and available assets and capital (Franzel et al. 2001, Mercer 2004). Others regard biophysical factors like the slope and soil of the farmland as very important (Nair 1998, Franzel et al. 2001, Denning 2001, Pattanayak et al. 2003).

On the other hand, many agree that the research focus of previous studies was to a large extent concerned with biophysical conditions, while the importance of factors of risk was often neglected (Nair 1998, Pattanayak et al. 2003). This is why the importance of risk variables like land ownership, labour availability and market fluctuations are stressed by a lot of researchers (Caveness and Kurtz 1993, Franzel et al. 2001, Denning 2001, Pattanayak et al. 2003, Mercer 2004). Some of them also include institutional factors (Nair 1998, Mercer 2004, McGint et al. 2008) like governmental policies or development projects.

Mercer (2004: 313) summarises that “viewed from a multidisciplinary perspective, adoption is a multi-dimensional process dependant on a variety of factors.” To assess all factors possibly influencing AF adoption would be too ambitious a goal. It is, nevertheless, essential to not only analyse one single determinant, but a combination of several factors to be able to define the adoption potential of agroforestry (Nair 1998).

3.1.2 Lessons learnt from research

Now, the most important factors that research is (or should be) focused upon have been highlighted. Another important aspect to take into consideration is the actual impacts, successes and also failures that have been brought along by agroforestry projects and research. Therefore, a look will be taken at what studies have found out about the decision-making processes of individual farmers that lead to the adoption, non-adoption or abandonment of agroforestry practices.

Denning (2001: 408) aims to “provide a conceptual foundation for scaling up” if agroforestry innovations led to adoption and what impact they had. He refers to the so-called “innovation-decision process”[20] that is leading to adoption and divides it into four different stages. The first one is *knowledge* about the existence of the respective practice and how it works. The second one is *persuasion* and entails how the attitude towards the practice is formed. The third step is the *decision* to engage or not to engage into action, that is, to adopt or reject the practice. The fourth and last step is called *confirmation*. When a farmer had some experience with a practice, he either reinforces his activities or reverses them. Denning (2001: 408) also categorises different groups of individuals

[20] Denning (2001) is referring to a concept by Rogers and Shoemaker (1971).

according to their adoption behaviour "as 'innovators', 'early adopters', 'early majority', 'late majority', and 'laggards'." This classification can describe the adoption of traditional AF practices, as well.

The different types of adopters are, however, not static. There is, in fact, certain homogeneity between them and a lot of interaction happening (Mercer 2004). The discouraging effects of different factors that influence farmers' attitude to adopt an AF practise – like biophysical or socio-economic constraints[21] – decrease when other farmers successfully implement AF innovations. This so-called 'free ride' or 'neighbourhood' effect implies a tendency of non-adopters to shift to adoption influenced by demonstration effects and experiences of innovators or early adopters (Caveness and Kurtz 1993, Mercer 2004).

In this context Caveness and Kurtz (1993) stress the importance of the information that is available to the individual farmer. Farmers take two main aspects into consideration when deciding if there is a practical need for adopting AF: First, their perceptions of the agroforestry practice's economic and social benefits and its practicality play a role. Second, the capital and consumable commodity risk they are taking when adopting is of major significance. "Including the safety-first constraint shows that adoption is costly, the probability of falling below the subsistence level for low-income households is crucial to decision-making." (Mercer 2004: 315).

To tackle these challenges and change adoption behaviour, previous development projects and / or government initiatives often focused on the use of regulations and on setting economic incentives to encourage adoption. As Pretty and Buck (2002: 27) argue, "though these may change behaviour, there is rarely a positive effect on attitudes: Farmers commonly revert to old practices when the incentives and / or regulations are no longer enforced." Such experiences have steadily been leading to a shift of focus in agroforestry projects: The importance of working with the individual farmer and improving his knowledge, capacities,

[21] See factors and categories described earlier in this chapter.

skills and motivations to take action has been recognised. Moreover, many organisations concentrate on working with communities and on helping to establish local farmer associations (Pretty and Buck 2002).

As agroforestry has very complex management requirements, the approach to improve adoption potential by increasing farmer education implies an on-farm testing phase with experimentation and modification of the practice. By taking enough time for that into account, it is easier to understand the problems and perspectives of an individual farmer (Denning 2001, Mercer 2004). In addition, a trained farmer with more knowledge and experience is more likely to reach ‘self-efficacy’. McGint et al. (2008: 100) define this term as follows: “Self-efficacy means that a farmer is capable to manage and control the agroforestry system and fulfil all the required tasks to maintain it.”

The second approach is to spread AF information and practices more cost-efficiently and successfully via community or farmer organisations (Raussen et al. 2002, McGint et al. 2008). Such groups can contribute to establishing structures that make adoption more feasible for association members and to disseminate information about success, constraints and improvements faster and to many farmers. Associations are also beneficial to the efficiency of projects.

> Working through established community groups allows the development organisation to concentrate on what it is best at: providing training and the few necessary materials. It also allows the local council to concentrate on its strengths: planning, mobilising the community, facilitating joint efforts, and resolving conflicts. (Raussen et al. 2002: 76-77).

An ideal strategy to improve AF adoption covers a lot of other fields that might influence adoption potential, like for example, improved seed supply or better product marketing (Denning 2001: 413-414). Yet, the two main approaches mentioned here can provide a good framework for further development project work and research about agroforestry. Both entail that farmers build upon their own knowledge, skills, experiences and preferences when establishing AF practices – either individually or in groups. Understanding the attitudes and needs of local stakeholders, let them work together and exchange knowledge is an approach to adoption research with a high success potential.

3.1.3 Current and future challenges to research

It remains a challenge to develop a predictive framework to understand the whole complexity of farm households' long-term decision-decision-making (Pattanayak et al. 2003, Mercer 2004). Even with a more farm-based research focus, it is difficult to figure out, how to capture the full range of an adoption process. Innovations are often combined with traditional indigenous practices and it is often not easy to see what is new and what has been established for a long time. Moreover, the communication between farmers and their forming of local association cannot be influenced that easily. It is difficult to empower such organisations and make them successful and sustainable (Franzel et al. 2002).

Another critical issue is that "constraints to and motivations for adoption do not necessarily remain constant." While land tenure issues and seed availability were large topics in the 1990s, policy changes in land tenure, subsidy and credit systems appeared and partly altered the situation (Caveness and Kurtz 1993: 24). This is also an issue one must consider when doing factor analysis based on frameworks that rely on meta-analyses of previous studies.

Agroforestry practices are distinguished by their uniqueness and complexity. "Multiple interacting outputs, (…) temporal variability, (…) multiple economic contributions, and (…) off-farm impacts has hampered both conceptual and empirical economic analysis." (Pattanayak et al. 2003: 139). Most agroforestry practices take longer than usual agricultural innovations before benefits can be realised. So, self-sustainability and self-diffusion do not happen immediately (Mercer 2004) and it is neither easy for farmers nor for development initiatives to persevere until there are long-term benefits.

Another problematic aspect is that research and literature about agroforestry adoption is mainly based on economics. So their focus frequently lies on increased productivity, output stability and enhanced economic viability compared to alternatives (Mercer 2004: 312). There is a need for increased interdisciplinary research approaches to agroforestry adoption (Pattanayak et al. 2003, Mercer 2004).

3.2 Livelihood Diversification and Sustainable Livelihoods

The World Agroforestry Centre (ICRAF 2008: 6) refers to a "dual role of agroforestry": AF practices can contribute, on the one hand, to improving livelihoods of poor smallholders and, on the other hand, to making agricultural landscapes more sustainable and productive. They can provide food security, decrease poverty, create new trade opportunities and markets, improve rural employment and help the development of enterprises. Moreover, they enhance natural resource management and biodiversity conservation (Elliot 2006). As agroforestry can contribute in such diverse ways to rural livelihoods, it is imperative to gain a better insight into the various conditions that influence the different choices of livelihood strategies of households. A framework for livelihood diversification can at the same time function as a framework to explain agroforestry adoption.

3.2.1 Livelihood strategies

Before going deeper into the different livelihood strategies, it makes sense to first of all define what actually a 'livelihood' is. Chambers and Conway (1991: 5) state that "a livelihood in its simplest sense is a means of gaining a living." Furthermore, it "comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers and Conway 1991: 6). There is a connection between available assets and the actual options of people to pursue diverse activities. These factors define to what extent a certain level of income can be reached to assure survival (Ellis 2000: 7). Livelihoods describe the resources and strategies that individuals and households use to survive and reach their goals. They are basically concerned with “people, their capabilities and their means of living” (IAASTD 2009: 27).

Livelihood strategies are in some way comparable to survival strategies that people apply as responses to or as preventions against all sorts of risk, shocks and stresses that might face them. However, a distinction must be made between adaptive strategies and coping strategies. While coping strategies are reactions to crises or disasters seasonably employed by vulnerable households, adaptive strategies are planned long-term responses to foreseeable risks that often occur in cycles (Hussein and Nelson 1998, Ellis 2000). Still, all household risk strategies have in common that they aim at spreading risk. As households are not static (Ellis 2000: 43), they can change their structure and activities. As Bolwig (2001: 278) states:

> Research from the Sahel shows that households which have differential access to resources and economic opportunities adapt to change and cope with uncertainty in very different ways and enjoy very different levels of income.

Together the different strategies that household apply to spread risk and secure survival can be described as the households’ ‘adaptive capability’ (Ellis 2000: 3).

Different livelihood pathways and livelihood portfolios

In risk-prone areas like the Sahel, people choose between different strategies to achieve secure livelihoods. In order to be able to do so, many of them even alter their traditional livelihood activities (Toulmin et al. 2000, Barrett et al. 2002).

There are three main livelihood strategies that are pursued: Agricultural intensification (or extensification), livelihood diversification (LD) or migration (Hussein and Nelson 1998, Scoones 1998, Ellis 2000, Toulmin et al. 2000). While agricultural intensification does normally not lead to a change of the core activity of a farmer, in the case of migration, both effects, a change in activity and a change in space, take place. Livelihood diversification means that farmers extend the range of activities they pursue to make ends meet (Toulmin et al. 2000), e.g. they start a shop, plant a fruit orchard or start fishing.

Often, farmers do not only pursue one of these three main strategies, but combine them. People aim to build up a portfolio of activities to have a wider range of opportunities (Ellis 2000, Luckert and Campbell 2002). As Scoones (1998: 8) puts it: “At any scale, livelihoods are composed in complex ways, with multiple and dynamic portfolios of different activities, often improvised as part of an on-going ‘performance’.” (Scoones 1998: 8). Even if crop and livestock often remain the main income sources of rural people, additional activities can include asset accumulation, mortgaging or selling assets, borrowing and lending, utilising common resources and draw upon social and family relations (Hussein and Nelson 1998, Ellis 2000, Bolwig 2001).

> Rural households typically have a wide livelihood portfolio, encompassing a range of activities. It is not uncommon for a household to be involved in livestock-raising; growing a diversity of crops; collecting forest products for subsistence needs and sales; being involved in a variety of reciprocal transactions with fellow community members; having one family-member in off-farm employment who remit money back to the household and having another member involved in some small-scale industry. (Campbell and Luckert 2001: 7).

An important factor for the choice of strategy is the availability of labour, which includes work at the household or farm level as well as wage work at the off-farm level[22] (Ellis, 2000, Bolwig 2001).

> People generally respond to local resource scarcity and climatic and economic uncertainty by diversifying their access to resources and incomes –socially, spatially, and between sectors – and by a flexible use of resources in farm and off-farm activities. (Bolwig 2001: 278).

In the context of agroforestry adoption, the strategy of livelihood diversification probably plays the most important role. Nevertheless, there are inter-relations between LD and other livelihood strategies like migration and off-farm employment (Hussein and Nelson 1998).

[22] Non-farm work opportunities are dependent on the labor market. Migration is often the only option to find off-farm work. However, migration can lead to a smaller livelihood portfolio as it is often not possible that other activities are undertaken (Ellis 2000).

Livelihood diversification

Hussein and Nelson (1998: 3) provide a quite broad definition of what livelihood diversification entails:

> Livelihood diversification refers to attempts by individuals and households to find new ways to raise incomes and reduce environmental risk, which differ sharply by degree of freedom of choice (to diversify or not), and the reversibility of the outcome. Livelihood diversification includes both on- and off-farm activities which are undertaken to generate income additional to that from the main household agricultural activities, via the production of other agricultural and non-agricultural goods and services, the sale of waged labour, or self-employment in small firms, and other strategies undertaken to spread risk (…).

Ellis (2000: ix) stresses that one of the main goals of livelihood diversification is to secure rural households against risks and seasonality: “Diversity enhances the resilience of hazard-prone livelihoods by spreading risk and increasing the options for substitution between diverse livelihood components.” People are able to react to sudden shocks by switching or redeploying different activities (Ellis 2000: 42) by using LD as a “household risk strategy” (Hussein and Nelson 1998: 13). Another aim is the creation of an income portfolio with low covariate risk between its components, which means that the potential risk factors for the different activities are not the same (Ellis 2000: 60). Sometimes, the purpose of LD can also include the accumulation of capital or assets for consumption and investment (Hussein and Nelson 1998).

Although people aim to put together a portfolio of activities to reach the different goals mentioned, it is not always easy to fulfil them as subsistence needs often are more pressing (Elliot 2006: 145). There is a discrepancy between the necessity to survive and the choice to diversify for “voluntary and proactive reasons” (Ellis 2000: 55). The possibility to diversify and how the income generated by LD is used are dependent on wealth. If stakeholders are poor they are unlikely to diversify more but tend to use all of their income for current consumption expenses (Hussein and Nelson 1998: 12). Or, as it is quite common in West Africa, people sometimes rather diversify into a wider portfolio of activities than invest further into agricultural intensification (Hussein and Nelson:

10) or the intensification of activities they already pursue. "Households are considered to be risk averse, and for this reason are prepared to trade lower total income for greater income security." (Ellis 2000: 60).

On the other hand, there is a certain tendency that poor rural people – either due to an absence of other possibilities or because of external stresses – adopt more vulnerable livelihood strategies than they had used previously (Hussein and Nelson 1998, Ellis 2000, Elliot 2006). Thus, it is very important to make a distinction between involuntary coping strategies and voluntary long-term adaptive strategies against risk (Ellis 2000: 60), although they are not always easy to tell apart.

As Ellis (2000: 56) puts it: "Diversification obeys a continuum of causes, motivations and constraints that vary across individuals and households." The most common pressures that influence that the most vulnerable households tend to diversify are connected to rural population growth, farm fragmentation and declining agricultural incomes (Ellis 2000: 56). Hussein and Nelson (1998: 10) talk about the roles of push factors, like environmental risk and declining incomes and pull factors, like changing trade conditions and individual perceptions of and attitudes towards the situation.

> Dynamism (i.e. diversity over time) is a further key feature of rural livelihoods in the developing world. Indeed, the capacity to move the emphasis of any particular element within the livelihood system or to introduce new components has been central often to survival itself. (Elliot 2006: 146)

The diverse forms of livelihood diversification do not necessarily include a diversification of income but rather of activities and social support capabilities (Hussein and Nelson 1998: 4). Moreover, even in rural areas, not all household activities are automatically related to farming or livestock breeding anymore (Toulmin et al. 2000, Ellis 2000). Elliot (2006: 145) claims that in Sub-Saharan Africa in the end of the 1990ies, more than 60 per cent of the income of rural households came from non-farming sources. In this context, it is necessary be attentive not to confound mixing up non-farming activities with off-farm activities. Agroforestry practices are normally practiced at the farm-level[23] but cannot be easily categorised exclusively as farming or non-farming activities. On-farm diversity often involves techniques like mixed cropping and field fragmentation, which make risk spreading possible without income loss (Ellis 2000: 60). Besides the raising of farm income by intensifying livestock production and land use, farmers try to get into niche markets for high value farm outputs. Next to cereal and dairy products, this can also include vegetables, spices and fruit (Ellis 2000). The latter and other outputs and benefits related to agroforestry can contribute a lot to livelihood diversification at the farm-level.

Agroforestry can be considered as a LD strategy because it can contribute to its main goals. Products, like fruit or wood can either be used for auto-consumption or the revenues used for investment into other activities or intensification of practices. The diverse functions of agroforestry e.g. enhance soil fertility or provide animal fodder in the dry season, can help to spread risk and cope with crises. Positive ecological effect, e.g. a potential augmentation of biodiversity can work as an insurance, reduce a farming system's vulnerability and sustain it in the future (Bass et al. 2001).

3.2.2 The sustainable livelihoods framework (SLF)

The framework of sustainable livelihoods[24] has become more and more prominent as an approach to livelihood strategies of the rural poor (Scoones 1998). Following Chambers and Conway (1991: 6) Scoones (1998: 5) gives the following definition of sustainable livelihoods: "A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base."

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[23] In some cases villages have commonly owned or plantations, which makes AF practices off-farm activities or at least activities outside the household. Shared AF resources are, however, not common in the sample used for the field research of this study.

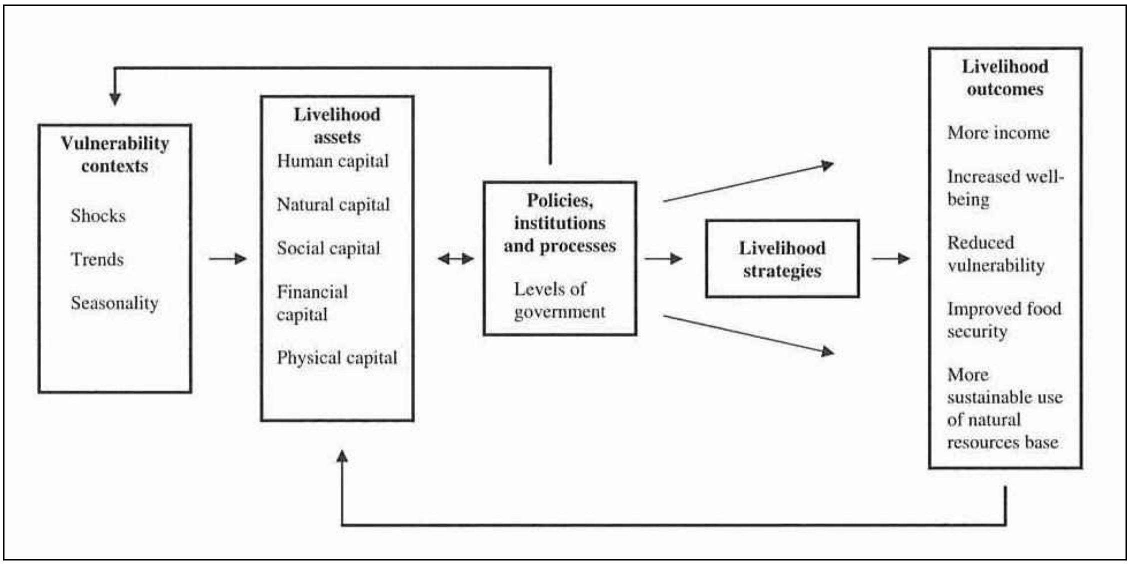
[24] The sustainable livelihoods framework (SLF) is also often referred to as 'sustainable livelihoods approach' (SLA).

The sustainable livelihoods framework is used to gain a better understanding of the various complex interactions that influence livelihood strategies.

> "It is premised on the understanding that rural livelihoods are diverse, complex, dynamic and socially differentiated, and that the types of livelihood strategies and activities they engage in are mediated and influenced by the economic, political, ecological and institutional environment within which they find themselves." (Cundill et al. 2011: 73).

The SLF addresses this complexity by providing a model, which includes different aspects that play a role in explaining livelihood strategies. The following graph depicts the model that is referred to in this thesis.

Figure 1: The Sustainable Livelihoods Framework (SLF)



Source: Cundill et al. 2011 adapted from DFID 2000

The SLF focuses on household production activities set into the context of available livelihood assets or capitals; an institutional, organisational and political context; and a vulnerability context (Cundill et al. 2011: 73). Other scholars have developed slightly altered versions[25] of the SLF model. The SLF is a holistic approach as it includes all possible influence factors of livelihood strategy choices taken by households or individuals. Those are comparable to the groups

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[25] Scoones (1998: 4), for instance, does not speak of a vulnerability context but instead more generally of "contexts, conditions and trends". Ellis (2000: 30), on the other hand, presents a more detailed framework with more sub-components than other scholars.

of factors influencing agroforestry adoption that were presented in the first part of this chapter. Agroforestry can be seen as part of a livelihood strategy chosen by a stakeholder and the different factors influencing adoption behaviour can be seen as a part of the sustainable livelihoods framework.

The context of risk, uncertainty and vulnerability

The first aspect of livelihood analysis with the SLF is the vulnerability context, which consists of factors like shocks, trends and seasonality. Risks and shocks can include extreme weather conditions that affect crops and livestock, like for example droughts or flooding; diminished farm outputs because of illness; macro-economic changes of markets, prices etc. (Campbell and Luckert 2001, Luckert and Campbell 2002, Cundill et al. 2011). “Understanding the vulnerability context is key to understanding adaptive capabilities, coping strategies and the role of environmental resources in securing livelihoods and potentially providing a safety net.” (Cundill et al. 2011: 75). Especially the West African Sahel is a region with highly risk-prone natural and social environments. So the influence of risk perception on the adoption of strategies to cope and adapt is particularly high there (Luckert and Campbell 2002: 232).

Other contextual factors that can be included when analysing rural livelihoods are, among others, policy, history, politics, macro-economic conditions, terms of trade, technological change, climate, agro-ecology, demography, migration and social differentiation (Scoones 1998, Ellis 2000).

The five capitals

“The ability to pursue different livelihood strategies is dependent on the basic material and social, tangible and intangible assets that people have in their possession.” (Scoones 1998: 7). Livelihood assets or livelihood resources, which are “owned, controlled, claimed accessed or in some other means accessed by the household” (Ellis 2000: 31) are the second aspect of the SLF. Those assets are also referred to as capitals.

There is a wide range of different capitals but most sources mention five main types: Human capital (1), natural capital (2), social capital (3), financial capital (4) and physical capital (5) (Ellis 2000, Luckert and Campbell 2002, Sirhole 2002, Cundill et al. 2011). Human capital includes skills, knowledge, health and the availability of labour. Natural capital has quite a large range of factors from natural resource stocks to resource flows and services. That can entail land quantity and quality; forest, marine and wild resources; water, air and soil quality; erosion and storm protection, and biodiversity. Social networks, groups and relationships are part of the social capital of a household or individual. Financial capital entails credits, savings, cash income and household assets. The last of the five main capitals is physical capital, which includes infrastructure and producer goods, like roads, transport and communication facilities (Ellis 2000, Sirhole 2002, Cundill et al. 2011).[26]

When using the sustainable livelihoods framework for analysis it is important to acknowledge that the different sorts of capitals are flexible and can be exchanged, combined and substituted with each other (Scoones 1998, Ellis 2000). If one aims to understand how the different household assets that are available to farmers and combinations of them influence the choice of livelihood strategies, it is necessary to always see it in the vulnerability context mentioned above and take into account external influences that modify the access to and availability of capitals (Luckert and Campbell 2002). Bass et al. (2001: 38) regard a constant level of capital as a main prerequisite to sustainable development and according to Ellis (2000: 44); assets are facilitated by and in return facilitate livelihood diversification.

Institutions, processes and policies

Another important aspect that is taken into consideration in the sustainable livelihoods framework is the influence of institutional and policy factors on

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[26] Sirhole (2002: 217) uses the term produced capital to describe both physical and financial capital. Moreover, he suggests cultural capital as an additional important asset. This entails cultural practices, identity maintenance and traditions.

livelihood strategies. This does not only include governmental institutional processes, but also activities of informal institutions and organisations (Scoones 1998, Cundill et al. 2011). Ellis (2000) points out the importance of institutions and organisations like local administrations, state agencies, NGOs and farmer associations, especially concerning rules and customs. They often play influential roles, for example, concerning land tenure rights and market practices. On the other hand, institutions can also be important as they are “regularised practices (or patterns of behaviour) structured by the rules and norms of society which have persistent and widespread use” (Scoones 1998: 12). Institutions define to a high extent power relations and access to resources.

Livelihood outcomes

In the SLF model of Cundill et al. (2011: 74) the different livelihood strategies that are adopted by rural households – influenced by assets, institutional factors and the context of vulnerability – are leading to various (in the best case positive) livelihood outcomes (Elliot 2006). Those, in turn, influence the livelihood assets or capitals of the respective household, so that a sustainable system can come into being. Sustainable livelihoods include an improvement of the capabilities of and the assets available to individuals and their livelihoods (Sirhole 2002).

The choice of livelihood strategies that include versatile and diverse portfolios of activities leads to people being capable to retreat into subsistence in cases of shocks and being able to adapt to any kind of pressures (Ellis 2000). Cundill et al. (2011: 74) mention diverse potential livelihood outcomes: One is income generation and increase. Another one is increased well-being. Then, there are improved food security, reduced vulnerability and a more sustainable use of the natural resource base. Scoones (1998: 4) refers to the same outcomes, but additionally mentions increased work days.

3.2.3 Using the SLF for agroforestry adoption analysis

The sustainable livelihoods framework does not only provide a theoretical foundation for agroforestry adoption, it can also be used for generating a basis for research and as a framework for analysis of specific situations and examples of livelihood diversification (Scoones 1998: 3). In the case of this thesis, agroforestry adoption as (part of) a diversification strategy can be analysed in the SLF. Especially the multifunctionality of tree species and the preferences and attitudes that farmers have concerning tree use and agroforestry practices can to a large extent be connected to livelihood diversification.

The approach is a holistic and integrated view of how people can achieve sustainable livelihoods, which might lead to the assumption that the provided framework actually is much too large for the proposed research topic of this thesis. But Scoones (1998: 13) argues:

> If the full range of differentiated and nuanced quantitative and qualitative information is to be amassed for the analysis, even a major field research effort may be insufficient to uncover all aspects of sustainable livelihoods in a given site.

The aim of the SLF is not to demand completely holistic and at the same time not realistically feasible research. Not all possible livelihood pathways and strategies are supposed to be analysed. Instead, there can be a focus on a specific livelihood pathway, like in this case, agroforestry adoption. By using the principle of ‘optimal ignorance’, it is allowed and encouraged to research “only what is necessary to know in order for informed action to proceed” (Scoones 1998: 13).

The sustainable livelihoods approach is quite flexible and dynamic. It can be applied to different scales, ranging from the individual or household level to groups, villages, regions, or even nations. In the case of this study, the data, which is being analysed and set into the framework is coming from the household level. As the scope of the different indicators that influence livelihood strategies is very high, a combination of quantitative with qualitative data acquisition methods, as used in the research for this thesis, is recommended (see also: Scoones 1998).

4. APPROACHES TO DATA ANALYSIS

Naturally, there are differences in the methods of analysis for the diverse kinds of data used to answer the research questions of this thesis. The prerequisites of secondary data analysis are quite different to those of primary data analysis and not all techniques of analysis can be applied to the various types of variables that have been produced by research.

First of all, there is the household survey data that tools of statistical analysis can be applied to. In order to calculate statistics and generate graphs and tables to "provide a 'snapshot' of the village and its diversity" (Scheyvens and Storey 2003: 45) it is necessary to create a 'cleaned' data set from the raw data and enter it into a software package[27]. Thus, it is possible to depict central tendencies, like ranges, variances and frequencies with the help of simple tables and histograms. The initial descriptive visualisation of the data enables to make first observations and find out, which variables are interesting to investigate further (Shively and Luckert 2011). Then, a specific tool for creating probabilistic so-called 'Bayesian Belief Networks' (BBNs), is employed to graphically display assumptions about interrelations between factors and to evaluate those relationships. This data analysis method will be explained in more detail in the next part of this chapter.

The five texts that were generated from the written notes from the qualitative interviews are being approached with a thematic analysis (Bryman 2008). Different recurring themes are identified by reading the fieldwork notes thoroughly, and categorised into groups and sub-groups for a better management and organisation of the data. The data includes, for example, information on different revenue sources, on the use of them, on savings, education and different types of problems at the respective farm. The analysis of the qualitative data is to

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[27] In this case, 'Microsoft Excel' was used.

some extent transcending from thematic to narrative analysis as stories have been told that might indicate more about the farmers' situation than is actually said.

Project data and literature are mainly used to provide background information. As Cundill et al. (2011: 73) state:

> Once data has been collected, contextual data is important for interpreting findings and placing these into perspective. (…) Contextual information often proves useful when trying to establish causal relations behind the observed correlations.

Some of the aggregated data provided by the FunciTree project and the MVP can be useful to verify findings from the fieldwork of this thesis. However, aggregated findings – unlike primary data – cannot be analysed with statistical tools due to the risk of a so-called ecological fallacy, which "is the error of assuming that inferences about individuals can be made from findings relating to aggregate data." (Bryman 2008: 307).

4.1 Bayesian Belief Networks (BBNs)

To understand why a Bayesian Belief Network (BBN) is a useful tool to graphically depict relations between different variables, it is, first of all necessary to explain their main characteristics and advantages.

4.1.1 What is a Bayesian belief network?

"Bayesian belief networks (BBNs) are models that graphically and probabilistically represent correlative and causal relationships among variables." (McCann et al. 2006: 3053). Those causal relations are depicted in a graphical model with the help of direction arrows, which are showing how the knowledge one has about one variable (A) determines the knowledge one has about another variable (B). A causal relation between the two variables means, that if the knowledge about one of the variables changes, the knowledge about the other changes as well (Naim et al. 2008).

BBNs are also referred to as probability networks or probability models (Smith 2010, Marcot et al. 2006, Greenberg 2008). They do not show a definite causal outcome, but also take uncertainty into consideration. The data being represented can be based on explicit knowledge, but also empirical data or subjective observations (McCann et al. 2006). In BBNs the probability and consistency of hypotheses is calculated based on the available knowledge or observations (Naim et al. 2008). Classical hypothesis testing usually requires a null hypothesis, which can be rejected if the required significance level (or p-value) cannot be reached by the available evidence. In contrast, "Bayesian methods ask: What is the probability of the hypotheses being true given the observed data" (Greenberg 2008: 8) and not vice versa. Thus, they can be evaluated with any available data and are not restricted to a minimum size.

BBNs are able to show probabilities of various outcomes and function as a decision aid. McCann et al. (2006: 2054) point out that BBNs have a lot in common with decision trees as they are "models that denote effects of alternative decision pathways." BBNs are used to structure a model in a way that its various causal conditions are most likely to lead to a certain outcome. To calculate these different conditional probabilities of events that have causal links to each other is called 'inference' (McCann et al. 2006, Naim et al. 2008), while on the other hand, drawing outcomes from the thus constructed model is called 'deduction'. Some of the main goals of the graphic representation of data in a Bayesian belief network are: To predict the behaviour of the system, to diagnose the causes of an observed phenomenon, to control and stimulate the behaviour of the system, to analyse the used data and to take decisions in the system (Naim et al. 2008: 200).

4.1.2 Why use BBNs?

The advantages that BBNs have in comparison to other statistical analysis tools are related to the following main issues:

- Complexity, acceptability and representation
- Variability and flexibility in data requirements

- Decision-making and risk analysis
- Available software

First of all, the graphical representation of Bayesian belief networks shows different variables in a clear and simplified way (McCann et al. 2006, Greenberg 2008: 95). It is the most intuitive representation of knowledge (Naim et al. 2008), which makes it also possible for non-specialists to validate, develop, and use the models. This is particularly relevant for studies with a multidisciplinary approach as used in this thesis. BBNs provide a way to transparently communicate the "cumulative effects and outcomes of alternative conditions and decisions" (McCann et al. 2006: 3054). In comparison to other data analysis techniques BBNs have the ability to provide a complete formalisation of a field of knowledge in one causal graph (Naim et al. 2008: 199). Different kinds of information can be gathered in one flexible and transparent model with a wide structure[28] (Naim et al. 2008, Smith 2010). Empirical data and expert knowledge can be combined (Marcot 2007). Knowledge can include prior information and also be updated with new information over different periods of time (McCarthy 2007, Greenberg 2008, Marcot 2007). "In contrast, conventional statistical methods are forced to ignore any relevant information other than that contained in the data" (Greenberg 2008: 2). Bayesian analysis

> draws together sometimes diverse sources of evidence, generally acknowledgeable facts, underlying best science and the different objectives relevant to the analysis into a single coherent description of the given problem (Smith 2010: 4).

Another advantage of BBNs is that modelling is possible in both data-rich and data-poor situations (McCann et al. 2006). Even if only the values of some variables are known, one is able to calculate conditional probabilities with the available data. This is possible because only approximate solutions are shown (Charniak 1991): Missing or unknown data are taken into account (McCann et al.

[28] BBNs are thus differing from "more static models such as decision trees and other traditional statistical approaches like classification or regression trees" (McCann et al. 2006: 3054).

2006, Smith 2010) and aspects of uncertainty are automatically integrated into the model. However, one possibility to mitigate uncertainty is by developing learning models via data mining of the available information. By building predictive models, a priori conditions for unknown variables can be identified with the help of expert judgement. It is possible to experiment with those a priori conditions and to revise the model and its data over time, so that the most probable explication is shown based on the given information (Naim et al. 2008). As Greenberg (2008: 95) phrases it, "a well-fitting model will describe both the central tendency of the data and the variation in the data, and will make both unbiased and precise predictions." By incorporating key uncertainties BBNs can contribute to decision-making under uncertainty (McCann et al. 2006).

Moreover, "BBNs can be used to identify key factors that most influence some outcome of interest, to help prioritize, monitoring or research" (Marcot 2005: 5) A Bayesian belief network can at the same time evaluate, predict, diagnose and optimise decisions (Naim et al. 2008: 188). When using it to solve a given set of problems, the best possible decision is being found on the basis of probabilistic information originating from both prior and updated knowledge (Marcot 2007, Smith 2010). The results appear in the form of probability laws, which make uncertainty visible to decision makers (Naim et al. 2008: 295). Decision models show different decision pathways, which can, for example, contribute to minimising costs or maximising benefits. Furthermore, "outcomes are expressed as probabilities, which are expressions of uncertainties and which fit well into risk analysis and risk management" (Marcot 2007: 2). The probabilities of information can be tested and updated by sensitivity analyses. By testing how the probability of an outcome changes when an observation is made, it can be found out which part of the available data is crucial and which variables are less informative relative to the outcome of interest and can be neglected in an updated version of the model (Naim et al. 2008).

One more criterion for the choice of BBNs as a main tool for data analysis is the availability of an adequate software package (Naim et al. 2008). In this thesis, computer software called ‘Hugin expert’, is used to structure and develop BBNs, to calculate Bayesian statistics and to present models graphically.

4.1.3 How to build a BBN?

As explained earlier, “a BBN is a graphical network of nodes linked by probabilities. (McCann et al. 2006: 3055). It is therefore necessary to take a closer look on what a ‘node’ and a ‘probability distribution’ are and to explain in detail the different steps that have to be taken to develop a model:

Model building with nodes and arrows

BBNs consist of nodes that depict the various variables and arrows showing direct causal links between them.

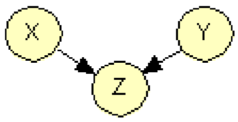
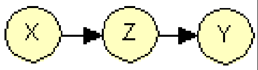
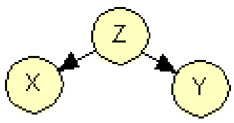
> Nodes can represent constants, discrete or continuous variables, and continuous functions, and how management decisions affect other variables. Nodes are comprised of states that are independent, mutually exclusive, and exhaustive propositions about the values or conditions that the variable represented by the node can assume. (McCann 2006: 3054).

There are different types of variables. In a causal network, one important distinction is made between dependent response variables and independent variables, which are also called ‘covariates’ or ‘regressors’ (Greenberg 2008, Shively and Luckert 2011). In BBNs the variables without influences are called ‘parentless’ ‘root nodes’ or ‘input nodes’, while the ones that are influenced by the others are called ‘child nodes’ (Naim et al. 2008, McCann 2006). The bottom node of the causal network is an ‘output node’ (Charniak 1991).

The first step in building a Bayesian belief network is to identify the different variables that are supposed to be a part of it. Then, all their possible states or values have to be defined (Naim et al. 2008, Marcot 2007). Those states can be expressed in the form of categories. For example, a variable indicates information about the soil type in a millet field and can have the states ‘sandy’, ‘loamy’ or ‘mixed soil’. Another variable type can be a dichotomous variable with two categories, which are often simply ‘yes’ or ‘no’. Then, there are interval variables that are expressed in numbers, e.g. 'age of a person'[29] or 'numbers of trees in a field' (Bryman 2008, Friis and Lund 2011).

The next step is to design an influence diagram by linking the identified nodes with each other and thus, creating causal relations between them (Naim et al. 2008, Marcot 2007). There are different types of causal relations that can be presented by direction arrows:

Figure 2: Types of causal diagrams and their properties

Graph structure	Node properties	Example
	**X** = land title **Y** = protection incentive **Z** = trees protected	The graph shows a convergent connection between the variables. Information cannot pass from X to Y without knowing Z. The knowledge about the farm's land title (X) has supposedly no relation to the knowledge about if incentives to protect (Y) were received by the farm. But the knowledge land title (X) makes it less likely to believe tree protection (Z) is influenced by incentives (Y). If Z is known an observation of X can be used to infer what the probability of observing a particular value of Y might be.
	**X** = precipitation rainy season **Y** = price of Shea fruits **Z** = fruit harvest from Shea tree	This graph shows a serial connection between the variables. If there is already knowledge about a rich tree harvest (Z), the knowledge about the precipitaiton in the rainy season (X) does not provide additional knowledge about the price of Shea fruit (Y).
	**X** = leaves of *Balanzan* on my farmland **Y** = leaves of *Balanzan* on neighbour's farmland **Z** = grazing cattle at night	The last example shows a divergent connection between the variables. If I have knowledge about leaves having been grazed from Balanzan trees at my farm (X), I tend to think cattle has been grazing at night (Z) and therefore, the leaves of the neighbours trees have been grazed (Y), too. However, if Z is known, Y is also known and the information about X does not change anything. From the knowledge of Z I am also able to deduct knowledge about X and Y.

Source: Barton 2010 (based on Naim et al. 2008): Adapted from PPP of the training in BBN modelling workshop in Dakar, Senegal 2010

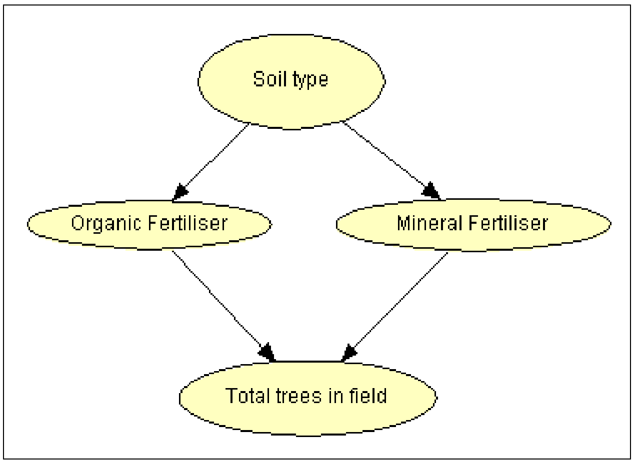
There are some main 'best practice' rules that are useful to follow when constructing a Bayesian belief network (Marcot et al. 2006):

- There must be less than three parent nodes influencing one other node.

[29] Numbers can be rank ordered (or discretised) into groups for better operating with them, like for instance 'age 20-30', 'age 31-40' and 'age 41-65'.

- It is most useful if one node has not more than six states.
- The depth of a model should preferably have less than five levels.
- All nodes should have defined quantifiable states.

Figure 3: Causal network example



In this example[30], the main input or root node describes the type of soil that is prevalent in the millet field of a farm. The main output node depicts the total number of trees in the field. The two variables in between are ‘summary child nodes’ (McCann 2006: 3054), which have both incoming and outcoming arrows. They present information about the use of mineral and organic fertiliser in the field. With the help of this Bayesian belief network a hypothesis about a cause-effect relationship between the variables can be evaluated (Shively and Luckert 2011): It is postulated that the soil type influences the use of organic or mineral fertiliser in a millet field, and the use of one, both or none of these fertilisers influences the number of trees in the field.

The states of each of the nodes in a BBN are specified with probability distributions: While parent nodes have unconditional prior probabilities, the values and states of child nodes are indicated with conditional probability distributions (Naim et al. 2008: 193).

> The arcs in a Bayesian network specify the independence assumptions that must hold between the random variables. These independence assumptions determine

[30] The example is randomly chosen to present a typical Bayesian belief network.

> what probability information is required to specify the probability distribution among the random variables in the network (Charniak 1991: 51).

Dependent on which probability distributions are provided by the available data set(s), it is possible to infer or deduct probabilities for the various nodes. In the example above, it is, e.g. possible to deduct the use of fertiliser if one has knowledge about the soil type in a millet field. Or if one, for instance, has information about the total number of trees in the field and the conditional likelihoods represented in the arrows, one can infer the level of fertiliser use.

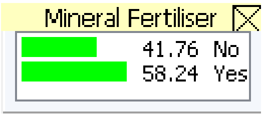
Attributing probability distributions

After the linkages in the BBN are defined, the (prior) probability information for each of the nodes is required to be able to calculate posteriori probability distributions of the output node(s) in a BBN (Marcot 2007, Charniak 1991, Naim et al. 2008). It is thus necessary to assign prior probabilities to the different states of root nodes and find conditional probabilities of the states of the non-root nodes (Charniak 1991). There are three main approaches to define prior probabilities: First, there is the frequency approach, in which probability is defined by the frequency of an observation. Second, the objective approach regards probability as based on valid scientific evidence. The third possibility is the subjective approach, in which probability is defined by an individual's belief in the occurrence of an event (Naim et al. 2008: 17). If there is a variable for which no probability data is available, it is possible to set the a priori probability to 50 per cent for both states (if the variable is dichotomous) as there is no evidence that permits to say that one of the states is more certain than the other. Also, it is often possible to estimate an equal probability distribution of two states from subjective knowledge (Naim et al. 2008): If for example, the two states of the variable 'season of the year' are 'rainy season' and 'dry season', the prior probability is 50 per cent for both states as both events are equally probable. The information can, however, be corrected by empiric data or peer review afterwards (Marcot 2007). In the best case, prior probabilities are a mixture of real field data, observations and of the modeller's best judgement (Marcot 2005).

As Smith (2010: 3) sums it up, "in a well-built Bayesian model logical argument, science, expert judgements and evidence – for example given in terms of well-designed experiments and surveys – are all used to support this probability distribution." With the 'Hugin' software that is used in this thesis, it is possible to construct Bayesian models like the one demonstrated in the example above. The so-called 'learning wizard' function[31] can help to acquire numbers from the available data bases. Then, probabilites from the data can be attributed to nodes, if necessary their different states can be categorised and causal links attributed to them. Afterwards, the BBN can be used to calculate the conditional and output probabilities of the various nodes.

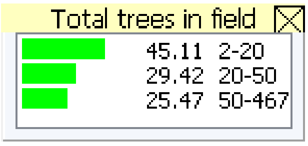
The following two example nodes are developed with Hugin. The bars and numbers express the probabilities for each state:

Figure 4: Example of a dichotomous node



This node represents a dichotomous variable with two possible states, yes and no. As the probabilities of the states are based on fieldwork data, the distribution is not equal. Based on the available data, the probability of the use of mineral fertiliser on millet fields by the farmers in the sample is 58,24 per cent, while the probability of them not using it lies at 41,76 per cent.

Figure 5: Example of a node with discretised variables



In this node, the possible values of numbers of trees in the fields are divided into intervals following subjective judgement based on observations in the field. It is necessary to discretise the ranges of continuous variables into a few intervals, so that tables of probabilities do not get to huge or causing data processing problems

[31] The learning wizard is also used for data mining.

in larger networks (Naim et al. 2008). It is possible to undertake a sensitivity analysis of the chosen discretisation via testing and refining a model.

During the modelling process child nodes[32] are given conditional probabilities when being linked with parent nodes. Their output probabilities can be made visible with the help of a “conditional probability table” (CPT). The final posterior probabilities of states or values of output nodes are being calculated by using standard Bayesian learning statistics (McCann 2006). In the case of this thesis, these output probabilities are calculated by the Hugin software. It is possible to show the results in a simple and rather deterministic way, but in most cases, there is more than one result (Marcot 2005). The following example shows the CPT of the total number of trees in a millet field from the example BBN shown above:

Figure 6: Example of a conditional probability table

Organic Fertiliser | Soil type | Mineral Fertiliser | Total trees in field

Organic Fer...	No		Yes	
Mineral Fert...	No	Yes	No	Yes
2-20	0.333333	0	0.552632	0.384615
20-50	0.333333	1	0.315789	0.269231
50-467	0.333333	0	0.131579	0.346154
Experience	0	0	0	0

The table displays the distribution of probabilities for the different intervals of the output node showing all states the child nodes can take. Thus, all possible outcomes are visible to the modeller; The probability for a farmer having a small (2 to 20 trees), a medium (20 to 50 trees) or a large (50 to 469 trees) amount of trees in his millet field under the conditions of using either organic, or mineral fertiliser, both or none, are depicted. The hypothesis proposed in this example is that there is a causal relation between fertiliser use and tree density in millet fields. A conditional probability table like this does not prove the hypothesis to be wrong or right but it can give indications about the extent to what one can believe its presumptions. “BBNs can also be built with explicit decision and utility nodes

[32] Child or output nodes can also be called ’bottom nodes’ as they usually are at the bottom of a causal diagram as can be seen in the example above.

which represent, respectively, alternative management actions and the values (costs or benefits) of those actions or of model outcomes." (Marcot 2007: 8).

4.2 Challenges of Data Analysis

There are several challenges and caveats concerning the conduction of both quantitative and qualitative data analysis. As this thesis is mainly focused on the analysis of quantitative data, the focus lies on the challenges with that.

One of the largest sources of mistake connected to survey data analysis is associated with the generalisation of the findings. As Bryman (2008: 332) puts it: "There is no feasible way of finding out whether they do in fact apply to the population! What you can do is to provide an indication of how confident you can be in your findings." Therefore the most important rule is to always take issues like sampling error and the manifold sources of bias that necessarily come up during fieldwork into consideration. Moreover, it is important to keep in mind that there is a difference between correlation and causation (Shively and Luckert 2011, Charniak 1991) and to not generalise observations too fast. "No matter how collected, (...) the analysis of observational data requires special care, especially in the analysis of causal effects (…)" (Greenberg 2008: 4). It is often possible to make assumptions about likely causal relations between variables but their real relationship could be completely different. In BBNs, this difference is made explicit, whereas it is not distinguished in classical statistical hypothesis testing. Considering all the difficulties that came up during fieldwork and data acquisition for this thesis, it is important to always take into account the fact that variables could be missing or inconsistent during data analysis (Bryman 2008).

4.2.1 Aspects to consider when using BBNs

The challenges of using Bayesian belief networks as tools of data analysis can be divided into two groups:

- Complexity, acceptability and communication

- Uncertainty and variability

One problem of analysing data with BBNs is accuracy. On the one hand, a large number of nodes make a model more accurate and realistic; on the other hand, data needs to be put into a simple and useful model (Charniak 1991). A diagram with too many nodes is not easy to read and can give the impression of being chaotic. Moreover, the probability distributions of the nodes, as well as the causal links between them must all be specified and quantified, while at the same time, there is no formal way of calibration and validation of a BBN. Marcot et al. (2006) agree that a set of guidelines and insights to avoid spurious or unreliable models is needed. The structures of models that are constructed by data mining are often unwieldy and the discretisation of the values of some of the nodes leads to information loss.

Moreover, it is not easy to judge how to discretise continuous variables in a good way: Is it best to divide prior probabilities into categories that represent an equal distribution of how often answers came up in the survey data (the categories could be as unequal as e.g. 0-5, 5-50, 50-60, 60-95)? Should the answers rather be divided according to numerically equal distance (e.g. 10-20, 20-30, 30-40 etc.) or according to subjective judgement and observations?

Another problematic aspect is that bias, variability and uncertainty are not sufficiently evaluated in Bayesian belief networks.[33] According to Smith (2010: 173) naïve Bayesian models do not faithfully represent the uncertainty between variables. Techniques to prove if a model actually fits the data are not always available. The possibilities of sensitivity analysis and peer review are intensive in time and effort and do not guarantee generating models that are valid in other settings. The reason for this is that BBNs are very flexible concerning the kind of data they are based upon. It can happen that the data of one model is uniquely based on expert judgement and not on empirical studies at all. This is why McCann et al. (2006: 3054) argue that

[33] In multivariate regression this is the case, as well (McCann et al.2006).

> the use of expert judgement necessitates documenting, defending, and, where possible, validating the basis for the model structure and conditional probabilities. BBNs based mainly on expert experience should be used to generate testable hypotheses and should follow a rigorous procedure for developing, testing, and updating the model.

It is important to remember that the proposed hypotheses are always subjective and thus, BBNs do not depict the truth but can merely help finding out more about and trying to explain aspects of different kinds of phenomena and problems. This is why BBNs can be a bridging tool between qualitative research – used to define hypotheses – and classical statistics used to test them formally. “In their most theoretical forms these probability models simply purport to explain observed scientific phenomena or social behaviour”, as Smith (2010: 3) states. For this reason, BBNs – and any other model of reality – should be used for decision support rather than decision making.

4.2.2 Challenges of qualitative data analysis

“One of the main difficulties with qualitative research is that it very rapidly generates a large cumbersome database because of its reliance on prose in the form of such media as field notes, interview transcripts, or documents.” (Bryman 2008: 538). It is often difficult to find analytic paths as the sources of qualitative data are manifold, not available in a concise and quantifiable form and almost completely subjective. The best way to tackle these challenges is to be even more careful and considerate concerning the risk of bias and uncertainty than in quantitative data analysis.

5. FINDINGS FROM THE FIELD RESEARCH

In the following chapter, the main findings of the fieldwork in the Tiby cluster will be presented. First of all, some important terms and expressions will be defined to gain a better understanding about the site. Then, general household and socioeconomic characteristics[34], as well as information about farm activities and agroforestry adoption will be displayed.

Some provisional answers to the research questions are given as several of the factors that are important to agroforestry adoption are presented. Moreover, indications are made about benefits of different tree functions and disadvantages as well as uncertainty and risk factors mentioned by farmers.

From the information provided in this chapter the most important variables are picked to investigate, analyse and discuss further in chapter six.

5.1 Household Characteristics

There is not much information available about household characteristics of the sample. However, some assumptions based on observations can be supported by aggregated data from other surveys and from the qualitative interviews.

Gender and age of the informants

All of the 94 farmers interviewed are male and presumably older then 25, as the role of the household head is usually inherited by the eldest son. A few informants told us they had recently become the heads of the household because of their fathers' deaths (e.g. respondent#83: interview 08.11.10). According to the MVP household survey 95 per cent of the households in the Tiby village cluster are male headed[35] (The Earth Institute / MVRP 2011).

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[34] Household characteristics collected by the MVP household survey but not shared with the FunciTree project and unavailable for this thesis are listed in chapter two and appendix F.

[35] Moreover, the land belongs to a male household member in 89 per cent of the cases and the official land title belongs in 98 per cent of the cases to males.

Concerning the average age of the interviewees, my observation was that they were approximately in their fifties. In the data of the FunciTree survey that had been conducted in early 2010 the average age of the household heads interviewed is 54 (FunciTree / IER 2010), which supports this assumption. There are no fundamental differences in how households are organised in the communes of Dioro and Farakou, so the average age from this larger sample is comparable with the average age of the interviewed in this study.

Household size and composition

As there is no information in the data set about household size and composition, it is referred to the aggregated data of the MVP survey here. According to the MVP the mean household in the Tiby village cluster has 13 members, six of them adult and seven of them under 18 years old (The Earth Institute / MVRP 2011).

Ethnicity and migration

The population in the Tiby village cluster is 78 per cent Bambara, an ethnic group that traditionally works in agriculture and six per cent Maraka, a group that is essentially integrated into the Bambara population[36] and speaks the same language. This is why they are treated as one ethnic group in this study. There are also about ten per cent Fulani and about six per cent of other / unknown ethnicities present at the site (The Earth Institute / MVRP 2011). The dominant group in the sample is Bambara/Maraka. Only one farmer has a different ethnic origin, as he belongs to the Songhai, an ethnic group mainly living in the North East of Mali in the border region to Niger. The Songhai are, similar to the Bambara / Maraka, traditionally farmers who use the Niger River for irrigation.

The sample of the Tiby village cluster population interviewed in this survey is quite stable with regard to migration patterns as all but two farmers were born in the villages where they live. One of the two informants who had immigrated to the Tiby village cluster is Bambara / Maraka and one is Songhai.

[36] The historic integration of those two tribes goes back to more than two centuries ago. Now they are almost completely affiliated.

Two of the six people who could not be included into the survey although they were part of the original sample had emigrated. One of them had moved to the South of Mali and the other one to Dioro, the municipality’s capital. Moreover, even though the heads of the households, who were interviewed in this survey, did not migrate, it is possible that parts of their families have. It is quite common that some of the children of farmers leave the village to earn money in the city or in different countries instead of taking over the farm (see theory chapter). One farmer and his son told us that all three sons of the family sometimes work in Bamako for a period of time. Mostly, they are in the capital during the rainy season, and return to the village to help with the harvest or other important tasks (respondent#82: interview 22.11.10).

5.2 Socioeconomic Characteristics

Data about socioeconomic characteristics is incomplete, too, but there is some information about land ownership, association membership and project support.

Land ownership

Of the 94 interviewees 93 stated that they have their own land[37]. Only one mentioned that he is currently renting land in addition to his own and another one claimed to have rented land in the past. About a third of the informants mentioned that there is a possibility to rent additional land, but that they do not use it.

A different farmer talked about land divisions that had been conducted by the Office riz Ségou in the past. He claimed that several farmers had to give up their old land because it had been transformed into rice fields and had to move to hamlets further in the bush (respondent#37: interview 23.11.2010).

[37] Even if it is the case that secure land tenure plays a huge role in agroforestry adoption, it seems to be a less important factor in Tiby, as 97 per cent of the cluster population have secure land tenure. In 93 per cent of the cases, the land is inherited (The Earth Institute / MVRP 2011).

Association membership

Out of 94 household heads being interviewed in the survey, 76 stated that they are members in some sort of farmer association. This includes associations of the Millennium Villages Project, which 53 farmers are members of. These associations are partly based on farmer initiatives and community engagement. In the framework of the MVP "meetings were held to identify already existing grassroots organizations" and "sector committees were formed or revitalized" (The Earth Institute 2010: 12). However, as we do not know to what extent these associations involve active participation or are more of a formal nature, a distinction is made here between the MVP association and other associations.

About half of the informants are members of other local associations than the one of the MVP. In the table below, the main association types and their fields of activity are shown. Associations with traditional Bambara names[38] that were not specified as farmers', village or youth organisations are referred to as 'other organisations' here.

Table 3: Association membership and fields of activity (except MVP association)

TOTAL members	**48**	**Agriculture**	**Finance/credits**	**Livestock**	**Forestry**	**Other**
Village association	16	13	1	0	0	3
Farmers' association	8	8	0	0	0	0
Youth organisation	12	9	0	0	2	2
Other organisation	14	12	2	2	0	1
TOTAL		**42**	**3**	**2**	**2**	**6**

The main part of these associations are concerned with agriculture, while there are just some with other more specific foci, for example on forestry or livestock breeding.

Although the informants gave quite detailed answers about the associations, they are active in, there might still be some information missing

[38] The associations are called Benkadi ("together"), Anissarton, Bendia, Missiriton, Nyeta and Djéton.

about association membership of single household members. For example, sometimes, the wives of the farmers are members of women's organisations (Respondent#89: interview 22.11.2010).

Development projects

The question if the household is or has in the past been under the auspices of some sort of development project was answered positively by 58 farmers. As the sample is in the project site of the Millennium Villages Project, it is logical that a lot of farmers, namely 53, mention cooperation with it. Only 15 farmers have experiences with other organisations or projects than the MVP.

About eight of them mentioned the governmental Office riz Ségou (ORS). The organisation has a long history in the area of Ségou as it is the governmental institution which is responsible for the management of the dam of Markala, and thus, of the rice plantations and their irrigation. Farmers mention positive as well as negative experiences with cooperating with the ORS. People do not have the autonomous control over the irrigation of their farm land and, for instance, have to ask for permission of the ORS if they want to use other or new fields for rice cultivation, as one of the farmers stated (respondent#46: interview 23.11.10). Another informant told us that people had to move when the state decided to begin with the rice cultivation in the area. He said that all the trees were cut down by big machines when the fields were transformed into rice fields, because birds might seek refuge in them (respondent#37: interview 23.11.10).

One other organisation is Africare, which has implemented alphabetisation and education projects and was mentioned by three informants. Five other organisations are mentioned by only one person, respectively. One is the National Bank of Agricultural Development (BNDA – la Banque Nationale de Développement Agricole). Then, there are three smaller individual projects initiated by university students and governmental organisations. The only organisation with a specific focus on agroforestry mentioned by one respondent is ICRAF (The World Agroforestry Centre).

5.3 Farm Activities

The farm activities of the households, which are not directly – but often indirectly – connected to agroforestry, will be presented in the following.

5.3.1 Livestock breeding

One of the main farm activities of households in the Tiby village cluster is animal breeding. Due to the problems mentioned in the methodology chapter, data about numbers of livestock owned by the farmers is not available. Nevertheless, the different animal species owned, the main sources of animal nutrition, as well as problems with livestock breeding are presented.

Animal species at the farm

Of the 94 farmers in the sample, 91 state that they have farm animals, like sheep, goats (small ruminants), cattle (big ruminants), donkeys or horses. The different types of animals present at the households at the site are shown in the following table:

Table 4: Animal types owned by the informants

Farmers with:	**Cattle**	**Sheep & goats**	**Donkeys**	**Horses**	**Farmers TOTAL**
TOTAL	84	81	40	1	91

The most common domestic animals are cattle, followed by small ruminants, like sheep and goats. Donkeys are owned by less than half of the livestock breeders, while horses are not very common, at all.[39]

Main nutrition of the animals

All 91 informants who stated that they own farm animals were asked what kind of fodder the different types of animals consume during the dry and the rainy season.

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[39] We assumed that all farmers had poultry.

Table 5: Different animal types[40] mentioned and their fodder sources (number/percentage)[41]

	Animal type	Cattle		Goats/ sheep		Donkeys	
	Farmers	**84** (100%)		**81** (100%)		**40** (100%)	
Dry season	Crop residuals	**82**	98%	**55**	68%	**35**	88%
	Pasture	**5**	6%	**31**	38%	**8**	20%
	Hay	**11**	13%	**4**	5%	**25**	63%
	Purchase of nutrition	**53**	63%	**18**	22%	**2**	5%
	Agro-forestry plants	**1**	1%	**13**	16%	**-**	-
Rainy season	Crop residuals	**26**	31%	**-**	-	**1**	3%
	Pasture	**75**	89%	**79**	98%	**39**	98%
	Hay	**4**	5%	**-**	-	**-**	-
	Purchase of nutrition	**26**	31%	**9**	11%	**3**	8%
	Agro-forestry plants	**2**	2%	**9**	11%	**-**	-

The most common source of fodder mentioned for all types of farm animals during the dry season is crop residuals. Farmers usually collect and store those parts of the crops they do not sell or consume or they let animals eat them directly from the harvested fields, which implies less effort and the additional advantage of manure for the soils. They mainly use residuals from rice and millet, but also from niébé[42] or groundnuts. It is more usual to feed donkeys and cattle with crop residuals as small ruminants often pasture during the dry season. When stored hay and crop residuals are not sufficient, it is very common to buy additional food[43] for the animals. This applies in particular to cattle, which usually need larger amounts of nutrition. Nutrition is mostly purchased during dry season and less often during rainy season. In the rainy season farmers tend to use pasture as a main fodder source for all animal types.

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[40] Only one farmer owns a horse, which is why horses are not represented here.

[41] It is useful to show percentages here as well for a better visualisation of the differences between the animal types.

[42] ’Niébé’ is the French word for the West African variant of the black-eyed pea / cow pea (Bambara: sho).

[43] Purchased nutrition mainly consists of crop residuals.

Not many farmers mentioned agroforestry products, like leaves and fruit, as a fodder source when being asked about what their animals eat and those who did mainly let their small ruminants consume tree products. However, when we asked farmers about preferred tree species and functions, almost all of them mentioned fodder tree species (see 5.4.3). Agroforestry plants are rather regarded as an additional fodder source for both, small and big ruminants and it seems that their role is not very important to farmers. The different tree species farmers mention to be consumed by their animals are discussed later in this chapter. Moreover, appendix A provides a complete list of all the fodder tree species.

Problems in livestock breeding

All of the 91 farmers who own farm animals state that there are problems connected to livestock breeding. The most common difficulty is a lack of nutrition which is mentioned by 78 informants. Closely related and mentioned by 11 of them are too high prices for animal nutrition on the market. About the same amount of the informants with domestic animals mention that there is a lack of pasture land, another problem related to animal nutrition.

The respondents were also asked about what measures they take against the problems related to livestock breeding. Only six of them see no solution at all to the mentioned problems. The most common solution related to fodder shortages is the storage of (more) crop residuals, mentioned by 66 informants. Others mentioned the purchase of additional nutrition (53 respondents) agroforestry plants as an additional fodder source (12 respondents) and transhumance (2 respondents).

5.3.2 Agriculture and crops

As many common AF practices, like agroforestry parklands, are agrisilvicultural, the main agricultural activities of farmers can play a role related to agroforestry adoption. Information about crop types, field size, soil type, fertiliser use and problems with cultivation are presented in the following. As the survey did not provide sufficient data, information is supported by field observations.

Main crops at the farms

Of the 94 informants 80 stated that they grow rice and have to pay the rice irrigation fee[44]. All in all, the irrigated rice land in the Tiby village cluster makes out about 40 per cent (The Earth Institute / MVRP 2011).

Although there is no data available on how many farmers have millet fields, the answers from a survey question about fertiliser use enables us to conclude that at least 91 of the 94 farmers grow millet on their farmlands because this is the amount of farmers who use fertiliser on their millet fields.[45]

From the question on fertiliser use, it is also possible to conclude that at least seven farmers have groundnuts, at least three grow sorghum and, respectively, one grows water melons and one niébé. However, as the survey question was only about fertiliser use, one can assume that the real amount of farmers having these crops is in fact higher. Furthermore, there are probably other crops that do not use fertiliser. In the qualitative interviews, for instance, a farmer mentioned that he has rice, fonio, couscous and millet (Respondent#89: interview 22.11.2010). The data set shows that the same farmer only uses fertiliser on the rice and millet fields, but not on his other crops.

Figure 7: Photo of a typical rice field in the Tiby region

Trees are only seen very far in the distance where the rice fields end.

[44] The rice irrigation fee ('la redevance eau') is a yearly fee of 15500 FCFA per hectare of cultivated rice land that has to be paid to the ORS.

[45] It might, however, be possible that the other three farmers also have millet fields, but do not use fertiliser.

Plot sizes and distance

In the household survey, it was not particularly asked about field sizes. However, 44 farmers gave additional information about field size when answering a survey question about the number of trees in their fields. As trees almost never grow in rice fields (see figure 7) and traditional agroforestry parklands are rainfed croplands (e.g. Sinclair 1999) with cereals like sorghum or millet this piece of data can provide an indication about average plot sizes of other fields than rice fields[46]. The field sizes mentioned by the 44 farmers range from 0.5 to 17 hectares and are on average 4.7 hectares.

Rice fields in the sample are of a size ranging between 0.5 and 18 hectares and their average size is 3.2 hectares. This is a bit higher but not too far away from the average rice field size of two hectares that the Earth Institute (2010: 8) indicates as prevalent in the Tiby village cluster.

The Earth Institute (2010: 8) states 10 hectares as an average total plot size in the Tiby cluster. Adding the average size of rice fields and the estimated average plot size used for other crops found in this study, the total average plot size of farms from the sample lies at about 7.9 hectares, which is a bit lower than the average of 10 hectares from the MVP report.

The average distance from the compounds to the closest fields lies at 553 metres and to the furthest fields at 2731 metres. There are 25 informants who just have bush fields that are 1000 metres or further away from their compounds.

Soil types

Of the 80 informants who have rice fields, 46 say that the soils on which rice is cultivated are a mix of loamy and sandy. While 27 respondents state that they are just loamy, only six say that they are just sandy.

In the case of millet, 65 of the informants say that they grow it on sandy soils and 25 of them have millet on mixed soils that are sandy and loamy.[47]

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[46] The other crops are mostly millet, which is why this data can at least to some extent compensate for unavailable data about the plot size of millet fields.

[47] One farmer, respectively, did not indicate information about the soil type in the rice fields and the millet fields.

Use of fertiliser[48]

Almost all (79) of the 80 informants who say that they have rice fields use fertiliser. 55 of them use organic fertiliser, which mainly consists of household waste (compost) and manure, mostly once a year. There are 74 respondents who state that they use mineral fertiliser – which normally consists partly of urea and partly of DAP[49] – for their rice fields. The larger part of them, 49 informants, use it once a year and a smaller part, 25 informants, use it two to three times a year. The amount of mineral fertiliser used ranges from 50 to 300 kg per hectare and is most often 150 kg per hectare.

91 respondents use fertiliser for their millet fields. Most of the 90 of them who use organic fertiliser use it once a year. There are 53 respondents who state that they use mineral fertiliser on their millet fields, mostly once a year. The amount of mineral fertiliser used on millet fields ranges from 15 to 150 kg per hectare and is most often 50 kg.

Seven farmers who mention that they use fertiliser for their groundnuts, four of them use organic fertiliser, and six use mineral fertiliser. The other three crop sorts that fertiliser is in some cases used on are Sorghum, Melon and Niébé.

Problems in agriculture

All of the 94 respondents state that they have problems related to agriculture. The most common one, mentioned by 93 of them is the decrease of soil quality and along with it, insufficient yields. People acknowledge that this problem derives from cultivating the same fields for many years without fallows. A related problem mentioned by 85 informants, is a lack of agricultural material. Many farmers stated that they especially needed ploughs, chariots and oxen for working their fields, which would also contribute to improving soil quality. Another 74 informants mention a lack of agricultural inputs, that is, fertilisers for their crops.

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[48] Of the sample interviewed by the MVP, 94 per cent use agricultural inputs. Organic fertiliser is used by ca. 61 per cent, chemical fertiliser by ca. 66 per cent (The Earth Institute / MVRP 2011).

[49] DAP is diammonium phosphate.

In this context, many farmers emphasised the role that mineral or organic fertilisers can play in reconstituting soil quality.

Other common problems are the following: 32 informants have difficulties with the commercialisation of their agricultural products. Either, the price they get for the harvest is too low or there is simply no market for their products. Moreover, a lack of land is a problem often mentioned by farmers in informal conversations and during qualitative interviews (respondent#37: interview 23.11.2010). Another issue, mentioned in both, the household surveys and the follow-up interviews (Respondent#82: interview 22.11.2010, respondent#89: interview 22.11.2010, respondent#46: interview 23.11.2010, respondent#37: interview 23.11.2010) is the flooding of the fields.[50] Further issues are insect or animal attacks on the crops and insufficient precipitation.

5.4 Agroforestry

In the following, an overview about the main agroforestry practices adopted by farmers in the sample is given. This includes information about preferences and benefits, as well as problems and disadvantages. Furthermore, the actions and efforts undertaken by farmers to maintain AF practices are presented.

5.4.1 Important terms

To understand the data that has been collected in the framework of this study it is, first of all, important to define the different types of agroforestry practices that are mentioned by the farmers in the sample. The main AF practices discovered in this study were also identified earlier by the FunciTree (2010: 11) project as common in the Tiby village cluster. In addition, some other terms that are relevant relative to the findings of the survey will be explained.

[50] Farmers say that their millet fields are often flooded by the irrigation water from the rice fields. In addition, the rainy season was particularly long in 2010 and led to dissatisfying harvests.

Agroforestry parklands

As already mentioned in the background chapter, the agroforestry practice that is most present in the Sahel region is 'agroforestry parklands' which make out about 90 per cent of the agricultural land in Mali (Atta-Krah et al. 2004, Kalinganiré et al. 2007a). Agroforestry parklands are

> characterized by the deliberate retention of trees on cultivated or recently fallowed land. Trees are an integral part of the system, providing food, fuel, fodder, medicinal products, building materials and saleable commodities, as well as contributing to the maintenance of soil fertility, water conservation and environmental protection (Boffa 1999: xvi).

As trees are integrated in farm production systems, that is, into the livestock and crop production of the farms, it is also possible to use the term 'agroforestry parkland systems'. The protection and assistance to tree regeneration in these parklands plays an important role and is often defined as a distinctive AF practice called 'Assisted Natural Regeneration' (ANR) (FunciTree 2010: 18).

As parklands are extremely common, it is useful to distinguish them from the following – comparably – less common practices. In particular in data analysis it is useful to look at differences between and similarities of farmers who have adopted additional AF practices and those who 'only' have parklands.

Figure 8: ***Photo of a typical agroforestry parkland after the harvest***

There are mainly Faidherbia albida to see, but also one huge Baobab in the back left.

Live fences

One of the other AF practises mentioned by farmers in the survey sample is 'live fencing'. According to Harvey et al. (2004: 262) "live fences refers to narrow lines of trees or shrub species planted on farm boundaries or between pastures, fields or animal enclosures whose primary purpose is to control the movement of animals or people." Next to the defensive and delimiting purpose, live fences can work as instruments of erosion-control, contribute to water and soil conservation and be part of the farm production system providing additional uses, for example for medicine, economic revenues or nutrition (Levasseur et al. 2004).

Although dead fences are more common than live fences in the Ségou region (Yossi et al. 2006), some mixed or live fences, mostly of the species *Euphorbia balsamifera* are present. Other multifunctional species that are useful for live fencing are for example, *Ziziphus mauritiana*, *Acacia nilotica* or *Acacia senegal* (Levasseur et al. 2007).

***Figure 9: Photo of a mixed live and dead fence*[51]**

Home gardens

Another agroforestry practise mentioned by farmers in the case study site in Tiby is 'home gardens'. There are several tree species that contribute to human nutrition because their fruit, leaves or other tree parts are edible. Many of these

[51] It actually proved difficult to find an examplarily live fence to take a photo of – this can be an indicator for the low adoption rate in the sample (see 5.4.2).

trees usually are scattered in parklands – often far away in the bush. The original idea of food banks is the establishment of plantations of those tree species that can provide human nutrition, e.g. *Adansonia digitata* (Baobab), near the compounds. Thus, they are better available for harvesting for farmers and their families (Kalinganiré et al. 2007b).

The FunciTree project staff in Mali use the expression 'food banks'[52] instead of home gardens. However, the main part of the literature that mentions the traditional agroforestry practise to plant fruit tree plantations, either at the compound or in the fields nearby refers to the term 'home gardens' (Lundgren and Raintree 1983, Scoones et al. 1992, Current et al. 1995, Atta-Krah et al. 2004). This is why this expression will be used throughout this thesis as well.

Figure 10: Photo of a larger home garden

Eucalyptus family forests

Another agroforestry practise which is common in the Tiby project site is 'family forests' or 'woodlands'[53] (FunciTree 2010: 36). It is usually the cultivation of tree species that are useful to fulfil the farmers' need for wood, either service wood used for construction or fuel wood. The trees of these forests, which are often located close to the dwellings of the farmers, are also used to gain revenues.

[52] The staff of the Malian Institute of Rural Economy (IER) calls home gardens with (mainly) fruit trees for human alimentation 'banques nutritionelles et alimentaires' (FunciTree 2010: 36).

[53] The IER staff use the term 'bosquets villageois et familiales' (FunciTree 2010: 36)

The most common species found in the project sites' family forests is *Eucalyptus camaldulensis*, which is why this AF practise will be called 'Eucalyptus family forest' throughout this study. Lundgren and Raintree (1983) regard the species *Eucalyptus camaldulensis* as one of the best adapted species in difficult environmental conditions and contributing to higher farm productivity.

Figure 11: Photo of a small Eucalyptus family forest at a compound

Bush fields and village fields

The terms 'champs de brousse' and 'champs de case' were often used in the survey. Bush fields (champs de brousse) are easy to define because they are those fields that are further out in the bush and not so close to the dwellings of farmers.

As it usually only refers to the fields that are located in close proximity (around 50 metres) of the farm, the fields near the house (champs de case) will not be described with the term 'compound fields' in this thesis. Fields that are several 100 metres away from the dwellings are often referred to as 'village fields' (Boffa 1999, Bolwig 2001). As farmers in the sample only made a distinction between fields that are close to their compounds and fields that are further away, this expression is the most useful to describe the closer fields.

During the implementation of the survey it turned out that most farmers considered fields as 'village fields' when they were less than 1000 metres away from their houses. These 1000 metres can, thus, be regarded as the distinction between village and bush fields.

5.4.2 Practice and adoption of agroforestry

In fact, all of the 94 farmers interviewed in the sample practise agroforestry, as all the informants practise agriculture and have trees in the fields. Hence, all the fields can be defined as ‘agroforestry parklands’[54].

Other AF practises identified in this study are live fences, home gardens and Eucalyptus family forests. They have lower adoption rates than agroforestry parklands. Live fences are used by seven informants, 18 state that they have home gardens and Eucalyptus family forests are mentioned by 12 informants. All in all, 30 respondents (about one third) practice one or several of these AF types in addition to parklands.

Agroforestry parklands

Agroforestry parklands are practised by all 94 informants interviewed in the survey to the extent that there are at least some trees in their fields that fulfil different functions and contribute to some extent to the farm production systems. Trees in the fields are often contributing to the households’ nutrition with their fruit or leaves. Moreover, they often provide animal fodder and either fallen fruits or the manure of animals eating the fruit or leaves contribute to soil fertility. The branches of trees or whole smaller trees and shrubs are often used for fuel wood.

Faidherbia albida and *Vitellaria paradoxa* (Shea) are not only tree species that are quite abundant, but also most frequently mentioned by the informants, as 83 of them said they have *Faidherbia albida* in their fields and 52 stated that they have *Vitellaria paradoxa*. The third most common species in the fields is *Sclerocarya birrea* mentioned by 39 farmers. Then, there are 25 households with *Adansonia digitata* (Baobab) growing in their fields, which makes it the fourth most common species in the parklands of the sample. There are another 31 species that were each mentioned by less than 21 of the interviewees. All the species in the fields are listed in appendix A.

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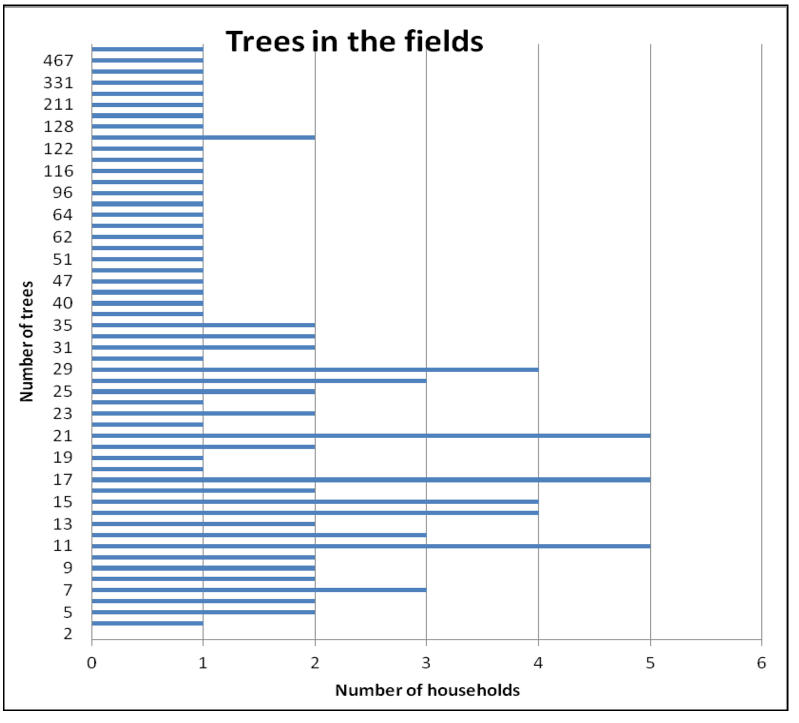
[54] Of course, there are differences concerning numbers of trees in the fields, how much tree functions are integrated in the respective farm systems and if tree regeneration is promoted.

The lowest number of trees[55] in the fields mentioned is two and the highest 467. The average lies at 48 trees. The following graph shows how many respondents indicated to have which number of trees.

Figure 12: Distribution of the total abundance of trees in the fields



Except from different field sizes, another explanation for the outliers with extraordinarily high numbers of trees is the abundance of particular species like *Piliostogma reticulatum*, *Guiera senegalensis* and *Prosopis africana* in some fields. The high numbers of these particular species can be due to the fact that farmers often do not let them grow to their full size. Thus, the trees need fewer resources than full-grown trees with a developed root-system and can grow more abundantly[56]. Some informants also state that the species *Faidherbia albida* (Shea) or *Vitellaria paradoxa* (Balanzan) are quite abundant. My observations at the site confirm this information: There were fields of different sizes, some with only few dispersed trees and some with a lot of trees of a particular species.

[55] Respondents were asked about how many of the different tree species they mentioned they have in their fields. The numbers were added to indicate approximate total amounts of trees in the fields.

[56] See also the problems relative to how questions were posed and interpreted presented in chapter 2.2.2 (Specific issues with the household survey).

A quite rough average tree density can be calculated from the average plot size of the fields – although the variable is only available for 44 informants – and average tree abundance in the non-rice fields. It lies at about 10 trees per hectare.

Life fences

The seven farmers in the sample who have live fences at their farms mainly use them to protect their fields or orchards from straying animals. One farmer argued that live fences are cheap, maintenance is easy and that people use them if they cannot afford other solutions (respondent#89: interview 22.11.10).

Six of the informants with live fences said they use the tree species *Euphorbia balsamifera*. There are two who stated that they use *Acacia nilotica* to protect their fields or orchards with and one who mentioned *Azadirachta indica*.

Four of the seven respondents informed us that their live fence is a traditional practice that had been used for a long time on their farm. Only one of them stated that he had created the live fence himself and two said that the practice had been introduced by a development or governmental organisation. There is quite a wide range of how long people had used live fences on their farms, which lies between five and 45 years. The most common time period, mentioned by three informants is 10 years.

In half of the cases, the live fences are located in the village fields and in the other half of the cases they are in the bush fields. The sizes of the areas surrounded by live fencing systems do vary from 0.5 to four hectares, but are most commonly around one hectare large.

Home gardens

Home gardens are adopted by 18 informants who have between one and eight different tree species on their plots. The most common ones are the mango tree, *Mangifera indica*, the lemon tree, *Citrus lemon*, and *Psidium guajava*, the guava tree. They are all species of which the fruit can be eaten. There are 14 other species, of which the fruits, leaves or nuts can be consumed or be used to produce other consumable products, like wine or butter (See also: Baumer 1995).

Appendix A shows a table with all tree species used in home gardens in the sample.

Half of the 18 respondents who have home gardens said that their fruit orchards are traditional. Five informants stated that they created the home gardens themselves and four of them said that the agroforestry practice had been introduced. To the question on how long people have practiced the home gardens on their farms, answers ranged from 5 to 50 years but it is most common that farmers had their home gardens for a period of more than 15 years.

The majority of the farmers stated that their home gardens are located in the village fields while only two said that they are in the bush fields. The average distance to the location of the orchard is about 500 metres. The range of the plot size of home gardens varies from 0.25 to five hectares. However, it is not very common that the plot size is 2 hectares or larger.

Eucalyptus family forests

12 of the respondents said that they have Eucalyptus family forests and all of them stated that they provide them with firewood and service wood. In most cases, the wood is sold on the market as well.

None of the informants stated that the practice is traditional. Most of them (nine of the 12) said that the practice was introduced, while three had created the forests themselves. The duration of how long the farmers had their Eucalyptus forests ranges from two to eight years and is on average circa five years.

11 respondents said that their Eucalyptus forests are in the village fields, while only one has a forest in the bush fields. The distance to the forests ranges from zero to 1000 metres from the house, and most of them are not further away from the compound than 500 metres. The average size of the Eucalyptus family forests is – with 0.65 hectares – a bit smaller than the size of the home gardens. However, with 25 m^2 to one hectare, the range is quite large. This can be an indication that a part of the farmers only use the forests for auto-consumption, while other market wood on a larger scale.

Trees at the compound

All informants but one have trees at their houses. Most of them have only one and seldom more than three trees, which are often of the species *Azadirachta indica*, mentioned by 92 respondents. Other important species that grow near the house are *Terminalia mantaly*, mentioned by six respondents, and *Eucalyptus camaldulensis*, mentioned by six as well. There are further species that only four or less farmers have near their house, like *Citrus lemon*, *Mangifera indica*, *Faidherbia albida*, *Adansonia digitata* and *Vitellaria paradoxa*. Another nine different species were only mentioned by one informant, respectively.

The FunciTree (2010a: 36) project lists 'trees at the compound' as agroforestry practice. This makes sense to that grade that those trees often provide goods or services to the farm households, for example providing shade or nutrition. Nevertheless, 'trees at the compound' will not be defined as specific AF practice alongside the other four practices referred to in this chapter. As most farmers have at least one tree at the house, there is not much variation in the data for analysis. However, it should be recognised that the trees at the compound can play an important role for the households, too.

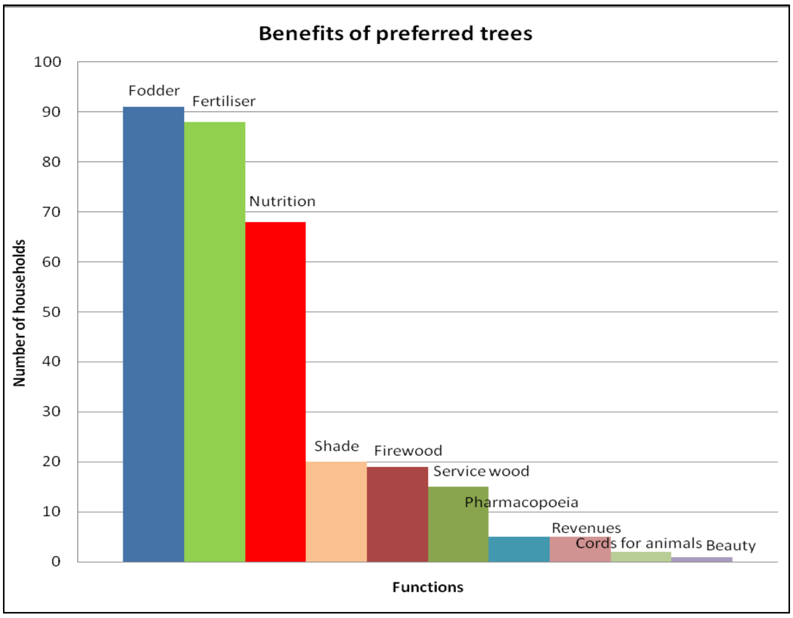
5.4.3 Preferred tree species and their functions

One of the research foci of this study lies on figuring out the benefits farmers attribute to different tree species to better understand their adoption of agroforestry practices. For this reason, the household survey included questions concerning the preferred tree species, the multifunctionality of trees and the variety of trees present at the farmland.

The four most preferred tree species mentioned by the informants are *Faidherbia albida*, *Vitellaria paradoxa*, *Adansonia digitata* and *Tamarindus indica*. A list that includes all 27 species that were most preferred can be found in appendix A. Another indicator for tree preferences of the farmers is the context in which different tree species were mentioned. Eight species are present in more than one agroforestry practice. This indicates the role that those trees play, especially relative to multifunctionality and farm diversification. A table in appendix A shows the tree species that are present in more than one AF practice.

The table below presents the different functions of preferred trees that informants mentioned to be most beneficial to them. In the following section, the different functions and the trees they are associated with are explained further.

Figure 13: Goods and services provided by preferred tree species



Fodder

As figure 13 shows, the most mentioned tree function is animal fodder. All in all, 91 respondents mention tree species of which the fruit and leaves are being consumed by small and big ruminants. Most of them refer to between one and three different fodder species. Those are rather relied on in the rainy season than the dry season, because many trees are deciduous – they lose their leaves during dry season – and only some species are semi-deciduous – just loosing part of their foliage – or evergreen. An exception is *Faidherbia albida*, as it has an “inverted phenology” and is “deciduous in the wet season and foliated in the dry season” (ICRAF 2011a).

Faidherbia albida is also the most important fodder plant to the informants. Due to its inverted phenology, it provides leaves during the long dry season when there is almost no pasture land left. The leaves are often harvested with the help of a long pitchfork or sometimes whole branches are cut. Then they are stored. The fruit of *Faidherbia albida* also provide a fodder source, either they are collected or the animals eat them directly from the ground.

Other important fodder plants mentioned by the informants are *Ficus gnaphalocarpa*, *Pterocarpus erinaceus*, *Celtis integrifolia*, *Sclerocarya birrea* and *Terminalia macroptera*. A list of all mentioned fodder tree species can be seen in appendix A. Most of these trees are semi-deciduous or deciduous and thus, more often consumed during rainy season than *Faidherbia albida*. Sometimes leaves are also collected and dried so that they can be consumed by the animals in the dry season as well. It is mostly the leaves of the trees that provide fodder, while fruit are rather seldom consumed by animals.

Fertiliser

The second most mentioned benefit of agroforestry plants is a fertilising effect. According to all of the respondents *Faidherbia albida*, the tree which is mentioned by most of them as preferred species, contributes to the fertility of the soil in the area where it grows. A further advantage of the tree’s inverted phenology is that as it loses its foliage during the rainy season, it adds nutrients to the soil instead of taking them and does not compete with the crops for sun during that time (ICRAF 2011a).

There are not many other species that have a fertilising effect on the soil. Only a few informants mention species like *Vitellaria paradoxa*, *Sclerocarya birrea* and *Pterocarpus erinaceus*. Many farmers state that an improvement of the soil fertility deriving from the manure of farm animals, either seeking shade under trees or consuming fruits and leaves.

Human nutrition

A lot of informants (68) regard the provision of food as an important tree function. *Vitellaria paradoxa* or the Shea tree, which is preferred by the second largest group of farmers, is regarded as useful for human nutrition by all informants. The main product is the butter extracted from the fruit of the Shea tree, which is very rich in oil and can be used for cooking (Respondent#89: interview 22.11.2010).

Many farmers prefer the Baobab tree, *Adansonia digitata*, because of its utility for nutrition. The fruit and leaves are edible. The latter are often dried and used by many for cooking sauce, which is eaten with rice or millet porridge (see also Baumer 1995). This information can be confirmed by observations in the field. All informants state that the leaves of the tree are consumed and half of them mention that the fruit are used for human nutrition.

Moreover, six farmers mention *Mangifera indica* – the Mango tree – as their preferred tree species because of its edible fruits. Other nutritious trees are for example *Tamarindus indica*, *Sclerocarya birrea* and *Diospyros mespiliformis*.

Shade

Shade is mentioned by 20 informants as a benefit of preferred trees species, especially by many of those who prefer *Vitellaria paradoxa* (Shea). Some of the other species, which are appreciated by farmers because they provide shade, are *Azadirachta indica*, *Adansonia digitata* and *Mangifera indica*. It makes sense that *Azadirachta indica* is most present at the compounds where the tree can provide shade to people pursuing household activities.

Firewood and service wood

Most of the tree species mentioned by the informants as providing fire wood are at the same time providing service wood, mainly used for construction, to them.

The preferred tree that is most mentioned as a provider of fire or service wood is *Eucalyptus camaldulensis*. All of the 12 respondents who state that they have adopted Eucalyptus family forests use the trunks and branches of the tree as fuel and service wood. One farmer told us that he has been saving a lot of money because of the availability of construction wood from his Eucalyptus family forest (respondent#72: interview 22.11.2010).

The other preferred tree species that provide wood most mentioned by the farmers are *Pterocarpus erinaceus*, *Azadirachta indica*, *Vitellaria paradoxa* and

Faidherbia albida. In the case of these trees, which are mainly growing in parklands[57], farmers do not always cut the full-grown trees. Some of them cut only their branches or they cut the more abundantly growing small shrubs or younger trees in the fields and dry and store them for fire wood (Respondent#89: interview 22.11.2010).

Revenues

There are some farmers who informed us that they sell tree products, like fruit, nuts or leaves that are used as fodder, food, or wood on the market. Most informants were not able to give detailed information about how much of the respective tree product they harvest, sell and how high their revenues are. This might be due to the fact, that it is often women and / or children who are responsible for related tasks at the farm, so household heads did not have an overview.[58]

Several respondents told us that they sell parts of the fruit[59] of *Faidherbia albida* they harvest each season for fodder. The amounts harvested are very varying, as well as the amounts sold and revenues earned.

Many of the informants regard the revenues from selling the wood of *Eucalyptus camaldulensis* as a main advantage of the species. As the trees need a few years to grow, there are different harvest times for the Eucalyptus trunks, which takes place, as some farmers indicated, between every five and every seven years. The prices and amounts sold are varying.

Often food products from trees that are sold, like for example Mango or other fruit from home gardens or Shea butter produced from the nuts of *Vitellaria paradoxa*. Another tree species used for nutrition that provides revenues is *Adansonia digitata*. Some farmers showed us the dried Baobab leaves that that

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[57] Or in the case of *Azadirachta indica*, which is mainly present at the compounds.

[58] It is also probable that some farmers felt uncomfortable speaking about their financial revenues in detail.

[59] The leaves are uniquely used for auto-consumption by the farmers in the survey sample.

they sell on the market, others told us about buying them from neighbours or on markets (Respondent#89: interview 22.11.2010).

5.4.4 Planting effort and regeneration of trees

One aspect of agroforestry adoption is the effort that farmers have to put into planting and maintenance of trees. This is particularly relevant to the practices of live fencing, home gardens and Eucalyptus family forests. In the case of agroforestry parklands, trees are seldom planted by the farmers. Usually, farmers decide to leave some young seedlings that grow naturally on the fields and only in some cases they actively protect and nurse them.

Tree planting and maintenance work

In the survey, farmers were asked about the effort and costs that are connected to establishing and maintaining the three agroforestry practices mentioned above. It was, however not easy to achieve much data about costs and effort, as sometimes the AF practices were traditional, so plantation costs did not apply to the respective farmers themselves. But some tendencies are quite similar for both live fences, home gardens and Eucalyptus family forests. Almost all informants indicated that the planting effort was quite low and on average it just took between one and seven days and the work of two to three persons to establish the agroforestry practice.

In the case of home gardens, prices for fruit tree seedlings like mango, guava or lemon ranged between 150 and 200 FCFA, and Eucalyptus plants cost between 100 and 250 FCFA. All informants stated that they did not have to pay for plants for their live fences.

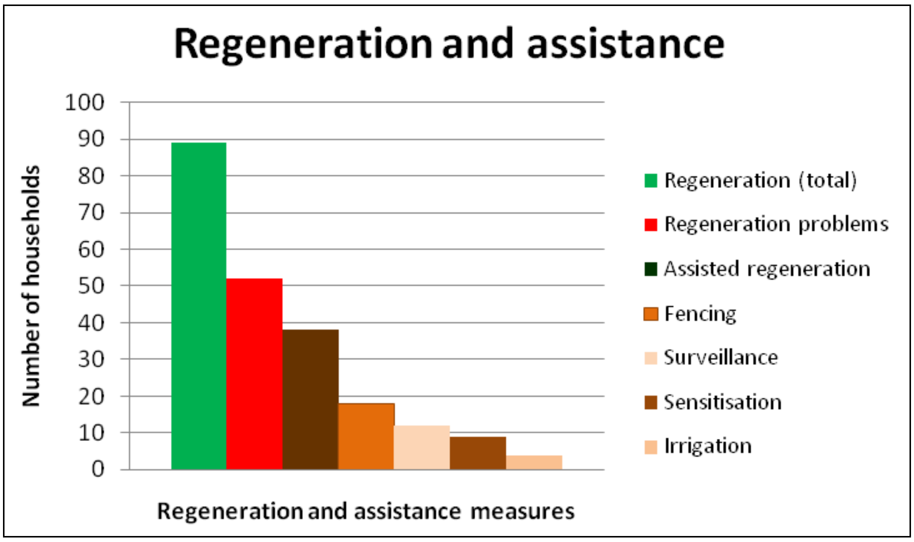
In home gardens, farmers usually planted between three and 10 plants, while Eucalyptus family forests often are of a larger scope, with between 40 and 500 plants. This might be a further indication that Eucalyptus plantations are often used for revenues. In the case of live fences, numbers of planted trees were not mentioned by the farmers.

The highest possible costs related to tree planting are irrigation costs. Many of the informants with home gardens or family forests – especially traditional users – already had good irrigation systems in place so only some of them mentioned extra irrigation costs, which ranged between 15.000 and 50.000 FCFA per year and often had to be continued in the year after the planting year.

Regeneration of trees in the parklands

As mentioned above, in the case of agroforestry parklands, it is the regeneration of young seedlings in the fields that plays a role relative to agroforestry adoption and maintenance. As found out in the representative survey, almost all of the informants mentioned at least one tree species they let regenerate in their fields. In some cases, they even engage in taking action to protect young seedlings. In this case, they practice Assisted Natural Regeneration. The figure below shows how many informants mentioned regeneration of trees in their parklands, how many of them mentioned problems with natural regeneration and the different kinds of measures taken to assist young plants.

Figure 14: Tree regeneration, connected problems and assisted regeneration



Almost half of the informants who let trees regenerate in their fields do not rely on natural regeneration alone, but use at least one of the protective measures that can be seen in the table. It is most common to put fences around trees to protect them. Other measures include informing people – especially children –

about the importance of regeneration and the active surveillance of the trees. Irrigation is only used for some tree species like *Adansonia digitata* and thus, not a very common ANR[60] measure.

Asked about the tree species they let generate, *Faidherbia albida* is – again – by far the most mentioned by the informants, followed by *Vitellaria paradoxa* and *Adansonia digitata*. A list of all species informants let regenerate in the fields can be seen in appendix A.

Figure 15: Photo of a young Baobab seedling in a millet field

The research assistants with a farmer who actively protects a Baobab seedling

5.4.5 Problems and disadvantages

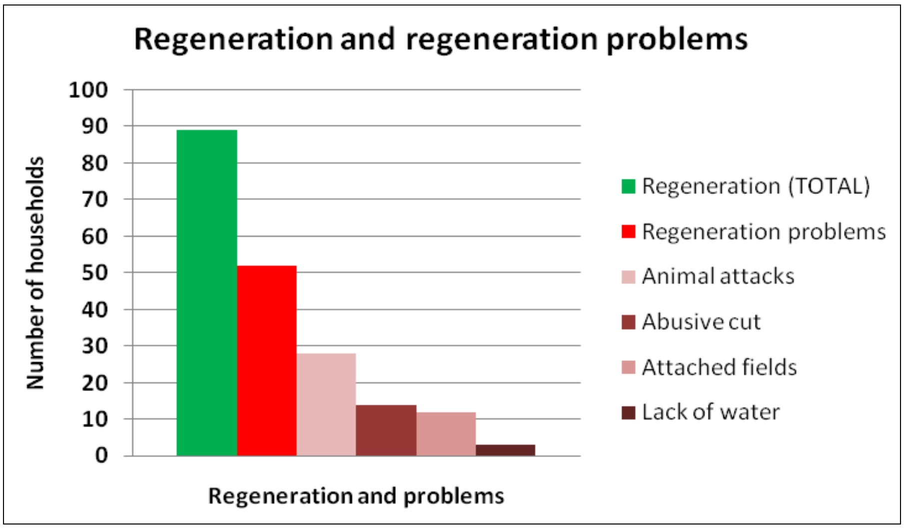
Even if agroforestry has been adopted and integrated into the farming system of a household, there are still constraints, either due to negative traits of trees or problems related to tree management that might influence long-term success.

Problems with regeneration and the maintenance of agroforestry

In the representative household survey as well as in the qualitative interviews, farmers mentioned problems relative to the regeneration and maintenance of trees both in the parklands, and connected to other agroforestry practices.

[60] The measures mentioned above are common among the farmers of the sample. ANR measures described in the literature often include suppression, weed control and attracting wildlife that spreads seeds. The focus does not only lie on protecting seedlings but on creating conditions for them to start growing, at all (Friday et al. 1999).

Figure 16: Tree Regeneration in the fields and connected problems



The most commonly stated problem is animal attacks. Many farmers specified that it is mostly grazing animals that destroy or eat small plants. In the follow-up interviews respondents additionally mentioned insects like termites[61] (Respondent#82: interview 22.11.2010, respondent#46: interview 23.11.2010).

Then, abusive cut is a commonly mentioned issue. Some farmers specified that it is either herders that feed young trees to their animals or people who use them as firewood (Respondent#72: interview 22.11.2010, respondent#46: interview 23.11.2010). One of the farmers told us an event that had happened to illustrate that abusive cut is a serious problem in the region. Last year, herders had cut down almost all the young tree species of *Faidherbia albida*, so there was almost no regeneration. This incident had caused a conflict in the village (respondent#72: interview 22.11.2010). Similar stories were told by farmers during the representative household survey. 24 respondents stated that people illegally cut trees or shrubs on their fields when they are absent.

Another important problem mentioned by farmers is the lack of demand for Eucalyptus wood (Respondent#82: interview 22.11.2010, respondent#72: interview 22.11.2010) and other tree products.

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[61] One farmer farmer regards Euphorbia *balsamifera* as an impractical plant for live fencing because it is not resistant to termite attacks and often dies during the rainy season (Respondent#89: interview 22.11.2010).

Furthermore, farmers regard it as a difficulty that trees in the fields compete with crops and – vice versa – that agricultural activities endanger young seedlings. One farmer also mentioned a lack of proper fencing to protect trees sufficiently (Respondent#89: interview 22.11.2010). Another issue is the lack of water especially needed by young plants.

Disadvantages of multifunctional tree species

In the representative survey, the informants were asked about the disadvantages they associate with the different multifunctional tree species they preferred.

Most of the 39 informants who see disadvantages at all, 34 of them, regard shade as a main problem. Then there are five farmers who mentioned that trees compete with crops for space and resources. Other problems mentioned are animals seeking refuge in the trees and trees with many branches or thorns.

The preferred tree species with the most negative effects mentioned by 22 informants is *Vitellaria paradoxa*, followed by *Adansonia digitata*; both are trees with a specifically large root system that can reach quite big sizes. Farmers almost never mentioned disadvantages of *Faidherbia albida*.

Disappeared tree species

Of the 94 respondents, 87 stated that trees have disappeared from their fields. The species that was most often mentioned in this context is *Adansonia digitata* mentioned by 29 respondents. All in all, 44 species have disappeared from the fields according to the informants. A complete list can be found in appendix A.

The main reasons for the disappearance of trees stated are drought – mentioned by 63 respondents – and the cut of trees, either illegally – stated by 62 informants or out of need – as 40 respondents said. Other reasons for tree disappearance mentioned are high age, lightning strokes and the flooding of the fields.

6. ANALYSIS AND DISCUSSION

The following chapter attempts to provide more explicit answers to this study's research questions. With the help of Bayesian belief networks, hypotheses about the most influential factors relative to AF practice and adoption are posed and different groups of farmers compared. The most relevant fieldwork findings are analysed and set into relation to the theoretical framework and the methodological approaches.

6.1 AF Adoption among Different Groups of Farmers

To gain a better understanding about the factors that influence the use of agroforestry in Tiby, some differences and similarities between farmers will be pointed out. It will be looked at how some of the characteristics presented earlier possibly influence the existence of different AF practices at the farms. It is suggested that variables related to the socio-economic situation, to trees and their functions, as well as perceptions of risk and uncertainty influence the practice of AF and thus, the potential willingness to increase tree density and AF use.

In the following, simple smaller or sub-hypotheses will be postulated about which of the factors available from our data set seem to influence the decision to practice / adopt AF the most. The proposed hypotheses for the respective BBNs will be based on survey data and on qualitative findings. Through these sub-models we can to some extent provide indications about relations between various factors and AF use. Moreover, we can explore how feasible the methodological strategy of this study is in providing variables to create a larger integrated model of AF practice / adoption. On the one hand, the lack of relevant socioeconomic and household data might lead to a less comprehensive model since it might be difficult to add an as large range of relevant factors as proposed in the theoretical approaches of this study. On the other hand, it is one of the qualities of BBNs that data can always be updated.

This can be useful in the context of the sustainable livelihoods framework[62]. According to the model of the SLF, the context of risk, uncertainty and vulnerability, different livelihood assets available, as well as the institutional and policy background can influence the decision to follow a certain strategy, like the adoption and practice of AF practices (e.g. Ellis 2000, Cundill et al. 2011). In the following, single aspects that can be part of decision-making will be analysed.

Hypotheses

Two general hypotheses or objectives for the analysis of all the following BBNs will be postulated here, the first one relative to the theoretical framework, and the second one relative to the methodological approach of this study.

- The first hypothesis is concerned with livelihood diversification with the practice of agroforestry based on the theoretical approaches of SLF and on the factors of adoption from previous studies. It can be formulated by a quote of Toulmin et al. (2000: 47): "The incidence of LD would be expected to follow a U-shaped curve, with poorer households diversifying to ensure survival, while richer households diversify to accumulate." This assumption requires a quite broad definition of wealth relative to livelihood assets available to farmers and their level of vulnerability (**A**).
- The second hypothesis – or rather objective – is related to the methodological approach of this study. It is postulated that the available household survey data can be analysed with Bayesian belief networks and differences between farmers relative to factors affecting AF adoption found. However, the methodology of the household survey is insufficient to identify reliable variables to develop an adequate integrated model of AF adoption. Further field research is needed (**B**).

As mentioned earlier, agroforestry parklands are used by all farmers, so the other AF practices, live fences, Eucalyptus family forests and home gardens,

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[62] See figure 1.

will be distinguished from them in the analysis. To look at factors influencing how the practice of parklands varies, different variables are compared with e.g. tree abundance, field size and the practice of assisted regeneration.

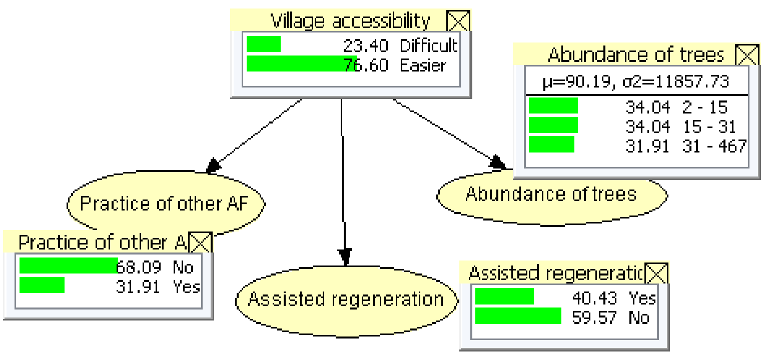
6.1.1 Accessibility of the villages

Data about differences in village accessibility is available through the previous household survey of the IER. As mentioned earlier, BBNs have the advantage that data from different data sets can be combined. The villages of Tiby Wère, Diaraka Wère, Wéna, and Kolomi are less easily accessible – due to their location and the bad quality of roads – than Koïla Bamanan, Koïla Markala, Tiby I and Tiby II (FunciTree / IER 2010). This difference can be a variable that explains variations in AF practice as it can be part of the vulnerability context in the SLF.

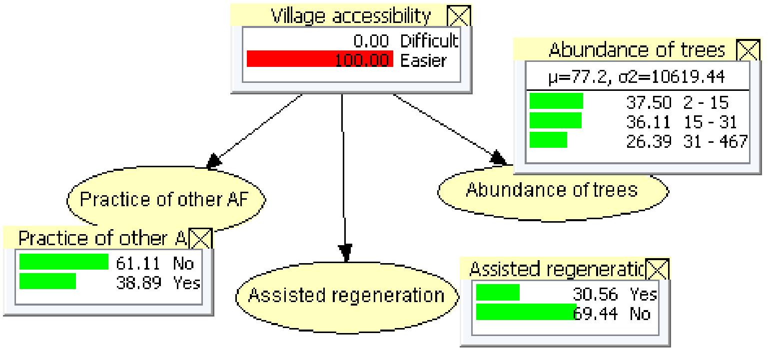
The hypothesis postulated in the following BBN is that the accessibility of the villages where the informants live influences AF use. Figure 17 shows the prior probabilities of all nodes of the model and the probabilities for the two different states of the parent node. One node is accessibility and its probabilities are easy and difficult. The other nodes indicate the number of trees at the farm, the practice of assisted regeneration and the adoption of one or several of the other three mentioned AF practices. As the group of informants with easier access to their villages is much higher than the other, 72 versus 22 respondents, it is not useful to compare the single practices of live fences, family forests and home gardens in this BBN as total adoption rates are not very high.

Figure 17: BBN about village accessibility

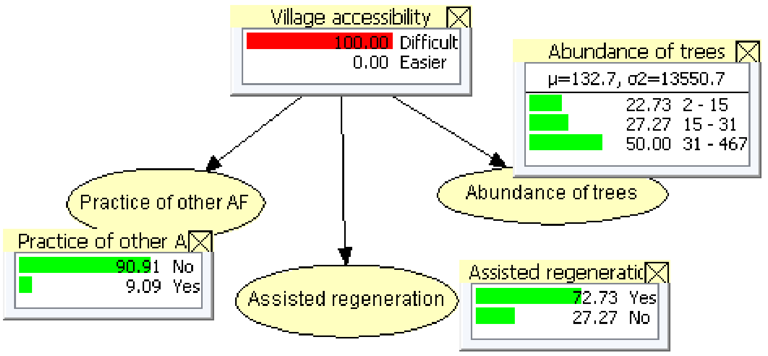
a) Prior probabilities:



b) Probabilities for easier access:



c) Probabilities for difficult access:



Part b) of the figure shows how the probabilities of the different child nodes do not change a lot for the larger group of farmers with better access to their villages – except for very slight tendencies to less assistance to regeneration, a lower abundance of trees in the fields and more practice of other AF.

The third part of the BBN shows the probabilities of the different variables for those informants with difficult access. There is a tendency that the abundance of trees in the fields is larger and the practice of assisted regeneration is much higher as well. This might indicate that farmers that have more difficulties accessing other villages, the markets and such also have less access to information about agroforestry and necessary resources like seedlings. This interpretation of the model supports the assumption, that those farmers rely more on the practice of traditional parklands, as their possibilities are restricted in comparison to others. The percentage of respondents in this group using other practices than parklands lies at about nine, which is much lower than the percentages of the total sample and the group with better accessibility, which is higher than 30. As probabilities of the nodes for the two groups differ very much this BBN can give indications for a real tendency.

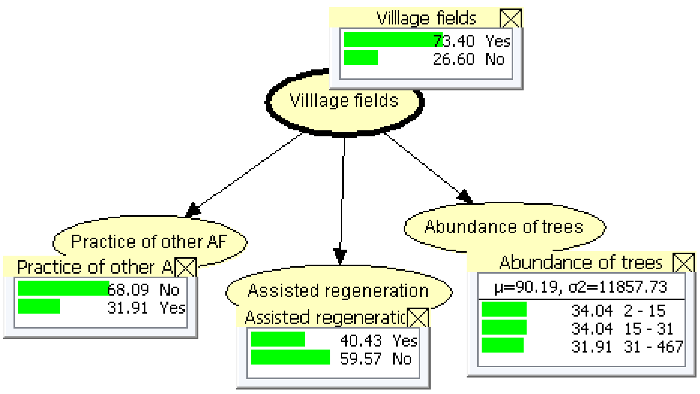
6.1.2 Accessibility of the fields

Another indicator that might be related to the vulnerability of farmers is the factor of field accessibility. 25 of the informants in the sample stated they only have bush fields more than 1000 metres away from their compounds.

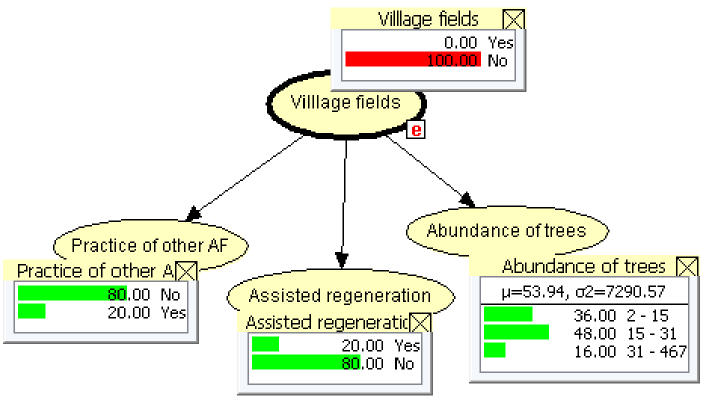
In this context, the hypothesis is postulated that there is a difference between farmers with village fields and farmers with only bush fields in tree abundance, tree regeneration assistance and the adoption of other AF practices.

Figure 18: BBN about field accessibility

a) Prior probabilities:



b) Probabilities for difficult access to the fields:



The graph for this BBN is quite similar to the one before. The node about accessibility has been exchanged by a node about the existence of village fields at a farm, stated by 69 respondents. For the same reason as in the previous example, only one node is used for adoption of other AF practices than parklands.

Only the variation of the figure with the probabilities for the group without village fields is presented because the probability distributions of the nodes for the farmers with village fields do not differ a lot from those of the total sample. This BBN gives the impression that farmers with only fields in the bush have a tendency to have – with 20 per cent – a lower adoption rate of AF practices like live fences, home gardens and Eucalyptus forests than farmers with village fields / the total sample. At the same time, they are less probable to have a very high abundance of trees in their fields than the other group and assisted regeneration is practiced about half as frequently as in the total sample. The conclusions one might be able to draw is that farmers with more distant fields generally have more difficulties at their farms and are thus, less likely / capable to adopt AF.

6.1.3 Field sizes, tree abundance and density

Data on field size is incomplete and only available for 44 of the informants interviewed in the household survey. The data is calculated from adding together the different sizes of bush and village fields mentioned in connection to different tree species present in the fields of the parklands. Farmers sometimes did not mention the sizes of all their parkland plots when they answered the survey question, which makes the data for this factor less reliable.

Nevertheless, a BBN can be constructed from incomplete data sets as well. In the best case, they are updated by follow-up research. As the average field size of the smaller sample is not very distinct from the average field size suggested by other studies[63] a model including AF adoption in relation to field size is presented here. It can, however, not easily be connected to other sub-models as the number of observations is only 44 and does not include the whole sample of 94.

The following graph shows the distribution of different field sizes for the 44 informants, which ranges from 0.5 to 17 hectares. The discretisation of the

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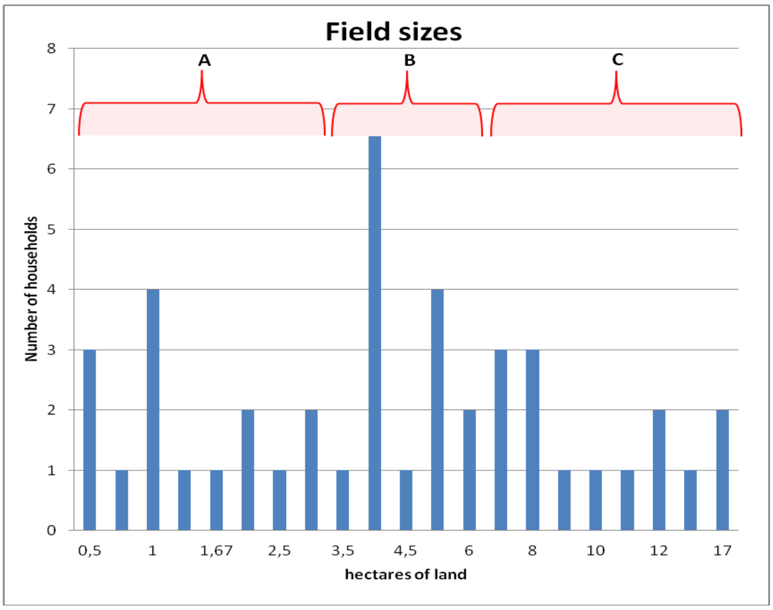
[63] See findings about field sizes in chapter 5.3.2.

values into three different groups in the BBN will be as equal as possible. Group A consists of 13 respondents with a relatively low field size between 0.5 and 3 hectares. The 15 respondents belonging to group B medium have field sizes of 3 to 6 hectares and the 16 of group C larger field sizes between 6 and 17 hectares.

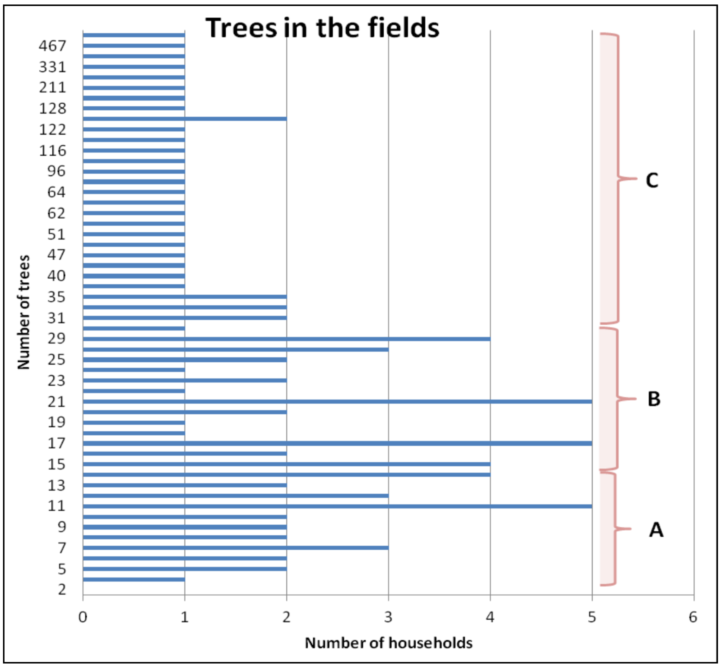
Figure 19: Field sizes in the parklands – discretised into groups



Also, for being able to use tree abundance as a variable in Bayesian belief networks, the range of answers given was discretised into three almost equal groups as can be seen in the figure below. Three approximately equal groups of households were identified: Households with a relatively low number of trees on their fields between 2 and 14 trees (group A consisting of 32 respondents); households with fields with a medium amount of trees between 14 and 30 trees (group B consisting of 32 respondents); and households for which a high number of trees between 30 and 467 trees (group C consisting of 30 respondents) was mentioned.[64]

[64] In this case, tree abundance is discretised differently than in the example in the explanation of BBN analysis (See chapter 4.1.3).

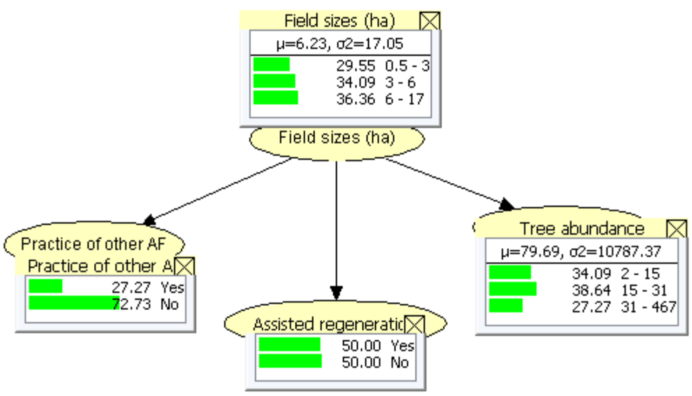
Figure 20: Abundance of trees in the fields – discretised into groups



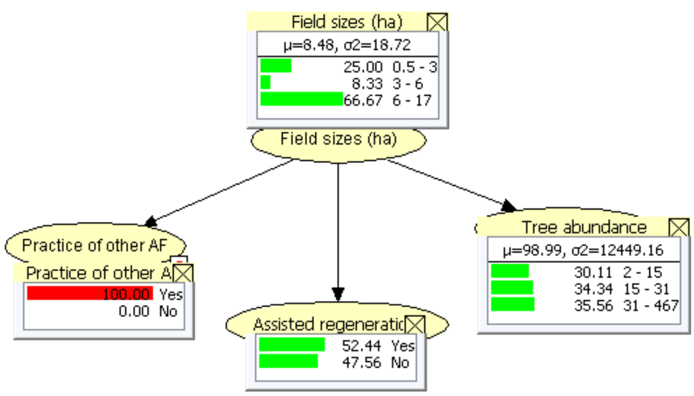
In the following BBN possible relations between field size and the number of trees in the field, ANR and the practice of other AF are shown.

Figure 21: BBN about field sizes

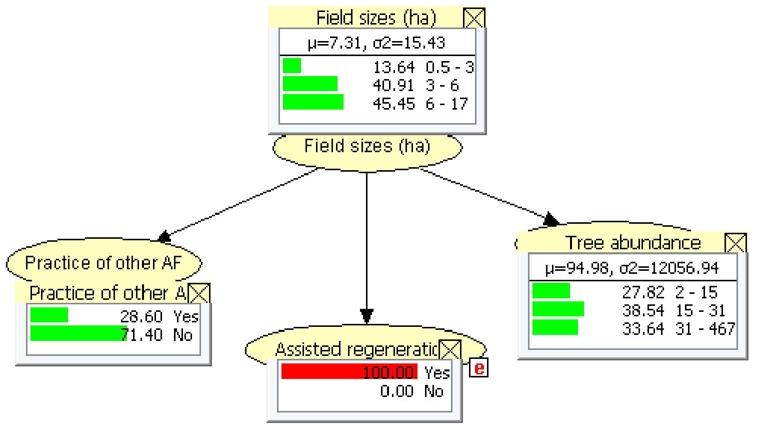
a) Prior probabilities:



b) Probabilities for practice of other AF:



c) Probabilities for practice of ANR:



It can be seen that the probabilities of tree abundance and practice of AF in the smaller sample of this BBN are quite close to the probabilities of the total sample, if one compares with one of the BBNs above. The probability for practising assisted regeneration, on the other hand, is about ten per cent higher than for the total sample of 94 informants.

The first example for a tendency that can be seen by looking at probabilities for the different groups of mentioned field sizes is that the respondents of the sample who practice other AF in addition to their farmlands mostly have lower (25 %) or larger field sizes (66.7 %), while only eight per cent of them have medium field sizes. This tendency might be due to an impractical discretisation of the three groups, but as the groups are almost equal, this is probably not the case. The result may support the hypothesis of a U-shaped tendency to adopt posed in hypothesis A. Poorer farmers with less available farmland / parkland diversify with other AF practices to reduce risk (push factors), while richer farmers with more land diversify because they have enough assets to do so (pull factors) (see also: Hussein and Nelson 1998: 10). Both share the goal of a larger livelihood portfolio to reduce risk and improve income.

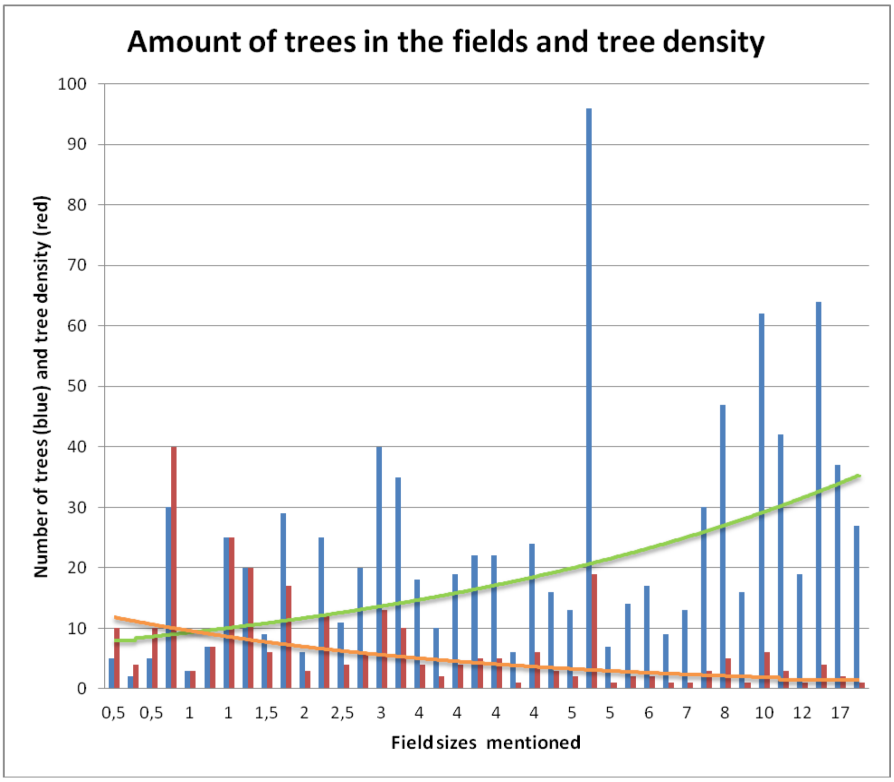
Another noticeable tendency from this BBN is that farmers with smaller field sizes have – with 14 per cent – a much lower tendency to practice assisted regeneration than group B with 41 per cent and group C with 46 per cent. An explanation for this might be the lower space available for tree growth. As mentioned in chapter five, many regard the competition between crops and trees as a problem. For farmers with limited available crop land, this issue might be even more relevant than in larger fields.

The probability distributions in the CPT of this BBN suggest that that the abundance of trees is higher for farmers with larger fields / parklands. This is why it makes sense not only to take the abundance level of trees into account but to take a look at the tree density to be able to infer conclusions.

Tree density

In the last example, the assumption came up, that farmers with larger fields also have higher numbers of trees in their fields and thus, a lot of different benefits from trees are available to them. However, it is necessary to make a distinction between tree abundance and tree density.

Figure 22: Abundance and density of trees in the parklands



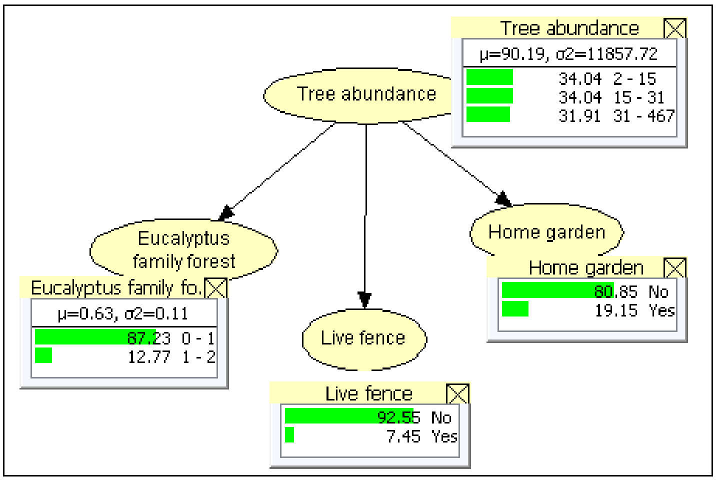
In this graph, the field sizes mentioned by the informants are shown again. The four outliers with extraordinarily high tree numbers that lie by over 100 are not shown for a better visibility of trends. This time the abundance level of how many trees per hectare different farmers have, are shown as well in form of red bars. The green trend line depicts the tendency mentioned above that farmers with more land have more trees in their parklands. In contrast, the orange trend line shows a tendency that tree density is not higher in larger parklands, but in smaller fields. This might support a quite different assumption: 'Poorer' farmers with smaller fields seem to have a higher tendency to diversify with trees in parklands than 'richer' farmers. However, the data from the BBN above indicates, the farmers in this sample who have more land available have a stronger tendency to practice ANR. This might be a sign for their willingness to improve tree density in their parklands as well.

6.1.4 Tree abundance in the parklands

As the numbers of trees in the fields is very variable, it can give indications about the quality, size and importance of agroforestry parklands to farmers. The factor of tree density might be more influential, but it is not available for the whole sample.

The assumption is made that the abundance level of trees in the agroforestry parklands of a farmer influences the adoption of other agroforestry practices. It can be an indicator of how much farmers rely on traditional AF parklands and how the number of trees available to them may influence the willingness to adopt one or several other AF practices, like live fences, Eucalyptus family forests and home gardens.

Figure 23: BBN about tree abundance



Below, the part of the conditional probability table with the probabilities for the different groups of farmers (A, B and C) having Eucalyptus family forests as calculated by the Hugin software is shown.

Figure 24: CPT for tree abundance and adoption of Eucalyptus family forests

Home garden | Live fence | Eucalyptus family forest | TOTAL trees in the field

TOTAL tree...	2 - 15	15 - 31	31 - 467
No	0.84375	0.875	0.9
Yes	0.15625	0.125	0.1
Experience	32	32	30

For a better overview, the following table presents the data from the complete CPT for all three AF practices. The differences between the probabilities to use them for the different farmer groups A, B and C can be seen.

Table 6: Probabilities of AF practice for farmers with different tree abundance levels

Farmer groups	Home gardens	Family forests	Live fences
Group A (2-15 trees)	12.5 %	15.62 %	9.38 %
Group B (15-31 trees)	21.87 %	12.5 %	9.37 %
Group C (31-467 trees)	23.33 %	10 %	3.33 %
TOTAL sample	19.5 %	12.77 %	7.45 %

The table shows a tendency that home gardens are more frequently practiced by farmers who have a medium or high abundance of trees in their fields. A possible conclusion is that farmers with fewer trees simply have less land, irrigation opportunities and / or financial capital available to create and maintain home gardens. For the supposedly ‘richer’ farmers who already have more trees and related benefits, home gardens might be an additional livelihood strategy that enlarges their income portfolio and spreads risk.

A rather different tendency can be seen for the practice of family forests. The more trees farmers have in the fields, the less they are dependent on wood from Eucalyptus for their own use or for sales. Parkland trees seem to already fulfil this role for them. ‘Poorer’ farmers with less available land for tree and shrub growth might have a small Eucalyptus forest near their compounds, as the trees do not have high maintenance costs, grow fast and regenerate after being cut (ICRAF 2011d).

Similarly, live fences are much more common for farmers of group A and B. Nevertheless, the explanation might be different. In principle, most plots that are used for agricultural purposes or AF plantations would benefit from being protected by live fences. However, several informal conversations and the qualitative interviews gave the impression that farmers are not as convinced of the benefits of live fences as of other AF practices. As mentioned in chapter five, many regard *Euphorbia balsamifera* as a very vulnerable species. One farmer told us that live fences are for poor people, while richer farmers use barbed wire or dead fences (respondent#89: interview 22.11.10). Farmers gave the impression that they are not informed and /or convinced enough of the positive effects live fences can have in addition to protection, e.g. for soil health and erosion control.

6.1.5 Tree species diversity

In chapter 5.4.2 the high range of different total numbers of trees in the fields was explained. However, people were not mainly asked about this but first of all about the tree species they have in their fields. Thus, it is relevant to use the number of tree species – or the diversity of species – that the farmers state to have on their fields as a variable in the BBNs.[65]

The following model explores the role of diversity of tree species[66]. It is postulated that species diversity is influenced by the practice of assisted regeneration and by the support of development or other organisations as they might provide farmers with additional knowledge. Furthermore, the probable influence tree species diversity has on the practice of AF practices like home gardens, family forests and live fences, and on the amount of trees in the fields is analysed.

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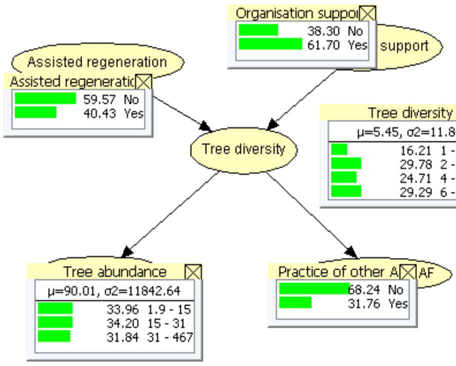
[65] Evaluating species diversity and tree functional diversity are the main objectives of the FunciTree project.

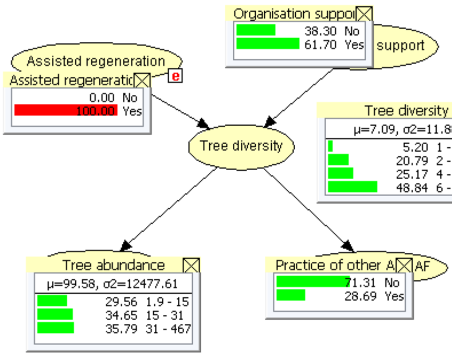
[66] The variable of species diversity has been discretised into four groups that are quite equal.

Figure 25: BBN about tree species diversity

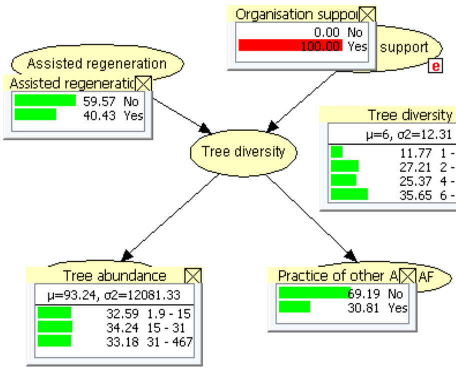
a) Prior probabilities:



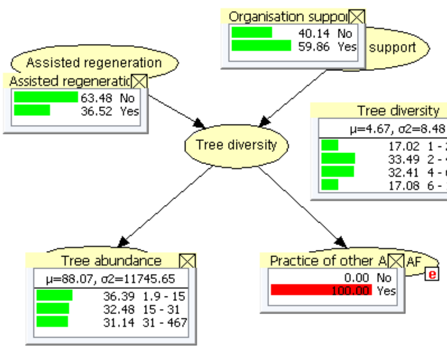
b) Probabilities for tree diversity when farmers practice ANR:



c) Probabilities for tree diversity with organisation support:



d) Probabilities for practice of other AF:



In graph b) it is showed how the probabilities for different levels of tree species diversity vary dependent on the practice of assisted regeneration. There are higher levels of diversity when AFS is practiced. It is logical to assume that the willingness to assist the regeneration of trees and to use many different tree species in the AF parklands are connected.

Graph c) supports the assumption that knowledge of different tree species is dependent on external factors like NGOs or other organisations as there is a tendency that those who receive support diversify more.

From the probability to practice other AF types a different distribution of tree species diversity can be inferred as can be seen in graph d). Informants with a low and a quite high number of different tree species are less probable to practice other AF then those in between. A high number of different tree species might make multiple tree functions available to the farmer and thus, contribute to a low covariate risk between the use of the different tree species so that further diversification is considered unnecessary. Farmers with few available tree species, on the other hand, might be too poor to afford other AF types. This result may partly support hypothesis A.

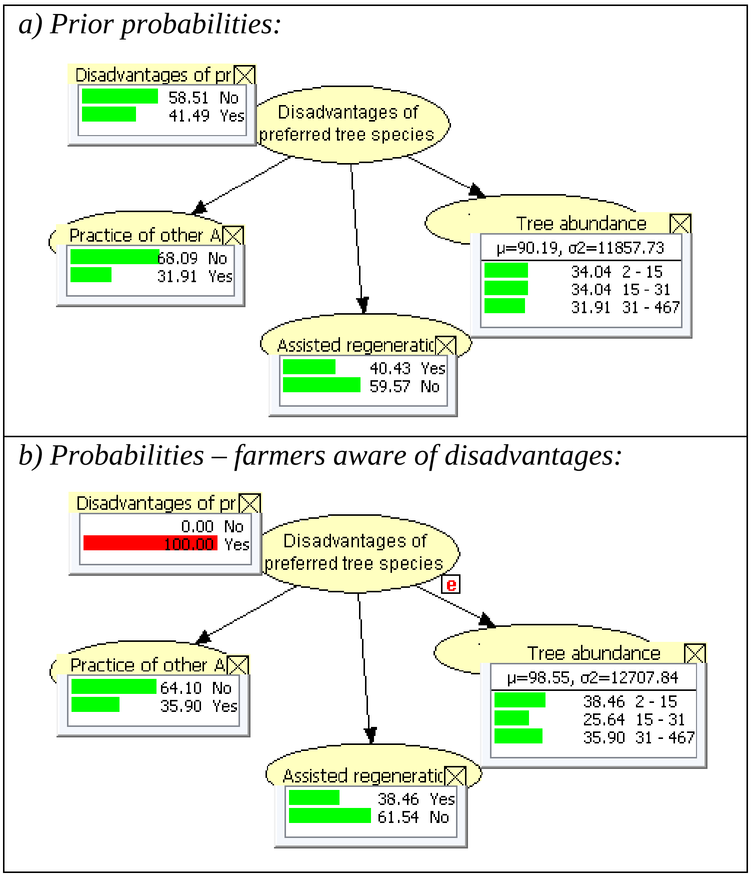
When analysing how tree diversity influences tree abundance, the results are very mixed and it is difficult to find a pattern or tendency. This supports part of hypothesis B about the insufficiency of data. Nevertheless, there is a slight – and quite logical – tendency that the number of tree species is higher when there are more different tree species present.

6.1.6 Disadvantages and benefits of AF tree species

Related to a context of vulnerability, risk and uncertainty that might influence the decision of a farmer to adopt AF practices into their livelihood strategy, it is interesting to look at how the perception of disadvantages (risk factors) related to AF tree species might influence adoption behaviour.

The following BBN might provide an insight into how farmers evaluate the covariate risk of agroforestry adoption. One node indicates if farmers see disadvantages of AF tree species or not, the other ones are tree abundance, the practice of assisted regeneration and the practice of other AF.[67]

Figure 26: BBN about disadvantages of AF tree species



There are 39 informants who mentioned disadvantages of preferred tree species. The probabilities of the nodes are just slightly different for this group than for the complete sample. The likelihood for them to practice other AF in addition to their parklands is about four per cent higher, and they are about two per cent less probable to practice ANR. These tendencies are quite low, which leads to the assumption that the awareness of risk connected to multifunctional tree species does not cause a lower adoption of AF. One reason for that could be that the covariate risk between those practices and other activities is quite low. Another explanation might be that these risks are not considered to be very high.

However, there is a tendency that the abundance level of trees for the farmers that are aware of inconveniences of tree species is either lower or higher

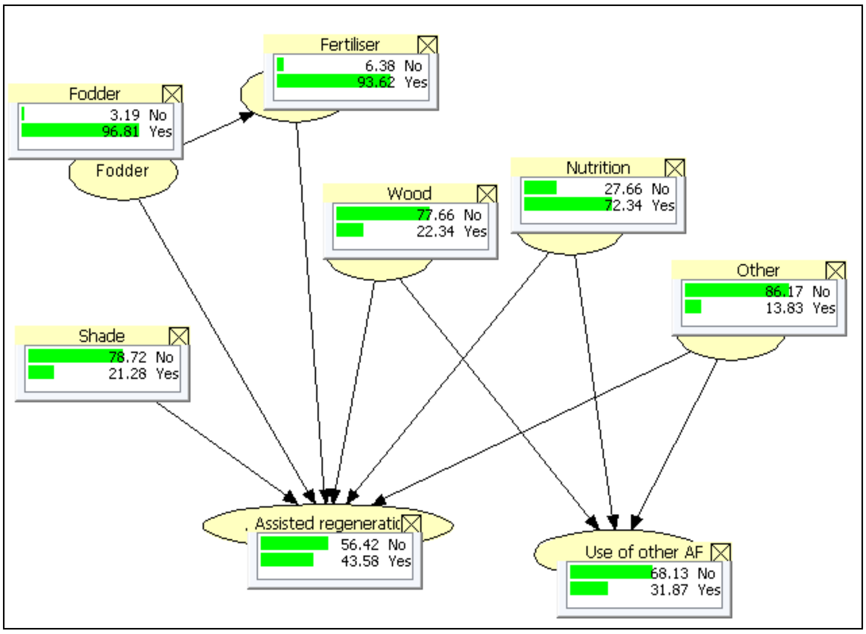
[67] Usually, the farmers we interviewed did not see disadvantages of tree species used for the other three AF practices.

as can be seen in the node below. Although this is just a small tendency, it provides support for hypothesis A. As poorer and richer farmers, with lower and higher abundance levels of trees, tend to diversify more with agroforestry, they are also more informed and aware of connected disadvantages and risks.

Benefits of AF species

A more complicated model has to be formulated for building a BBN including perceived benefits of preferred tree species. As more than one beneficial tree function was mentioned by each farmer, it is necessary that they all have their own nodes. The two variables that might be influenced by the farmers' knowledge about benefits from trees are ANR and the use of other AF practices. Some of the benefits are presumedly less influential to the use of other AF, like fodder, fertiliser and shade. Those AF types are often located in particular plots that are not used for crops or livestock breeding. There might be an additional correlation between knowledge of the benefit of fodder and fertiliser. As already presented in chapter five, animals that are eating from the trees in the parklands also provide fertiliser / manure to the soils.

Figure 27: BBN about benefits of preferred tree species



When comparing the probabilities of the child nodes for the different nodes influencing them, the result is that there seems to be either almost no or just a small difference in the probability distributions, independent on which input variable is looked at. This might be an indication of how farmer knowledge influences agroforestry adoption less than many scholars argue (See also Caveness and Kurtz 1993, Denning 2001, Mercer 2004, McGint et al. 2008)[68].However, farmers mentioned tree benefits in relation to single tree species, not to agroforestry in general. Moreover, if the knowledge about benefits of certain tree species is common knowledge, it has probably no influence on adoption / practice of AF. Therefore, this BBN rather supports hypothesis B about an insufficient field methodology.

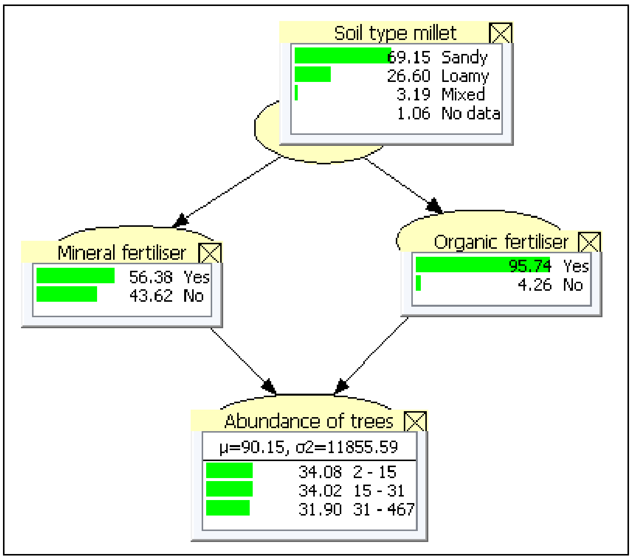
There are several variables that may have a small influence on the output nodes. The knowledge about the benefit of shade, for example seems to raise the probability of practicing ANR with five per cent. There is a similarly high tendency that both the knowledge about the benefit of nutrition and of (service and fuel) wood actually lowers the probabilities for the use of other AF slightly. The latter tendencies might indicate that those benefits are rather regarded as being fulfilled by parkland trees than by other AF practices.

6.1.7 Fertiliser use

Related to crops, there is not much data with a lot of variance available. Soil types are almost always the same for millet fields, which are usually agroforestry parklands, and for other crops, there is no data available. As fertiliser is used to reduce risk related to crops and agriculture the use of it can be regarded in the vulnerability context of the SLF. Moreover, the use of mineral fertiliser costs money, while organic fertiliser is usually produced by farmers themselves, so it can provide indication about the wealth level of the informants. The following BBN presents an assumption about how fertiliser use in the millet fields might influence the total number of trees in the fields

[68] Compare also chapter 3.1.2.

Figure 28: BBN about fertiliser use and tree abundance



As can be seen in this graph, the variance for the use of organic fertiliser is very low and not likely to influence tree abundance.

Figure 29: CPT of the BBN about fertiliser use

Abundance of trees | Mineral fertiliser | Organic fertiliser | Soil type millet

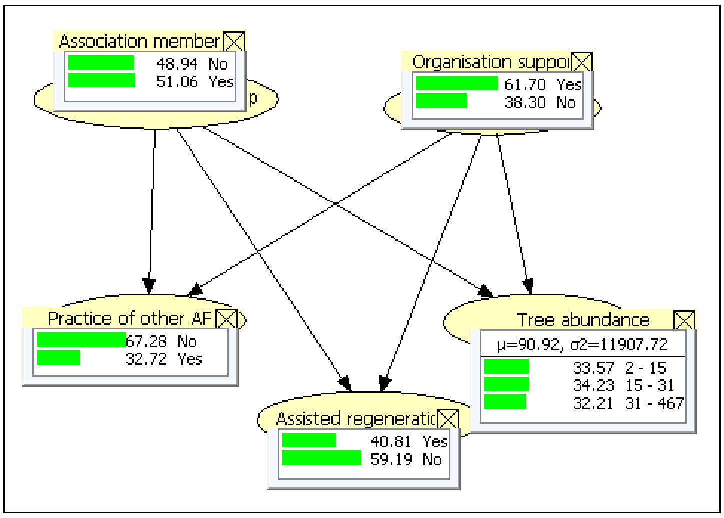
Mineral ferti...	Yes		No	
Organic fer...	Yes	No	Yes	No
2 - 15	0.25	0	0.473684	0.333333
15 - 31	0.326923	0	0.394737	0
31 - 467.1	0.423077	1	0.131579	0.666667
Experience	52	1	38	3

The CPT of this BBN can show how the use of mineral fertiliser might influence tree abundance in the fields. The two circles show how the probability for the use of mineral fertiliser is more common for farmers with a high abundance of trees, while farmers with a low abundance of trees tend to just rely on cheaper organic fertiliser. That richer farmers who tend to use mineral fertiliser also have more trees might support hypothesis A.

6.1.8 Institutional support and level of organisation

Relative to the sustainable livelihoods framework, the policy and institutional context plays a significant role in influencing livelihood strategies. As Scoones (1998: 12) argues institutional processes can be barriers or gateways to sustainable livelihoods. The follow-up interviews, informal conversations and field observations all showed that the influence of institutional interventions to decision-making is quite important in Tiby. For these reasons, the hypothesis of the BBN below suggests that experienced support by development or other organisations and association membership influences AF practice and adoption.

Figure 30: BBN about association membership and institutional support



The following CPT shows the probabilities for different levels of tree abundance for farmers in associations, with project support, with both or none.

Figure 31: CPT of the BBN about association membership and institutional support

Association ...	No		Yes	
Organisatio...	Yes	No	Yes	No
2 - 15	0.230769	0.45	0.34375	0.375
15 - 31	0.384615	0.25	0.375	0.3125
31 - 467	0.384615	0.3	0.28125	0.3125
Experience	26	20	32	16

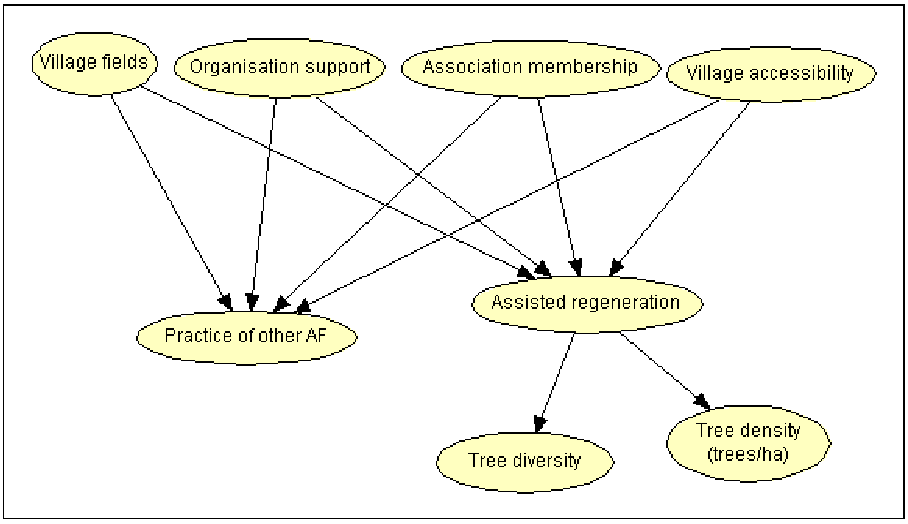
In this CPT only tree abundance levels and how they might be influenced by other variables are presented. It shows that association membership does not seem to have a very large influence on tree abundance in the fields. Organisation support, however, seems, at first sight, to be more common among farmers with low tree abundances than with high numbers of trees, as seen in the probabilities marked with circles. This tendency can lead to different assumptions: Either, project support influences AF negatively and leads to farmers having less trees, or project support is often directed to those farmers, that are least wealthy. The third assumption is that the available data from the survey is not sufficient to make conclusions about how associations and support by organisations influences agroforestry adoption as hypothesis B postulates.

The probabilities of the other nodes, about assisted regeneration and the practice of other AF types provide quite similarly results that are difficult to analyse. This is why this BBN supports hypothesis B.

6.1.9 Integrated model of AF practice and adoption

In the following, an exemplary comprehensive BBN is presented that integrates the sub-models that were shown in the previous examples. The variables used in this network are chosen from those that that seemed to be most statistically influential in the example BBNs. Tree density is integrated into the model although the sample size of the variable is smaller than the actual sample.[69] The child nodes in this BBN are the practice of other AF types then parklands, density of trees in the field and diversity of how many different species there are.

Figure 32: Integrated BBN about agroforestry in Tiby



This integrated model can be used to at least partly answer the two hypotheses / objectives posed in the beginning of this chapter.

Concerning hypothesis / objective B, the sub-models are to some extent able to provide answers to the research questions of this thesis. Many of the variables used give indications about why farmers have trees and practice AF.

[69] Tree abundance and field size are left out as they define tree density.

Moreover, some differences between types of farmers could be detected. To some extent, perceived benefits and risks related to agroforestry were shown.

Concerning the second postulation of hypothesis B, it is possible to build an integrated BBN as the one above. However, it consists of data that has different sample sizes, which makes its outcomes less reliable. Moreover, the three output variables are not necessarily the most significant for agroforestry adoption and practice, although, they can – similar to the sub-models – provide some indications. Nevertheless, the model shows multiple and more complex correlations than the smaller ones. Thus, it is recommendable to regard it as a basis for future models and continue improving it by adding updated data and new variables from both quantitative and qualitative research. The use of BBN proves to be optimal for conducting such changes and improvements.

It is not that simple to give a clear answer to hypothesis A. Although several of the sub-hypotheses showed tendencies that supported the idea that richer and poorer farmers use AF to diversify their livelihood portfolios, other BBNs contradicted this assumption. In the framework of sustainable livelihoods, some of the variables we looked at can be regarded as part of the context of risk, uncertainty and vulnerability. Other factors can be defined as livelihood assets, e.g. association membership can be defined as social capital or the soil type in a field as a biophysical factor being part of a farmer's natural capital. Nevertheless, the lack of available socio-economic variables makes it difficult to analyse a hypothesis about wealth. This, once again, supports hypothesis A. The data available through the field research methodology is insufficient to answer the research questions and more field research that provides reliable data is required.

6.2 Implications from the Qualitative Findings to the Theoretical Framework

The data analysis with BBN provided in the previous sub-chapter can partly be set into relation to the theoretical approaches presented in chapter three. But also the qualitative findings can be regarded in the framework of sustainable livelihoods and set into relation to previous research.

The sustainable livelihoods approach

Not only positive aspects of diversifying the livelihood portfolio with agroforestry could be observed. As traditional activities and connected identities get more and more blurred, relationships between people change and new conflicts arise (Hussein and Nelson 1998: 21, Toulmin et al. 2000: 9). Many farmers talked about problems connected to illegal tree cut, often by traditional herders who, in contrast to the Bambara / Maraka cultivators, belong to the ethnic (minority) group of the Fulani. Conflicts over land and resources for and from agroforestry can be regarded as part of the risk connected to the practice of AF. However, if the risk of conflict differs a lot from the risk connected to other activities of a livelihood portfolio, diversification with AF can still contribute to a lower covariate risk and thus, less vulnerability. Generally, attention must be paid to the fact that different livelihood strategies “may undercut others’ strategies by diverting such factors as land, labour, credit or markets” (Scoones 1998: 10).

It can be of interest to look at other livelihood strategies or activities that are part of the portfolio of a household (see also: Ellis 2000). Some farmers told us about migration patterns in their families, a type of information that did not come to the surface when questions related to this issue were posed during the household survey. As Ellis (2000: 105) states and as has also been observed in the field “it is typically, the younger, more innovative, better educated, and male members of farm families that leave the farm to undertake distance migration.” It can be significant to inquire further about how this might influence adoption of new or improved practices.

Many farmers mentioned other income generating activities than farming or agroforestry or they could be observed pursuing them. Two respondents said they also were working as tailors (e.g. respondent#46: interview 23.11.2010) and people could be seen preparing handmade products to sell on the market (e.g. respondent#37: interview 23.11.2010). Other activities mentioned by respondents include fishing and paid labour. It might be useful to learn more about if farmers who pursue additional activities also rely on AF and generally on larger livelihood portfolios that may add to reducing risk (See also: Scoones 1998).

Some of the factors from the fieldwork data of this study can be interpreted as parts of the vulnerability context of the model of the SLF. However, to gain a better understanding of how risk influences the decision to choose a livelihood strategy including AF, it is useful to focus more on farmers' experiences with and perceptions of risk and uncertainty The little people told us about this issue showed that the topic requires more in-depth research in very focused qualitative interviews.

The same applies to the institutional and policy context that was only inquired upon in very few questions of the representative household survey. Anyhow, the available qualitative data supports the assumption that big projects, like the MVP, or important organisations, like the governmental ORS, influence and define a lot of aspects in the daily lives of the farmers in the Tiby region. Individuals, like one farmer who used to work for the ORS (respondent#46: interview 23.11.2010), but sometimes also whole villages are concerned by their activities. For example, while we interviewed informants in Koïla Maraka, a huge conflict was going on concerning the management of a storage house built by the MVP. As many informants told us about their relationships to those and other organisations / institutions, it might be useful to learn more about how their influence relates to AF adoption and practice.

Previous studies on agroforestry

An important factor relative to agroforestry adoption is the prerequisite for the decision to diversify with a certain activity that there is enough knowledge about the benefits related to it. Many farmers in this study – in both, the household surveys and the follow-up interviews – mentioned many different benefits related to AF practices and multifunctional tree species. Nearly all farmers claimed that they would 'love' to practice agroforestry at their farms. On the other hand, as illustrated in chapter 6.1.4 with the example of the practice of live fences, there might still be a quite large lack of knowledge about the full range of multifunctional tree species and their benefits (and of disadvantages and risk factors) and the potential of long-term sustainability.

A related aspect from the theoretical approaches suggested in this study is the 'motivation-decision process' by Denning (2001) from chapter 3.1.2. It is based on the assumption that people learn from seeing a practice that has successfully been implemented by others. Some of the respondents told us about how they got the idea and motivation to start an AF practice which in many cases supported Denning's model. One farmer had heard about the benefits of an AF practice on the radio (e.g. respondent#82: interview 22.11.2010) and many others said they had seen it in their village. Some of the villages have one inhabitant who is famous for being a 'big agroforester'[70] and serves as a role model for others. Sometimes, villages also have their own tree nursery. The term 'neighbourhood effect' (Caveness and Kurtz 1993: 22, Mercer 2004: 317) fits very well to describe these situations. Also – although we did not gain a realistic idea of the scope – some projects had actively been promoting AF in the past.

Regarding the usefulness of different classifications and listings of important factors of agroforestry adoption mentioned in the theory chapter, it is difficult to draw individual conclusions for this study because a large part of the data that was intended to be used in the analysis is not available. Nevertheless, the qualitative data from the field research provides some support of the idea that the availability of land and of (financial) resources plays quite a decisive role in the decision to adopt AF or not. One farmer, for example, insisted several times during the interview on how the most serious lack and reason for most other problems at the farm was land scarcity. He claimed that having more trees in the fields would make cultivating crops impossible. As a root cause behind this, he mentioned the high number of births and an inheritance law that led to an increasing division of the farm land (respondent#37: interview 23.11.2010).

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[70] Many interviewees referred to 'le grand agroforestier' as translated from Bambara into French by the assistants.

By setting the results of this study in relation to the suggested theoretical approaches, parts of the research questions can be answered. However, to be able to provide more results, more has to be found out about institutional and policy factors that seem to play quite a decisive role in farmer decision-making in Tiby. Moreover, the vulnerability context, or as expressed in research question two, perceptions of risk and uncertainty, are important to focus upon. The lack of research about this factor group regretted by Pattanayak et al. (2003) in their meta-analysis of adoption factors remains a wide field for future research.

6.3 Discussion of the Research Methodology

Relative to hypothesis B, it has to be admitted that the choice to use an interdisciplinary approach with a mixed methods research strategy was a very challenging one. At least parts of the available survey data could be analysed with the help of BBNs and contribute to answering the research questions. A limitation concerning the development of an integrated model for agroforestry adoption with the available data is already included in the hypothesis. To better understand why this rather pessimistic hypothesis about the field methodology was postulated, the main benefits and disadvantages of the methodological approaches for fieldwork and analysis chosen for this thesis will be discussed in the following – this time in relation to impediments related to the findings. Ideas for improvement will be presented subsequently.

6.3.1 Benefits and disadvantages of the methodological approach

Although a multi-source field research approach with mixed methods can be very challenging and time consuming, it proved to be right, that the different types of data attained by the research for this thesis can corroborate one another. In the case of the BBNs, for instance, the postulations of hypotheses and the analysis of the results of the models would not have been possible without the support of qualitative findings. The models themselves, on the other hand, were developed with data from the representative household survey. Generally, a combination of qualitative and quantitative data can lead to results that are closer to the truth than when only one data type is used.

In the context of this thesis, some features of Bayesian belief networks were particularly useful. One of those is, that in BBNs, findings from different data sets can be combined, which allowed for adding parts of the data provided by a previous survey of the FunciTree project to the household survey data.

Moreover, not the whole range of variables has to be analysed. With BBNs several of the factors can be taken and smaller (sub-) models created. To look at and experiment with different probable causal relations between various factors in node-and-arrow models with the Hugin software made it possible to build a very large amount of models and test how useful they are to show potential factors influencing AF. A huge part of these 'test' models were dropped after they had been tested, as they were too imprecise, not containing important enough factors or for other reasons not suitable as examples to present.

Concerning the use and analysis of qualitative data, the chosen approach of a thematic analysis was very useful to organise the findings in groups of different topics so that they could be combined with the qualitative ones in both, the presentation of the findings, and the analysis of Bayesian belief networks.

Implications for future approaches

Despite the mentioned advantages, there are several methodological aspects, mainly concerning field methodology, that caused some of the problems stated in the second part of chapter two and led to the postulation of hypothesis B about the insufficiency of the household survey method to identify an adequate amount of reliable factors to develop a comprehensive BBN of AF practice and adoption.

Some of the main deficits are related to the questionnaire that was used (see appendix B and C). Independent of the fact, that – due to problems mentioned in the methodology chapter – a lot of relevant topics are missing in the questionnaire, many of the questions were not very well formulated, neither. As the questionnaire was developed during a methodological workshop that was mainly focused on learning how to use Bayesian belief networks, it obtained a quite one-sided focus. Questions were rather technical, complicated and scientific. This is not very suitable for a household questionnaire that is supposed to be answered by farmers who speak a language, in which the terminologies used do not even exist.

Many of the inconsistencies in the findings, concerning for example the availability of data about field sizes for only about half of the sample, are connected to problems in translating and explaining the questions. A very large amount of questions proved to be useless because people were simply not willing or able to answer them. And even if they did, answers were often not understandable in the aftermath. This is especially relevant concerning questions that asked for numeric variables, like for example, about how much of a tree product was produced or about preferred distances between trees in the fields.

The many aspects of the survey questionnaire that were problematic led to several ideas for improvements in future survey research:

- The survey questionnaire should at least partly be developed in collaboration with local non-scientific people, possibly in focus groups.
- Too complicated, scientific and technical questions should be avoided.
- Questions that require a numeric answer should be avoided, if possible. If the numeric answer is needed, it should be made sure that the unit of measurement is clearly defined and known by the prospective informants.
- A questionnaire should not be too long, as both, respondents and informants get tired and are not able to do their work well anymore.
- Also, when using a representative survey to receive data for using BBNs it might be better to interview less people and use more time for interviews, as there is no minimum data size necessary to use BBNs.

As the qualitative findings from the field research provided a lot of knowledge that is valuable for understanding the specific context of the site and corroborate the findings from the household survey, I argue that more and different qualitative methods can be useful to gain better insight into farmers' preferences and attitudes concerning agroforestry. A main advantage of qualitative research is that it is most often more open than representative surveys are. Translation and comprehension problems can be solved during the conversations. Topics can come up again and irrelevant topics do not have to be repeated. Moreover, not only the interviewer, also the informant can influence the direction of the conversation. This can lead to unexpected findings, which is especially important in a field like agroforestry adoption because previous studies traditionally included rather survey research and not on in-depth interviews.

The open-ended follow-up interviews conducted after the household survey provided a lot of qualitative information that was useful for answering research questions and for developing BBNs. Nonetheless, it is important to have a very clear focus about the aspects that are supposed to be inquired about in those. Therefore, it is necessary to on the one hand, use an interview guide and on the other hand, to reduce it to few very relevant topics.

Additional useful qualitative research methods include the use of focus groups and / or narrative research. Approaches of narrative research contribute to finding out more about shared perceptions about agroforestry in a sample. It can help to finding patterns and make sense out of stories that are repeatedly told by informants as for instance the ones about abusive tree cut.

Focus groups often 'come up' naturally and unplanned in some interview settings when respondents simply start discussing their statements with other people around them. They can contribute to finding out more about farmer knowledge and preferences concerning AF practice and adoption. Especially relative to information about the large range of different multifunctional tree species and their benefits, it is valuable if people are able to collect and categorise all different issues that they know and discuss them with each other. When focus groups 'came up' during the research for this thesis, they brought forward aspects that were most important to the informants and sometimes also common problems, respondents actually had not intended to discuss in detail.

7. CONCLUDING REMARKS

This thesis intended to inquire about the various factors influencing the practice and adoption of agroforestry of local smallholders in rural Mali. Field research was conducted in the framework of the FunciTree project in the Tiby village cluster, one of the sites of the Millennium Villages Project. By using a mixed method research approach consisting of a representative household survey and a few semi-structured follow-up interviews, it was aimed to gain different types of findings about farmer characteristics, their attitudes and perceptions towards multifunctional trees and agroforestry related benefits. One main focus lay on risk and uncertainty.

The data analysis approach was to create Bayesian belief networks that describe potential causal relations between different farm household characteristics and variables related to agroforestry. A goal was to identify and categorise the most relevant factors influencing AF practice and adoption. The theoretical foundation of the analysis was based on meta-analyses and results from previous studies about AF adoption. Moreover, the results of the analysis were set into the framework of sustainable livelihoods. Thus, it was intended to build a comprehensive integrated model of agroforestry adoption.

The main findings of this thesis are connected to farmer activities concerning the practice of traditional agroforestry parklands, which are present in all households that were interviewed. Other agroforestry practices that are common among the sample population are home gardens, which mainly supply farmers with nutrition and an income source, Eucalyptus family forests, which farmers primarily use for fuel and construction wood, and live fences, which have the main task to protect plots of land. Many different aspects of tree functions, related activities, benefits and disadvantages of different AF practices used by the farmers were identified. In addition, some socio-economic and farm characteristics that are relevant in connection to those were found. Many of these findings could be set into the framework of and compared with those of previous studies

However, due to various problems that came up during data acquiring, which led to a quite incomplete data set, the focus of data analysis had to be shifted. As many variables that would have been useful to compare the findings about AF practice and maintenance with were missing, the analysis of findings with BBNs became more focused on methodological issues. Qualitative data was employed more than originally intended to corroborate survey data. Thus, many insights were provided that made it possible to present results in BBNs and in connection to the SLF.

By combining different typed of data, it was possible to provide evidence for the assumption that adoption of agroforestry can be seen as a strategy of livelihood diversification. Farmers try to have a large portfolio of activities to spread risk and uncertainty, of which agroforestry practices can be a part. However, to show how livelihoods in a risk-prone area like Tiby can be made more sustainable by increasing and improving agroforestry practice in addition to other activities, more research is required.

Some of the main results of this study are lessons learnt from the impediments that came up. Although BBNs proved to be a very useful tool to analyse factors related to AF practice and adoption, it is necessary to change the focus of research to gain better data that is relevant to AF practice and adoption. An increased focus on qualitative research methods and an improved household survey strategy can provide more relevant variables about agroforestry to create useful BBNs. In this way, farmer decision-making can be analysed in more detail and strategies on how to improve practice of traditional agroforestry as well as adoption of new agroforestry practices can be developed and implemented. In each case, adequate research strategies require a very strong focus on the individual farmer and his attitudes, knowledge and preferences. Only then, sustainable implementation and use of agroforestry can be achieved.

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Hugin Researcher 7.3 Tool made by Hugin Expert a/s, Alborg, Denmark, 2010. http://www.hugin.dk. (licensed to NINA).

The photos in this thesis were all taken by Siri Lena Tholander.

APPENDIX

A. Lists of Tree Species Mentioned by Farmers

List of the 35 tree species in the field mentioned by the informants

Tree species	Households
Faidherbia albida	83
Vitellaria paradoxa	52
Sclerocarya birrea	39
Adansonia digitata	25
Piliostigma reticulatum	21
Anogeissus leiocarpus	17
Diospyros mespiliformis	17
Terminalia macroptera	17
Tamarindus indica	15
Prosopis africana	13
Guiera senegalensis	12
Balanites aegyptica	12
Combretum glutinosum	9
Azadirachta indica	7
Borassus aethiopium	7
Ficus gnaphalocarpa	6
Ficus platyphylla	4
Mitragyna inermis	4
Acacia nilotica	4
Pterocarpus erinaceus	4
Celtis integrifolia	4
Lannea microcarpa	4
Cordyla pinnata	3
Ziziphus mauritiania	3
Saba senegalensis	2
Securinega virosu	2
Vitex madiensis	2
Acacia raddiana	2
Calotropis prociera	1
Maytenus senegalensis	1
Combretum micrantum	1
Albizia chevaleri	1
Acacia seyal	1
Grewia bicolor	1
Eucalyptus camaldulensis	1

Tree species adopted by the respondents who have home gardens

Plot sizes	3	1,5	0,5	2	1	1	2	0,5	1,5	0,4	0,5	1	0,5	5	0,5	1	1	0,25	18
Mangifera indica	1	1	1	1	1	1	1	1	1		1	1	1	1		1		1	15
Citrus lemon	1	1	1		1	1	1		1	1	1	1	1		1	1	1		14
Psidium guajava		1	1		1	1		1	1	1	1	1			1				10
Borassus aethiopum	1		1	1			1			1				1			1		7
Ziziphus mauritiana		1		1	1	1													4
Eucalyptus camaldulensis				1	1														2
Tamarindus indica	1	1																	2
Hyphaena thebaica	1		1																2
Vitellaria paradoxa	1			1															2
Annona senegalensis		1																	1
Adansonia digitata		1																	1
Punica granatum								1											1
Citrus sinensis			1																1
Anarcadium occidental							1												1
Acacia nilotica				1															1
Parkia biglobosa	1																		1
Ficus gnaphalocarpa	1																		1
TOTAL tree species	8	7	6	6	5	4	4	3	3	3	3	3	2	2	2	2	2	1	TOTAL farmers

List of the tree species most preferred by the respondents

Tree species	**Households**
Faidherbia albida	89
Vitellaria paradoxa	54
Adansonia digitata	17
Tamarindus indica	10
Sclerocarya birrea	9
Ficus gnaphalocarpa	8
Pterocarpus erinaceus	6
Mangifera indica	6
Eucalyptus camaldulensis	6
Azadirachta indica	4
Diospyros mespiliformis	4
Psidium guajava	3
Ziziphus mauritiania	3
Khaya senegalensis	3
Anogeissus leiocarpus	2
Prosopis africana	2
Borassus aethiopium	2

Saba senegalensis	1
Carica papaya	1
Parkia biglobosa	1
Citrus lemon	1
Cordyla pinnata	1
Acacia nilotica	1
Pterocarpus lucens	1
Ficus platyphylla	1
Lannea microcarpa	1
Balanites aegyptica	1

Tree species that are present in different AFS.

Tree species	**Food banks**	**Agroforestry parklands**	**Eucalyptus family forests**	**Live fences**	**TOTAL used in AF**
Vitellaria paradoxa	2	52	0	0	**2**
Adansonia digitata	1	25	0	0	**2**
Tamarindus indica	2	15	0	0	**2**
Eucalyptus camaldulensis	2	1	12	0	**3**
Borassus aethiopium	7	7	0	0	**2**
Ziziphus mauritiana	4	3	0	0	**2**
Ficus gnaphalocarpa	1	6	0	0	**2**
Acacia nilotica	1	4	0	2	**3**

List of tree species most mentioned to be consumed by the animals

Tree species	**Households**
Faidherbia albida	76
Ficus gnaphalocarpa	31
Pterocarpus erinaceus	25
Celtis integrifolia	24
Sclerocarya birrea	17
Terminalia macroptera	11
Adansonia digitata	7
Vitellaria paradoxa	7
Balanites aegyptica	6
Ziziphus mauritiana	6
Anogeissus leiocarpus	5
Acacia seyal	5
Ficus platyphylla	3
Pterocarpus lucens	2
Acacia raddiana	2
Piliostigma reticulatum	2
Grewia bicolor	2
Acacia nilotica	2

Mitragyna inermis	1
Albizia chevaleri	1
Cordylla pinnata	1
Khaya senegalensis	1
Combretum glutinosum	1
Guiera senegalensis	1

List of tree species that informants let regenerate in their fields

Tree species	Households
Faidherbia albida	82
Vitellaria paradoxa	20
Adansonia digitata	14
Azadirachta indica	11
Sclerocarya birrea	5
Borassus aethiopium	5
Acacia nilotica	4
Tamarindus indica	4
Balanites aegyptica	3
Ziziphus mauritiana	3
Piliostigma reticulatum	2
Ficus gnaphalocarpa	2
Pterocarpus erinaceus	1
Terminalia macroptera	1
Ficus platyphylla	1
Combretum glutinosum	1
Acacia seyal	1
Saba senegalensis	1
Eucalyptus camaldulensis	1
Prosopis africana	1
Diospyros mespiliformis	1
Hyphaena thebaica	1
Stereospermum khuntianum	1

List of the mentioned disappeared tree species

Tree species	Households
Adansonia digitata	29
Vitellaria paradoxa	21
Pterocarpus erinaceus	15
Cordyla pinnata	14
Faidherbia albida	13
Ficus gnaphalocarpa	11
Sclerocarya birrea	9
Anogeissus leiocarpus	8
Terminalia macroptera	8

Tamarindus indica	8
Khaya senegalensis	7
Piliostigma reticulatum	7
Lannea microcarpa	5
Combretum glutinosum	5
Celtis integrifolia	5
Hyphaena thebaica	4
Prosopis africana	4
Albizia chevaleri	4
Stereospermum khuntianum	4
Guiera senegalensis	4
Mitragyna inermis	3
Saba senegalensis	3
Acacia nilotica	3
Pterocarpus lucens	3
Bombax costatum	2
Ficus iteophylla	2
Securinega Virosu	2
Ziziphus mauritiana	2
Balanites aegyptica	2
Pseudocedrala Kotschyi	2
Borassus aethiopium	2
Cordia mixa	1
Acacia raddiana	1
Afzelia africana	1
Grewia bicolor	1
Acacia senegal	1
Ficus platyphylla	1
Mangifera indica	1
Ximenia americana	1
Vitex madiensis	1
Crosaptyrus seglusia	1
Diospyros mespiliformis	1
Parkia biglobosa	1
Acacia senegal	1

B. Survey Questionnaire (French Original)

(The sizes of the tables was shortened)

QUESTIONNAIRE FunciTree **Fiche exploitation agricole de l'arbre (consolidation WP2-WP3-WP6)**	
Date de l'enquête :	
Nom Enquêteur :	
Nom de village : **Code MVP de village :**	
Numéro MVP de concession: **Numéro MVP de ménage:**	
Nom de commune :	
Location GPS :	

I. CARACTERISTIQUES SOCIO-DEMOGRAPHIQUE

1. Nom de l'enquêtée :

2. Ancienneté dans le village :

1. Autochtone 2. Immigré

3. Si immigré quelle est l'année d'installation au village ? /__________/

4. Membre d'un ou plusieurs groupements : Oui /____/ Non /____/

5. si oui lesquels

Nom	**Domaine d'activités**

6. Avez-vous été dans le passé ou êtes-vous actuellement encadré par un ou des organismes de développement ?

Oui /___/ non /____/

7. Si oui →

Nom d'organisation	**Durée des relations** **(année commencée – année terminée ?)**	**Domaine/type d'interventions**

II. AGRICULTURE

8. Répartition des terres au sein de l'exploitation /______/

1 = propriété

2 = emprunt saisonnière

3 = autre à préciser

9. Est-ce que vous pouvez emprunter ou louer des parcelles si vous voulez ?

Oui /_______/ non /_______/

10. Si oui quelles sont les modalités ?

_____ 0 = pas de modalités

_____ 1 = payement montant forfaitaire par saison Combien ?___________FCFA

_____ 2 = autres à préciser :...

11. Payez-vous la redevance eaux ?

Oui /_______/ non /_______/

12. Si oui, combien payez-vous ?

___________FCFA

13. Avez-vous des champs de case ?

Oui /_______/ non /_______/

14. A quelle distance se situent les champs de l'exploitation (champs de brousse) les plus proches ? /___________/ et les champs les plus éloignées ? /__________/

15. Quels problèmes rencontrez-vous dans l'agriculture ?

____ 0 = pas de problèmes

____ 1 = attaques insectes ou rageurs

____ 2 = matériel vétuste

____ 3 = déficit de matériel agricole

____ 4 = commercialisation

____ 5 = manque d'intrants

____ 6 = insuffisance de terres

____ 7 = autres...
....

16. Pensez-vous que la fertilité de vos terres a diminuée?

Oui /_______/ non /________/

17. Si oui quelles sont les causes ?...

....
.... Quelles sont les solutions adoptées et/ou envisagées pour les résoudre ?

....
....

18. Apport de fumure organique ou minérale ? non/____/ oui /____/ =>

Spéculation /culture	Type de fumure ? **O=organique** **M=minérale**	Type de sol (**1** = sol sablonneux ; **2** = sol argileux ; **3** = sol limoneux ; **4=** autre à préciser)	Fréquence d'utilisation (**0 =** jamais ; **1 =** rarement/ moins que chaque année ; **2 =** 1 fois par an ; **3 =** 2 à 3 fois par an ; **4=** autre à préciser)	Fum. Minérale : Quantité moyenne **kg/ha** (par saison)

III. ELEVAGE

19. Base de l'alimentation

Types d'animaux	Saison sèche	Hivernage
Bovins		
Ovins & Caprins		
Ânes		
Chevaux		

20. Quels problèmes rencontrez-vous dans votre élevage?..........................

....

....

21. Quelles solutions adoptez-vous pour les résoudre ?..............................

....

IV. COMPOSANTE LIGNEUSE

22. Considérez-vous que les arbres qui sont dans vos champs vous appartiennent ?

oui /____/ non /____/

23. Si oui votre droit de propriété est-il respecté par les autres ?

oui /___/ non /____/

24. Si non pourquoi ?...
....

25. Les espèces ligneuses rencontrées dans vos parcelles de cultures et domicile

Champs	**Vergers**	**Domicile**

26. Existent-t-il des espèces qui ont disparues de vos parcelles ?

Oui/___/ Non/____/

27. Si oui lesquelles et quelles sont les causes de leur disparition ?

Espèces	**Causes** 1= sécheresse ; 2= coupes abusives ; 3=cultures attelées ; *4= autre (à préciser)*

28. Quelles sont par ordre de priorité les espèces que vous aimez avoir dans vos exploitations ?

Espèces	**Utilités majeures** 1=fourrage ; 2=bois de chauffe ; 3= bois service ; 4= fertilisation ; 5= pharmacopée, 6= ombrage, 7=autre (à préciser).	**Inconvénients éventuels** 1 = ombrage; 2= attire les insectes, rongeurs, oiseaux ; 3= autre (à préciser).

29. Quelles sont les principales espèces d'arbres les plus appétées par votre bétail ?

Espèces ligneuses	Animaux **1=petits ruminants** **2= grands ruminants**	(Animaux=>) **Parties consommées** **t=**troncs**, fl**=fleur**, fe**=feuille, **br**=branche**, po**=pousse, **ra**=racine, **se**=sève, **fr**=fruit	**Période de l'année** (mois ou saison)

NB ! CONDITIONALITÉS ENTRE COLONNES => ANIMAUX => PARTIES CONSOMMEES

V. ADOPTION DES TECHNOLOGIES AGROFORESTIERES

A. Inventaire des pratiques endogènes, innovations, technologies agroforestières

31. Technologies agroforestières expérimentées dans le passé et maintenant

Pratiques agroforestières 1. Haies vives 2. Parc agroforestier 3. Plantation de délimitations 4. Régénération naturelle assistée 7. Banque alimentaire et nutritionnelle 8. Bosquet familiale 9. autre (à préciser).	**Emplacement** 1= ch. Cases 2=ch. Brousse 3=maison 4=axes routiers 5=autres (à préciser)	**Distance du village** (km)	**Origine de connaissance** 1= traditionnelle 2=introduite 3=modifiée (à préciser) 4=crée (à préciser)	**Situation** 1 : continue, 2 : abandon, 3 : discontinue, 4 : non adoption	**Durée de pratiques** (de quelle année à quelle année)	**Nombre Parcelles ?** => Superficie totale ? (hectares)	**Quels inconvénients, contraints, problèmes** *(à préciser)?* (à propos des situations 2-4)

B. Espèces agroforestières dans les champs

32. Quelles sont les caractéristiques des espèces dans les champs?

Espèces	**(Espèces →) Emplacement** 1= champs cases 2= champs Brousse 3= maison 4= axes routiers 5= délimitation 6= autres (à préciser)	**(Emplacement →) Espacement actuel en parcelles** (mètres/arbres) ou (nombre de pied)	**Quel est l'effet sur les cultures sous le pied de l'arbre ?** 1. Sol 2. Ombrage 3. Autres (à préciser)	**Désirez-vous plus d'arbres dans vos champs ?** (oui/non)	**→ Si oui, espacement désiré ?** (mètres entre les arbres)

NB : CONDITIONALITÉS ENTRE COLONNES → ESPECES → EMPLACEMENT → ESPACEMENT ACTUEL

33. Aspects utilitaires des espèces ligneuses dans les champs

					Produits (extraction):				**Vendues:**		
Espèces	**Parties utilisées** **tr=**troncs **fl**=fleur **fe**=feuille **br**=branche **fr**=fruit **éc**=écorce	(parties →) **Principales utilisations** *(à préciser)*	(utilisation →) **Méthodes de prélèvement** *(à préciser)*	(méthodes →) **Impact** (sur les arbres) *(à préciser)*	(impact →) **Quantité Produite** unités/s unités/m unités/a (si mesurable)	**Quantité Travail non-salarié** heures p./j jours p./s jours p./m mois p./an	**Quantité travail salarié** heures p./j jours p./s jours p./m mois p./an	**Saisonnier?** Oui/Non	**Quantité Vendue** unités/s unités/m unités/a 0=autoconsommation	**Valeur ou prix** (FCFA/ unité)	**Utilisation des revenus** *(à préciser)*

NB! CONDITIONALITÉS ENTRE COLONNES → Espèces → Parties utilisées → Principales utilisations → Méthodes de prélèvement → Impact et Quantité Produite

Régénération

34. Quelles sont les espèces que vous laissez régénérer dans l'exploitation, où et comment?

Espèces que vous laissez régénérer ?	**Utilités** 1=fourrage 2=bois de chauffe 3= bois service 4= fertilisation 5= pharmacopée 6= ombrage 7=brise vent 8=autre (à préciser)	**Emplacement** 1= ch. Cases 2=ch. Brousse 3=autres (à préciser)	**Principales entraves** à la régénération ?	**Actions** pour faire face aux entraves ?	**Actions implique effort ou matériel additionnel ?** (oui/non)	**Si oui, Coûts additionnels ?** (FCFA/hectare)

NB ! CONDITIONALITÉS ENTRE COLONNES → ESPECE-EMPLACEMENT → UTILITÉ → ENTRAVES → ACTIONS → COUTS

Plantations agroforestières

35. Principales technologies agroforestières (espèces utilisées)

			Année 1				**Année 2**		
Technologies agroforestières (espèces utilisés)	**Utilités** 1=fourrage 2=bois de chauffe 3= bois service 4= fertilisation 5= pharmacopée 6= ombrage 7=brise vent 8=commercialisation 9=autre (à préciser)	**Emplacement** 1= ch. Cases 2=ch. Brousse 3=autres (à préciser)	**Coûts plantes** (FCFA)	**Coûts de forage** (FCFA)	**Effort* plantation** (hommes x jours)	**Effort * entretien** (hommes x jours)	**Effort * entretien** (hommes x jours)	**Coûts plantes** (remplacement des plantes mortes) (FCFA)	**Coûts de forage additionnel/ réparations** (FCFA)

(Effort salarié et non-salarié en total (ne se distingue pas due à complexité des autres données demandées)

C. Survey Questionnaire (Translated English Version)

(Shortened and reduced the most relevant issues)

Name of the village:	
MVP number:	

I. SOCIO-DEMOGRAPHIC CHARACTERISTICS

1. Name of the informant:

2. Time period lived in the villages?

1. Indigenous 2. Immigrant

3. Member of one or several associations?

4. If yes, which ones?

Name	**Area of activity**

5. Have you been or are you right now under the auspices of one or several development organisations?

Yes No

6. If yes →

Name of the organisation	**Duration of the relations**	**Type / are of intervention**

I. AGRICULTURE

7. Division of the land at the farm?

1. Property 2. Seasonal rent 3. Other

8. Do you have the possibility to rent land plots if you want to?

Yes No

9. Are you paying the irrigation fee?

Yes No

10. If yes, how much are you paying?

_______ FCFA

11. Do you have compound fields?

Yes No

12. What is the distance to the fields that are closest? _____ And the fields that are furthest away? _____

13. Which problems do you have in agriculture?

0 = no problems

1 = animal or insect attics

2 = old material

3 = lack of agricultural material

4 = marketing

5 = lack of inputs

6 = lack of land

7 = other

14. Do you think the quality of the soil has diminished?

Yes No

15. If yes, what are the causes? ____

What solutions are there? ____

16. Are you using organic or mineral fertiliser? Yes No

Crop	Fertiliser type O = organic; M = mineral	Soil type 1 = sandy; 2 =loamy; 3 = mix	Frequency of use (0 = never; 1 = less than once a year; 2 = 1 time per year; 3 = 2 to 3 times per year; 4 = other)	Mineral fertiliser Average quantity: kg/ha (per season)

III. LIVESTOCK

17. Fodder base

Animal type	Dry season	Rainy season
Cattle		
Goats and sheep		
Donkeys		
Horses		

18. What problems do you have with livestock breeding?

19. What solutions are there?

III. TREE COMPONENT

20. Are your property rights concerning the trees in your fields respected by others?

Yes No

21. If no, why not?

22. The tree species that are present in your compound and plots

Fields	Orchards	Compound

23. Are there tree species that have disappeared from your land?

Yes No

24. Which species have disappeared and what are the reasons?

Tree species	Reason for disappearance 1 = drought; 2 = abusive cut; 3 = attached crops; 4 = other

25. Which are, by order of preference, the tree species you would like to have on your farm?

Tree species	Main use 1= fodder; 2 = fuel wood; 3 = service wood; 4 = fertiliser; 5 = pharmacopeia; 6 = shade; 7 = other	Potential disadvantages 1 = shade; 2 = refuge for animals, birds; 3 = other

26. Which are the main tree species that provide fodder for your animals?

Tree species	Animals 1 = small ruminants; 2 = big ruminants	Parts consumed 1 = Trunks, 2 = leaves; 3 = fruit	Season 1 = rainy; 2 = dry

III. ADOPTION OF AGROFORESTRY TECHNOLOGIES

A. Inventory of indigenous practices, innovations and technologies

27. Agroforestry technologies experiences in the past and now

AF practice 1 = Live fences; 2 =Agroforestry parklands; 3 = Assisted natural regeneration; 4 = food bank (home garden); 5 = family forest; 6 = other	Location 1 = compound fields; 2 = fields in the bush; 3 = at the house; 4 = other	Distance to village (km)	Origin of knowledge 1 = traditional; 2 = introduced; 3 = modified; 4 = created	Situation 1 = continued; 2 = abandoned	Duration (years)	Number / Size of plots Total area	Constraints / Problems

B. Agroforestry tree species in the fields

28. What are the characteristics of the tree species in the fields?

Tree species	Location 1 = compound fields; 2 = fields in the bush; 3 = at the house; 4 = other)	Distance in the field (metres between trees or number of trees)	What is the effect on the crops? 1 = soil; 2 = shade; 3 = other (positive or negative?)	Do you want to have more trees of this species in your fields? (yes / no)	If yes, what distance do you desire? (metres between trees)

29. Beneficial aspects of the tree species in the fields

			Production			Sale	
Tree species	Parts used 1 = trunks; 2 = leaves; 3 = fruit; 4 = other	Principal use	Quantity produced Unit / season; unit / month; unit / year	Quantity of work Hours / day; days / season; days / month; months / year	Seasonal Yes/no	Quantity sold Unit / season; units / month; units / year 0 = auto-consumption	Value and price (FCFA / unit)

C. Regeneration

30. What the tree species do you let regenerate on your farm, where and how?

Tree species	Use 1 = fodder; 2 = fuel wood; 3 = service wood; 4 = fertiliser; 5 = pharmacopoeia; 6 = shade; 7 = other	Location	Main obstacles to regeneration	Actions to tackle obstacles	Do they imply additional effort / material? (yes / no)	If yes, additional costs?

D. Agroforestry plantations

31. The main agroforestry technologies (tree species used)

			Year 1			Year 2	
Agroforestry technologies (tree species used)	Use 1 = fodder; 2 = fuel wood; 3 = service wood; 4 = fertiliser; 5 = pharmacopoeia; 6 = shade; 7 = marketing; 8 = other	Location 1 = compound fields; 2 = fields in the bush; 3 = other)	Plant costs (FCFA)	Irrigation costs (FCFA)	Planting effort (person x days)	Plant costs (FCFA)	Irrigation costs (FCFA)

D. Interview Guide – Follow-up Interviews (French original)

Guide d'interview

Introduction

J'ai déjà fait des enquêtes quantitatives pour trouver des informations sur la gestion des arbres pour écrire mon mémoire.

Maintenant, je veux apprendre quelque chose sur vos perceptions concernant les entraves et les avantages des pratiques agroforestières et apprendre un peu plus sur les facteurs différents qui influent l'adoption ou non adoption.

- Je veux seulement apprendre vos opinions, perspectives et expériences
- toutes sortes de réponses sont intéressantes et précieuses pour mes recherches
- si vous ne voulez pas répondre à une question vous avez, bien sûr, le droit de refuser
- Je vais rendre anonyme les résultats de mes recherches
- Est-ce que vous êtes d'accord si j'utilise un dictaphone pour enregistrer notre conversation ? Ca faciliterait mon travail.

Éducation :

- Quelle sorte d'éducation ou quelle sorte de formation avez-vous ? Est-ce que vous sentez que ça a contribué à la gestion de votre exploitation ?

Sources de revenus et Travail :

- Quelles sont les sources de revenues principales de votre exploitation ?
- Est-ce qu'il y a des autres sources de revenus (p.ex. la vente de produits fabriqués à l'exploitation, le salaire du travail permanent ou du travail à court terme de membres de l'exploitation) ?
- Est-ce que vous avez des revenues régulières ?
- Est-ce que vous avez des idées comment on pourrait stabiliser les revenues ?

Le terrain de l'exploitation :

- Pourriez-vous me raconter un peu comment vous avez obtenu les terres et si la taille du terrain a changé depuis ?

- Est-ce que vous sentez que vous avez assez espace pour L'agriculture/l'élevage ? Est-ce que vous aimerez avoir plus ? Est-ce que c'est possible s'acquérir plus d'espace ?
- Est-ce que vous assez d'espace à vivre ? De logement suffisant ?
- Quelles sont les choses qui manquent le plus dans votre ménage ?

Sécurité alimentaire, en eau et en énergie :

- Comment est-ce que votre système de stockage de nourriture/ fourrage fonctionne ? Est-ce que la quantité stockée est suffisante ?
- Est-ce qu'il y a souvent des manques de nourriture ? Pourquoi ? Qu'est-ce que vous faites ?
- Est-ce qu'il y a souvent des manques d'eau ? Pourquoi ? Qu'est-ce que vous faites ? Comment est la qualité d'eau ?
- Est-ce que vous avez accès à l'électricité (éclairage) ? Pourquoi/pourquoi pas ?
- Est-ce que vous avez accès à assez de combustibles ? Pourquoi/pourquoi pas ?

Vulnérabilité et chocs

- Est-ce qu'il y a souvent des évènements imprévus (p. ex. sécheresses, inondations, maladies, maladies de bétail, de cultures ou des arbres, vol, manque d'eau ou de combustibles, accidents, morts, variation de prix etc.) ?
- Est-ce que qu'il y a d'accès au transport si nécessaire ?
- Est-ce que qu'il y a d'accès aux médicaments/ assistance médicale si nécessaire ?
- Avez-vous de radio, télévision, portables ? Recevez-vous d'information sur des thèmes qui vous concernent (le temps, agriculture, politique, etc.) ?

Crédits, dons d'argent, épargnes :

- Est-ce que vous avez accès aux crédits si vous voulez ? Avez-vous des expériences avec de crédits ? Qui donne les crédits ?
- Avez-vous des épargnes ? Pourriez-vous raconter plus sur ça ?
- Est-ce que les agences de développement ou les associations paysannes ont influencés cette situation ?

Arbres :

- Quelles sont les causes principales pourquoi vous avez adopté/non adopté des pratiques agroforestières ?

- Est-ce que vous êtes content avec le nombre d'arbres vous avez ? Pourquoi/pourquoi pas ?

Fin :

- Merci pour votre participation
- Est-ce que je peux prendre de photos de vos champs / vergers ?

E. Interview Guide – Follow-up Interviews (Translated English Version)

Interview Guide

Introduction

I already conducted a survey to find information about tree management in the framework of the study for my master thesis.

Now, I would like to learn something about your perceptions concerning the obstacles and advantages if agroforestry and learn more about the different factors that influence the adoption and non-adoption.

- I simply want to learn about your opinions, perspectives and experiences
- All sorts of responses are interesting and valuable for my research
- If you do not want to respond to a question, of course, you have the right to refuse
- The results of my research will be kept anonymous
- Is it ok if I use a Dictaphone to record our conversation? It would make my work easier.

Education:

What sort of education or training do you have? Do you think that it helps you with the management of your farm?

Revenue sources and work:

- What are your main sources of revenues at the farm?
- Are there other sources of revenues (for example, sale of manufactured products, the salary of short term or long term employment of members of the household)?
- Do you have a regular income?
- Do you have ideas how to stabilise the revenues?

The farm area:

- Can you tell me how you obtained the farm land and if the size of it has changed since then?

- Do you feel you have enough space for agriculture / livestock? Would you like to have more land? Is it possible to acquire more land?
- Do you have enough space to live? Is your housing situation sufficient?
- What are the things that lack the most in your household?

Food, water and energy security:

- How does the storage of food / fodder work? Are the quantities sufficient?
- Is there often a lack of nutrition? What are the reasons? What actions are taken?
- Is there a lack of water? Why? What actions are taken? How is the water quality?
- Do you have access to electricity? Why / why not?
- Do you have access to combustibles? Why / why not?

Vulnerability and shocks:

- Are there often unpredicted events (e.g., droughts, floods, sickness, animal sickness, crop sickness, theft, lack of water, lack of combustibles, accidents, death, sudden market price fluctuations etc.)?
- Is there access to transport in case of emergency?
- Is there access to medication / medical assistance in case of emergency?
- Do you have a radio / television / mobile phone? Do you receive information that is important to you (e.g., about the weather, agriculture, politics, etc.)?

Credits, loans, savings:

- Do you have access to credits if you would like to? Do you have experience with credits? Who gives credits?
- Do you have savings? Can you tell us more about that?
- Do development agencies or farmer associations influence this situation?

Trees:

- What are the main causes why you have / have not adopted agroforestry practices?
- Are you satisfied with the number of trees you have? Why / Why not?

End:

- Thank you for your participation?
- Is it ok if I take some photos of your fields / orchards?

F. Data Request for the Joint Analysis of MVP and FunciTree Databases

Request for Millennium Village Project (MVP) 'non-sensitive microlevel household survey' – an opportunity to analyse probability of agro-forestry adoption by joint analysis of MVP and FunciTree databases

The FunciTree project submitted a data access request to the Millennium Villages Project for access to type II and type III data from the detailed socio-economic surveys conducted for the MVP year 3 interim evaluation. This box defines what types of data were requested. The present Technical Brief provides justification for how the data is to be used by FunciTree.

In January – March 2010 MVP Tiby and Potou, conducted household surveys aimed at providing data for interim (year 3) project evaluation. Detailed demographic surveys were conducted for a representative sample of the population in the whole project area, with detailed socio-economic surveys conducted for a sub-sample of villages. For example, in Potou 3268 households in the 112 villages (clusters MV1-6) of the Potou cluster were interviewed for demographics, while in one village cluster (MV1) counting 14 villages 300 households received detailed socio-economic surveys (pers. com. Ousmane Diouf, M&E Database Manager MPV Potou, Senegal). A similar although not identical sampling strategy was followed in MVP Tiby, Mali, using a very similar survey instrument.

The detailed socio-economic survey carried out by MVP contained the following variable categories. Requested type II 'non-sensitive' microlevel household survey data are indicated in the table: variable types originally contemplated by FunciTree WP6 methodology (*) and additional variables which would complement planned FunciTree analysis (#).

	MVP Survey section / Data type:		
*#	C/ Education	#	M/ Credit, gifts, remittances and savings
*#	D/ Employment	#	N/ Construction of lodging
*#	E/ Subsistence strategies /income sources	#	P/ Household goods
	F/ Utilisation of mosquito nets	*#	R/ Livestock
*#	G/ Land title and value	#	S/ Energy use
*#	H/ Agricultural activities		T/ Water use
*#	I/ Soil management practices		U/ Water treatment
	J/ Food storage and preservation		V/ Sanitation
#	K/ Food, water and energy security		W/ Communication and media
	L/ Consumption and spending		X/ Transport

Source: adapted from FunciTree Technical Brief No. 2 http:// funcitree.nina.no

G. Photos from the Fieldwork

A typical groundnut field and parklands in the background with many Balanzan trees (Faidherbia albida) and some Shea trees (Vitellaria paradoxa)

A field / parkland with the tree species Faidherbia albida, Adansonia digitata and Vitellaria paradoxa (from the left)

Animals grazing / eating crop residuals in a harvested field

An agroforestry parkland with abundant Faidherbia albida

Photo of a a living and a dead Baobab tree

A woman with with dried Baobab powder in plastic bags ready to be sold on the market

A man showing dried Baobab leaves

Two farmers show us the compost to be used as organic fertiliser

Women in Diaraka Wèrè preparing millet

The Mosque in Koïla Markala