Local ecological knowledge of tree-crop-livestock interactions on smallholder farms around Adda-Daoueni in Anjouan, Comoros

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ABSTRACT

Farmers have a wealth of local knowledge and this knowledge have been evolving with changes in the environmental conditions over time. Gaining an understanding of how smallholder farmers utilise this knowledge to manage trees on farm is a prerequisite for agro-ecological intensification in an area with limited landholdings and other constraining factors.

This study explored the local knowledge of smallholder farmers on tree-crop-livestock interactions and tree management to identify the opportunities and constraints to promote agro-ecological intensification through agroforestry around Adda-Daoueni in Anjouan, Comoros. This was done using participatory research tools and a semi structure interview guide. A total of 30 farmers were purposefully selected to represent the whole landscape and were interviewed using the semi structured interview guide. The interviewed farmers included Dahari supported farmers and non-supported farmers and young and older farmers. The essence of this stratification was to see the variation in perception and knowledge about trees and their interactions with crops and livestock.

The outcome of the study indicated that farmers have a rich knowledge of tree-crop-livestock interactions and management practices. Also they had a detailed knowledge of the products and ecosystem services of trees. A similarity in knowledge and practices about fodder and soil fertility management across the two strata was observed. A difference in knowledge and practice associated with erosion control was observed between Dahari supported and non-supported farmers.

The main key findings of the study included 1) A farming system which is heavily dependent on fodder/fertiliser interactions 2) fully established erosion control structures on plots, hence farmers priority have shifted towards trees for fertility, fodder, timber and fruits and 3) the particular need for tree fodder species on plots closed to settlement areas during the dry season. The study equally identified the opportunities and constraints for agro-ecological intensification.

Keywords: Local knowledge, agro-ecological intensification, tree-crop-livestock interactions, participatory research tools, erosion control, tree fodder species.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

BDPA	Bureau pour le Développement de la Production Agricole
CADER	Centre d'appui au Développement Rural
ECDD	Engagement Communautaire pour le Development Durable
GEF	Global environment facility
FAO	Food and Agricultural Organisation
MEA	Millennium ecosystem assessment
NGO	Non-governmental organization
spp	Species

1. INTRODUCTION

1.1 Background

Economic production and consumption opportunities rely on environmental resources. The loss or degradation of environmental resources such as forest has led to global concern. The tropics alone records an annual forest loss estimated at 15.2 million hectares (GEF, 2005). Agriculture has been estimated to cause about 80% of deforestation around the world (Kissinger & Herold, 2012) and this has caused degradation of agricultural lands. It has been currently estimated that land degradation affects 2 billion ha of the global cropping area (38%) (Eswaran et al., 2006), with 83% of the total degraded area affected by erosion (Bai et al., 2008). These problems are mostly felt in Africa, with over 80% of countries being deficient in nitrogen. According to Chianu et al., (2012) nutrient loss has been projected at a rate of 9–58 $kgha^{-1}year^{-1}$ in 28 most affected countries and 61 to 88 $kgha^{-1}year^{-1}$ in 21 other categories.

Anjouan one of the three islands that make up Union of the Comoros (Grande Comores, Moheli) with a high population density of over 600 people/$km^{2,}$ registered the highest deforestation rates in the world between 2000 and 2010 (FAO, 2010). This was caused by the over exploitation of trees for timber, fuelwood for household use but also for the distillation of ylang-ylang essential oil. The fast growing population exert pressure on the limited land resources leading to a marked decreased in landholdings worsened by the weak existing institutions (Doulton et al. 2015). In Anjouan, more than 90% of the population depend on agriculture (Doulton et al. 2015) and farming is the main land use and source of livelihood income. The high rates of deforestation has also been exacerbated by ill adapted and extensive agricultural practices (Scholle, 2012, Doulton et al., 2015), that resulted in severe soil erosion and fertility and severe impact on water resources. Out of the 45 permanent rivers 30 have become irregular in the last 40years after decolonization (ECDD, 2012; Doulton, 2015). The loss in soil fertility led to a decline in agricultural productivity which further pushes farmers to clear new portion of the forest for cultivation (FAO, 2010, Doulton et al. 2015). Small landholdings and competition for land from other human activities makes expansion of agriculture into novel lands a very costly solution to

increasing agricultural productivity in the case where biodiversity protection and the ecosystem goods have been accorded more attention (MEA, 2005). Despite the potentials Comoros has, food security is not guaranteed but considering Niumakele, indicates the possibility of rendering agriculture efficient and productive(Scholle, 2012) This makes traditional intensive agriculture the only means of boosting food production (Pretty et al., 2007) but with negative impacts on the environment (Matson et al., 1997). In order to reverse the trends, effective policies, competent institutions, legal and regulatory frameworks, monitoring mechanisms and knowledge sharing coupled with good practices that can lead to sustainable land management capable of generating global environmental benefits while at the same time supporting local, economic and social development must be promoted (Dimobe et al., 2015).

However, agroforestry has been increasingly considered as a practice that can in a sustainable way intensify agriculture to enhance food security by applying socially and cost effective management methods whilst conserving natural resources (Mbow et al., 2014). But never the less, land sparing for tree establishment might be problematic in the case of small land holdings and insecure land tenure (Mbow et al., 2014). The sustainable agricultural intensification concept is defined "as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services" (Godfray et al. 2010). This increases agricultural productivity while at the same time enhancing ecosystem services (Pretty et al., 2007). In order to efficiently and sustainably improve production farmers need to understand the conditions under which agricultural inputs can supplement or contradict ecosystem services or biological processes that favours agriculture (Settle & Garba, 2011).

Dahari, a local NGO whose mission is to "shape sustainable and productive landscapes with the Comorian communities" has been present in Anjouan since 2008 to improve rural livelihoods while concurrently conserving endemic biodiversity and remaining natural resources by developing an innovative integrated landscape management strategy. Using participative approaches with farmers groups fertility has been recreated in the lowlands and productivity raised to reduce the pressure exerted by agriculture on the upland forests, improve and promote existing agro-ecological practices and the introduction of novel techniques in the areas of action (Doulton et al, 2015). Some of the techniques being promoted include the integration of trees on

farms for erosion control, live fences, mulching, compost manure, market gardening and improved livestock management.

In order to identify the opportunities and constraints to promoting agro-ecological intensification, the local knowledge of farmers under the support of Dahari and those who are not will be will be examined to identify differences.

1.2 Justification of study

Agroforestry have existed in the Comoros particularly Anjouan since colonial times (1886-1975) where trees and food crops were associated together (Scholle, 2012). But paradoxically there is very little or no literature illustrating the significance of agroforestry. The objective of Dahari is in line with the sustainable development goals that seeks to increase land use efficiency, water and agricultural inputs to contribute to environmental objectives while keeping a close link between present yields and the predicted needs to feed the expanding population. The former ECDD project realised the importance of traditional agroforestry as key to agricultural development and as a starting point for innovation (Scholle, 2012). Incorporating trees on farms have been demonstrated to increase incomes of poor families and asset bases, boost farmers yields while complementing crop and livestock production and maintaining or enhancing ecosystem services (Paige, 2015). Limited farm sizes has caused intensive exploitation of the natural resources base leading to decrease soil fertility, erosion and decreased productivity. Food security is threatened due to insufficient agricultural production caused by increasing population. There is therefore need for rapid innovation following the limitation and consequences of extensive agriculture (Scholle, 2012). The use of inorganic fertilisers has been advocated by conventional agriculture to make up for the deficiencies in soil elements, but paradoxically in those most affected countries farmers are too poor to purchase them (Leakey, 2014). Dahari is currently improving and promoting the existing agro-ecological practices to in order to improve the living conditions of the farmers while concurrently sustaining the resource base. There is there need to take into account the local context before implementing actions to the establishment or improvement of agroforestry systems. This study will therefore make use of the local knowledge of farmers to understand

the tree-crop-livestock interactions on small holder farms and advice on which agroforestry practices best for sustainable agro-ecological intensification.

Farmers have been using local knowledge since a long time ago and their knowledge have been changing with changes in environmental conditions. They have a wealth of knowledge about the benefits and constraints of having trees on farms. According to Waliszewski (2005), studies on the local knowledge of smallholder farmers have shown that rural people are quite knowledgeable of the ecological processes taking place in the environment and this knowledge complements scientific knowledge.

In order to understand how agroforestry can be used to achieve agro-ecological intensification, it is important to understand how farmers have been using local knowledge in Adda to manage trees on farms and in the landscape. This will help to identify the opportunities and constraints to promoting agro-ecological intensification.

1.3 Objectives

The general objective of this study was to gain a solid understanding of the local knowledge underpinning tree management to identify opportunities and constraints to promote agro-ecological intensification through agroforestry around Adda-Daoueni.

1.3.1 Specific objectives

The specific objectives in the study area were

i. To explore tree management and agroforestry practices in the landscape around Adda-Daoueni.

ii. To collect and compare local knowledge about key tree-crop-livestock interactions at farm and landscape levels

iii. Analyze farmers' perceptions of opportunities and constraints to sustainable intensification

1.3.2 Research Questions

The research questions included the following:-

i. What are the dominant land use and livelihood systems?

ii. What are the key agroforestry practices within these land use systems)

iii. What are the key products and services provided by trees and their management at different times of the year

iv. What are the variations in farmers' knowledge about soil conservation processes and practices to improve soil fertility and control erosion

v. What are the variations in farmers' knowledge and practices about cattle management? What are the benefits, constraints and trade-offs associated with different management practices including fodder sourcing?

vi. What are the opportunities and constraints for agro-ecological intensification by improving tree-crop-livestock interactions, what role could agroforestry play in this?

1.4 Hypothesis

i. There will be a difference in perceptions and knowledge about trees and their interactions with crops and livestock between farmers who have received project training and those who haven't

ii. There will be a difference in perceptions and knowledge about trees and their interactions with crops and livestock between young and older farmers

2. LITERATURE REVIEW

2.1 Importance of agroforestry

In the tropics and sub-tropics agroforestry constitute a major practice in the rural areas by small holder farmers. *Agroforestry is a set of land use practices that involves the deliberate combination of woody perennials including trees, shrubs, palms and bamboos with agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions among the woody and non woody components (Sinclair, 1999).*

Agroforestry systems can be classified based on the components that are present i.e. associating crops and trees known as silvoarable, animals and trees referred to as silvopastoral and crops, trees and animals as agro-silvopastoral and others(aquaculturte with trees, multipurpose tree lots, apiculture with trees, etc) (Nair, 1993)Agroforestry systems allow the diversification of farm products for home consumption or sources of income and can provide short term and long term environmental and agronomic benefits.

Trees in the landscapes in the tropics provide a good number of important products and services that the people want and need (Schroth & Sinclair, 2003). The products range from firewood, construction materials, fruits, nuts, medicines, fodder, gums and resins to services as shade, wind protection and aesthetics and spiritual values (Scherr, 1995). These products sustains the livelihood of local people, as well as the regulatory ecosystems services such as carbon sequestration, water and air purification and soil conservation and sociocultural values (Weiwei et al., 2014), improved biodiversity and aesthetics (Williams-Guillen *et al.* 2008; *Nair et al*.2009). The role agroforestry play in income generation, food and firewood security to small holder farmers has increasing been accorded attention by scientists and development agencies (Cooper & al., 1996)

The presence of trees in the present day farming system has its origins in two important functions of trees. Firstly their role in maintaining and restoring the physical environment required to sustain agricultural production through the restoration of soil nutrients and energy. And secondly, the role played by different tree products in

helping to sustain rural household economy (Arnold & Dewees, 1997). The smallholder farm system in developing countries depend on trees and other forest products that are indispensable to the functioning of the farm system (Arnold & Dewees, 1997). Agroforestry has for long made use of low cost inputs, biological fixation of nitrogen by shrubs and leguminous trees to restore soils deficient in nitrogen across the tropics and subtropics (Young, 1997). This natural process of biological fixation of nitrogen limit the contamination of rivers by chemicals from the system. Leguminous trees also play an important role in nutrient recycling through their deep and extensive roots that absorb nutrients and return back to the soil surface through leaf litter (Nweta et al., 2007). The rich vegetation cover of agroforestry technologies reduce the speed of flow of runoff and enhance retention and deposit of sediments (Anderson et al., 2009).

A number of reasons have been brought forward to justify the role of agroforestry in biodiversity conservation and they include: a) the sequential or spatial interaction of the different combined components of agroforestry that provide healthy ecological niches to provide the survival of diversified species on the same land unit under management, b) the ecological balance provided by agroforestry system in the heterogeneous and complex unit of land gives a favourable condition for the preservation of germplasm of sensitive species, c) agroforestry has a structure similar to that of a natural forest that act as an ecological buffer, an alternative that is more productive, d) they perform other functions as erosion control and the recharge of water, nutrients recycling, and regulation of microclimate thus inhibiting destruction and degradation and maintaining the ecosystem in a healthy state necessary for the faunal and floral survival (Schroth et al., 2004; Harvey et al., 2006).

2.2 Planting and nurturing of trees on agricultural landscapes

Trees had been maintained or included on farms by farmers from the onset of agriculture (McNeely & Schroth, 2006). They provided fodder, food, firewood, shelter, shade including other goods and services that maintained the proper functioning of the farm. Integrating trees in the farming systems can improve crop yields, reduce use of external inputs, diversify farm outputs and sources of income while at the same time enhancing adaptation and mitigating climate change (Garrity

et al ., 2010). Because tropical farmers are aware of the multiple functions of trees, they have been planting and protecting, selecting and domesticating trees for thousands of years (Schroth & Sinclair, 2003).

Farmers may have different reasons for planting or protecting trees which include need for timber, fruits for nutrition, control against soil erosion, fodder and soil fertility (Schroth & Sinclair, 2003). According to Falconer & Arnold, 1989, farmers' decision to plant trees depend on institutional, social and cultural considerations and land tenure security (Walters *et al*., 1999). Moreover, farmers' willingness to plant trees on farm are influenced by their attitudes to the advantages and disadvantages and the factors that encourages or discourages planting of trees at the farm level (Zubair & Garforth, 2005). Oeba et al., 2012 based on a study in Uganda stated that tree retention on croplands are influenced by availability of markets, harvesting regulation, education, land size, sites, extension services, tree management, monthly income, age, aesthetic and environmental motivation and education. Other studies identified farmers' age, farm size, land value, rate of erosion, tenure system, expected net returns/resource endowment, site description/biophysical factors, and market incentives as factors that influenced tree growing (Valdiva & Poulos, 2009, Arbuckle et al., 2009, Moser et al., 2009, Konyar & Osbon, 1990). However, Aladi & John (2014) in a study in Kogi state in Nigeria identified lack of land, inputs, technical knowhow, time and labour as main constraints that hinders tree planting.

According to a study by Buyinza et al., 2015 in Uganda in the Kyoga region, some local communities planted and retained trees in the croplands while other communities concentrated tree planting around homesteads. One of the reasons for the latter being that they monitor fruits not to be collected by others (thieves). The planting and retention of trees around homesteads is an intentional act (Fernandes & Nair, 1986).

2.3 Sustainable agro-ecological intensification

The importance of ecological processes in agricultural sustainability has long been identified (Stenchly et al., 2011). Despite the role of ecological processes for future global agriculture (Tscharntke et al., 2012), it has not been applied at a level capable of positively impacting global land degradation. Agricultural crop yields and available productive lands are being affected by land degradation and deforestation in the tropics

(Leakey, 2014). In addition to this, poverty has made famers unable to buy inorganic fertilizers and pesticides making agroecosystem restoration the only means of rehabilitating degraded lands (Leakey, 2013). In Africa research has shown that land degradation is the root cause of yields gaps (Mueller et al., 2012, McIntyre, 2009). Traditional farming systems that restores yield limiting soil depletion opportunities are needed to close the existing yield gaps (Sileshi et al., 2008). Studies (Chappel & LaValle, 2011; Tscharntke et al., 2012) concluded that biodiversity and food security can be achieved using suitable practices that maintain functioning agroecosystems.

Cash crop and subsistence food production systems in most part of Africa are being degraded by the increasing demand for food and climate change (Carson et al, 2014). Increasing population growth and consumption of more intensive diets of calories and meat have been projected to double by 2050 (Mueller et al., 2012). This indicates that the food production system will be completely degraded if practices corresponding to the farmers' available resources and agro-ecological zone are not promoted. The importance of agroforestry in multi-functional agriculture has been saluted by many researchers (Sanchez et al., 1997, Udawatta et al., 2011). The result of a 94 peer-reviewed articles from western, southern and eastern Africa shows that global maize yields are positively significant with leguminous trees than unfertilized maize and natural vegetation fallows (Sileshi et al., 2008). When the competition for growth resources between tree and the crop components are effectively managed, the agroforestry system leads to increase in nutrients input, enhanced internal flows reduction in nutrients loses and environmental benefits (Sanchez et al., 1997).

In Africa the main factors that can lead to overcoming of rural poverty of small holder farmers are:-enabling policy environment, reversing soil fertility and depletion and intensification and diversification of land use with high value products. (Sanchez et al., 1997). Agroforestry practices involve diversification of agro-ecosystems at the level of species, result in direct benefits and resilience in specific aspects of agricultural production. Agro-ecological research have proven that biodiversity regulated services such as water regulation, genetic diversity and soil nutrients cycling are important to sustainable intensification at farm and landscape levels (Cardinale et al., 2011)

Incorporating trees into the agricultural landscape can provide a number of ecosystem services and rural livelihoods (Kimaro et al., 2012), and equally pave the way for more diversified and productive farm systems that gives marketable and staple food products (Simons & Leakey, 2014) at different times and ways with different labour requirements (Isabell et al., 2011). Integrating *Faidherbia albida* in evergreen agriculture have been reported to improve the yields of maize from 1 to 2-3t ha^{-1} (Sileshi et al., 2008). In the past 20-30 years the supply of firewood have been improved using agroforestry easing women pain and time required to fetch firewood (Sileshi et al., 2008). According to Minang et al (2012), trees provide a high volume of standing biomass and soils get enriched with carbon through litter fall and root turnover. Using *Gliricidia sepium* in agroforestry systems intercropped with maize have been reported to increase water infiltration efficiency in single maize treatments (Garrity et al., 2010) similar to increased infiltration and reduced run-off in temperate agriculture (Nair, 2011). Findings have shown that intercropping maize with coppicing leguminous trees such as *Gliricidia sepium, Leucaena leucocephala* can improve yields after many years following establishment (Sileshi et al., 2008).

However, decisions about tree planting and suitability of options is very much context specific and there is not much data to help make better decisions and recommendations about sustainable intensification

2.4 Local knowledge

Local knowledge refers to locally acquired understanding based on practical experience and observation compared to indigenous knowledge that denotes values and cultural beliefs (Sinclair & Walter, 1998). Local knowledge has gained importance in sustainable farm development by including the perceptions of stakeholder management practices (Rist and Dahdou-Guebas, 2006). The relationship between applied farm practices and local farming knowledge helps to improve management recommendations (Bandeira et al., 2002). The livelihood of rural people is dependent on their local knowledge to manage the natural resources at their disposal. Under changing circumstances this knowledge evolves based on observations and personal experience from secondary sources (Joshi et al., 2004). There is variation in local knowledge from place to place due to the fact that people's objectives, local

conditions and levels of reliance on natural resources are different (Joshi et al., 2004). In the same agro-ecological zone, some similarity in local knowledge may exist if farmers have same means of observations and farm in the same zone (Joshi et al., 2004).

Local knowledge is very important in managing tree-crop-livestock mixed farming systems because of trade-offs and synergies (Shiferaw et al., 2013). The local knowledge of the people gives an understanding of their system that leads to knowledge gaps being identified for targeted interventions. Documented and analysed Local knowledge from the agroforests in the cocoa growing region of Ghana has been used to determine farmers' preference and indicators in the management of the farms (Isaac et al 2009). Local knowledge of farmers in a study in a community in Nepal on farm fodder sources was used to understand tree-crop interaction and value of fodder (Thapa et al., 1997).

3. METHODOLOGY

3.1 Study site

The volcanic islands of the Comoros are situated in the northern canal of Mozambique between Madagascar and Tanzania on the East African coast. A former French colony, Anjouan is one of the three Islands that today form the union of the Comoros with Grande Comores and Moheli that gained independence in 1975. The fourth island Mayotte of the Comorian archipelago remained a territory under French administration following the results of 1974 referendum. Anjouan has a surface area of 424km^2 and represents the steepest of the 4 islands with a mountain range that reaches up to 1595m (Ntingui mountain) and a network of rivers that carves the steep massive slopes (Felix, 2009). The climate is tropical maritime, marked by local contrasting microclimates caused by the influence of relief on different climatic components especially rainfall (des Comores, 2006). Three major soil types have been classified in the island of Anjouan: - fertile andosols in the high slopes with large rocks of basalts, very fertile and humiferous brown soils that resulted from the accumulation of detrital and colluvium in flat areas and lateritic red soils of very low fertility (Sibelet, 1995).

Adda-Daoueni is a large village in the Niumakele region situated in the south of Anjouan at an altitude of 705m above sea level. In the North Adda, shares boundary with Magnassini, South by the Forest, East and West by rivers Boubouni and Jandza. Based on a census in 2009 by PDL, the population stood at 8262 individuals. The main economic activities are agriculture, livestock breeding and fishing. Agriculture occupies more than 70% of the active population and involves food (banana, taro, cassava, pigeon pea, tomatoes, and cabbage) and cash (Cloves, flowers of *Citrus sinensis*) crops. Livestock rearing occupies 60% of the active population and concerns especially men. Fishing is purely traditional using rudimentary equipment such as outrigger canoe paddles and lines. There is a high incidence of poverty and malnutrition, especially in rural areas where family poverty attains 78.8% caused by rapid population pressure and unstable climate (des Comores, 2006).

The climate is of tropical humid/maritime type with two distinct seasons. The rainy season runs from mid-November to mid-April with an average temperature of 27°C. The rainfall ranges from 2500mm to 3000mm with increase in altitude. Dry season starts from early June to September ending. During this period small amounts of rainfall are also recorded. Many microclimates exist due to the strong altitudinal gradient that causes a large variation in temperatures.

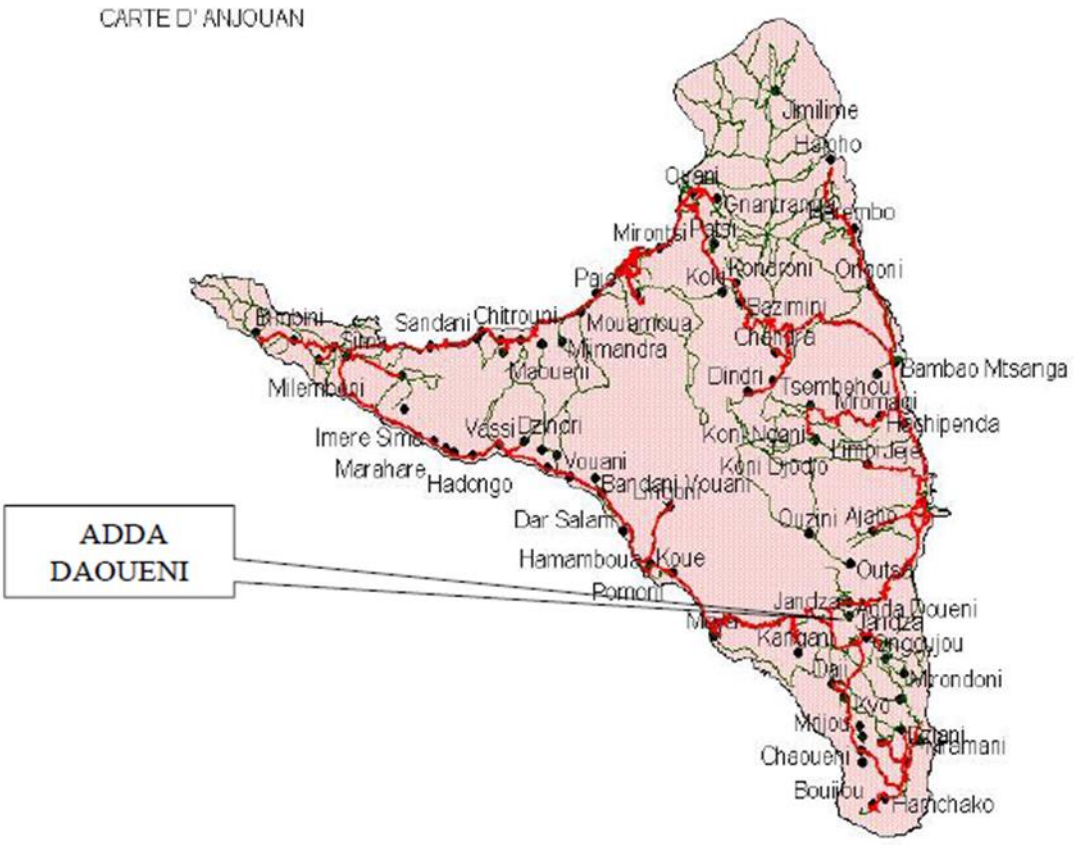

Figure 1: Location of Adda-Daoueni in the Niumakele in the South of Anjouan

3.2 Sample stratification

The interview strata were defined after a series of in depth interviews that explored issues of food security, environmental problems (water, soil, pests, diseases and climate), gender roles, and spatial characterisation, focus group discussions and transect walks in the village across the landscape during the scoping phase of the research.

During the scoping phase, it was observed that age and and project training influence differences in perceptions and knowledge about trees and their interactions with with crops and livestock. Two strata were defined as follows

a) Farmers less than 45 years old defined as young farmers and farmers above 45 years old defined as older farmers.
b) Project trained farmers and those who haven't received any training. Farmers were purposively chosen from each stratum (table 1) to cover different land uses of the landscape.

Table 1: Interviewed number of farmers according to different strata

Categories	**1st Interview**		**2nd Interview**	
	Women	Men	Women	Men
Trained(with cattle)	2	7	1	2
Trained (without cattle)	2	3	1	1
Not trained (with cattle)	5	6	2	2
Not trained (without cattle)	3	2	0	1
Total	30		10	
Young(with cattle)	3	6	1	2
Young(without cattle)	3	2	1	0
Older(with cattle)	5	7	1	3
Older(without cattle)	0	4	0	1
Total	30		9	

3.3 Methodological framework

A simplified knowledge base excel sheet version of the Agro-ecological knowledge developed at the University of Bangor was used to elicit and systematically record local knowledge of farmers on tree-crop-livestock interactions on smallholder farms around Adda-Daoueni in Comoros. Three stages namely: scoping, definition and compilation were followed to elicit local knowledge using guidelines (Walker & Sinclair, 1999).

3.3.1 Scoping

The objective of this stage was to familiarise with the local people and stakeholders have a snap shot view of the study area through key informant interviews, transect walks in the landscape, and focus group discussions. Information gotten during transect walks about the landscape and land uses was used to characterise the main land use and livelihood system.

Key informant interview with Dahari resource persons, champion farmers explored issues of food security, environmental problems, gender roles, spatial characterisation and boundaries of systems.

3.3.2 Definition

Immediately after scoping was completed the research objectives and questions were reformulated and semi-structured questionnaires prepared. An intensive interview (discussion) was conducted (Dixon, 2001) with purposively chosen farmers using the semi-structured questionnaires as a guide.

3.3.3 Compilation stage

The compilation stage involves repeated interviews with the purposively selected informants (Dixon et *al*., 2001; Sinclair & Walker, 1998). The iterative approach permitted informants to be interviewed for the second time for clarification of information initially obtained or probing to elicit more information. A knowledge base was created and the emerging knowledge statements were represented in excel sheets.

3.4 Data collection

The collection of data on local knowledge took place from the 29/05/2016 to 04/07/2016. The data was mainly qualitative and was obtained using semi-structured interviews, focus group discussions, transect walks and feedback session. 30 interviews were conducted with purposively selected farmers from the upper and lower catchments in different strata as indicated in section 2.2. Purposive selection was used to have a more representation of farmers from all parts of the landscape.

3.4.1 Focus group discussion

Five focus group discussions were carried out that involved the participation of farmers in activities such as seasonal farming calendars, land use and livelihood mapping and historical timelines (Figure 2). The farmers' livelihoods strategies and access to resources determined using information from focus group discussions.

Figure 2: farmers were actively involved in drawing the farming calendar of Adda-Daoueni

3.4.2 Transect walks

The transect walks in the landscape took 5 days led by Dahari resource person, extension worker, committed farmers and the research assistant on different days respectively. This took place during the scoping stage and in the course of the interviews. No resource map was available, so the transect routes were purposively chosen to appreciate the presence of crops, cattle on farm and trees. The main route used was through Hamkambui up to chava with the highest altitude recorded (890m) using GPS. From this an overview of the landscape was feasible. During the walks discussions about different trees (vernacular names), the functions of different trees, decreasing fertility of soils indicated by crops on farm and colour of soil, dried up rivers and other problems in the area went on. Also very important during the walks was the history of the formation of village and tree cover change has taken place, how various tree species were tested to control erosion on farms on slopes.

3.4.3 Semi-structured interviews

This was the main tool that was used to elicit knowledge in the first instance from farmers on different tree species, the functions of trees on farms, key products and services provided by trees and their management at different times of the year (utilities of trees), on soil conservation processes and practices and trade-offs associated with different trees and agroforestry practices (Appendix I). Knowledge and practices about cattle management, benefits, constraints associated with different practices and the constraints and opportunities that result from improving tree-crop-livestock interaction. Follow up questions were used in the second interview to probe further to clarify conflicting statements from other farmers and researcher. Farm sketches were equally done alongside interviews to represent the practices and components of the farming system of the farmer in question. Information on all the number of plots owned by the farmers was recorded, the types of trees and crops and the various locations in the landscape (Figure 5). The average time for each interview was an hour but in cases where the farmers were interested and wanted to continue it lasted up to 90 minutes

Figure 3: Interviewing a farmer on his plot. Photo taken by M. Mohamed

3.4.4 Farming calendar

Throughout the fieldwork, information of various activities that takes place in the farm within the year was documented. A specific session was also organised with 5 farmers that included 3 trained Dahari farmers to consolidate and draw a calendar of activities (fields preparation, planting, weeding and harvesting) for each of the main perennial and annual crops (Appendix II).

3.4.5 Historical timeline

This was conducted with 3 locals that have a solid knowledge of the village. The creation of village was narrated (derivation of the name of the village), the factors that led to the changes in tree cover, how farming in the forest started, which deforestation began, the consequences.

3.4.6 Feedback session

The preliminary findings on soil fertility, erosion control and fodder management was presented during the feedback session in the presence of 12 farmers (Figure 4). The objective was to share the findings with them and have their own comments to improve on the data.

Figure 4: Feedback session. Photo taken by author

3.4.7 Data analysis

The local knowledge of farmers was registered as unitary statements into the excel sheets. Data collected using semi structured interview guide was analysed using using excel.

4. Results

This chapter will present the findings from the study area. Characterising the main land use and livelihood system is presented in section 3.1 followed by utilities, products and services of trees in section 3.2. Section 3.3 will present field management and agrosilvopastoral interactions, 3.4 Local knowledge of tree-crop-livestock interactions and agro-ecological intensification. Opportunities, constraints and trade-offs in managing different trees and agroforestry practices will be treated in section 3.5 and finally section 3.6 will enumerate the opportunities and constraints for agro-ecological intensification by improving tree-crop-livestock interactions.

4.1 Characterisation of land use and livelihood system

This section is divided into the local land use classification, agroforestry practices and livelihood activities.

4.1.1 Local land use classification

There are distinct differences between the dominant land uses in the Adda-Daoueni catchment basin area. The distinguished main land uses are found in the upper and lower catchments and are presented as follows

Upper catchment

i. Mountain cloud forests

The dense forest locally referred to as “chitsahani” is located on the summits of the upper catchment and is about 2 hours walking distance from the settlement areas. It is characterised by a diversity of forest trees species with dense canopies under which staple shade tolerant plants such as banana and taro are cultivated. Based on the knowledge of the farmers, the forest performs very important functions in the ecosystem in the provision of goods and services. These included the important role in the water cycle, source of timber used for construction, firewood for household heating and in distilleries of ylang ylang, provides fodder for cattle during the dry months of the year when other fodder sources become scarce.

ii. Degraded forest lands

These are locally known as “mpapani” or “mparoni” and situated in the plateaux of the upper catchment area. Mpapani because Mpapa (*Anthocleista grandiflora*) constitute majority of the remaining native tree species found scattered in fields. Characteristic to this land use are the presence of *Psidium cattleinum* as an invasive species, a new trend of establishing live fences of *Gliricidia sepium* and *Pterocarpus indicus*, mixed cropping of taro, banana or horticultural crops such as cabbage, and tomatoes. Other species found in the area are *Ficus lutea, Gastonia duplicata* but in very low density. Plots sizes here are generally bigger than in all other types of cropland.

The lower catchment

The lower area is mainly made of cropland and a large settlement area with large ‘quartiers’ (neighbourhoods)

a) The cropland in lower catchment is locally further classified into the six following categories:

i. Nangani - This signifies the croplands found below the village towards the ocean

ii. Jumoidago- Croplands located above the village

iii. Keroni- Croplands in the immediate vicinity of the village

iv. Mirerenani- Former unfertile cropland caused by ill adapted farming methods . This cropland used to be very skeletal and unproductive due to decline in soil fertility. Thanks to the tethered cow practice these degraded croplands have regained their fertility and become productive again.

v. Kayansini

Planting fast growing trees species namely *Gliricidia sepium* and *Pterocarpus indicus* as live fences, hedgerows at contour lines was a common practice across all these different cropland types. The following tree species *Moringa oleifera, Tambourissa leptophylla, Ceiba petandra, Gastonia duplicata, Weimania comorensis, Eucalyptus sp, Syzygium aromaticum* and fruit trees *Artocarpus heterophyllus, Artocarpus indica, Citrus sinenis, Anthocleista grandiflora, Persea americana* are common at the

boundaries of farms. In terms of observable differences, the density of fruit trees on cropland increased with the proximity of the settlement areas. *Citrus sinensis, Persea americana, Mangifera indica, Cocos nucifera, Carica papaya Syzygium aromaticum, citrus reticulata* were found scattered on plots in the lower catchment. Mixed cropping of food crops (cassava, taro, sweet potatoes, banana and pideon pea) (See Figure 5), intercropping of cassava and pigeon pea, cassava and pigeon pea rotated with gardening (tomatoes, carrot, cabbage, cucumber and eggplant) are characteristics to this land uses. Crops like cabbage, pepper and carrot are cultivated twice a year meanwhile tomatoes three times per year (see Appendix II for the farming calendar). Nangani cropland is different from other cropland categories in that it has a high density of cloves (Figure 6) (*Syzygium aromaticum*) a perennial cash crop, due a warmer temperature that favours better growth.

Figure 5: Plate A indicates mixed cropping of pigeon pea, cassava, banana, sweet potatoes with clove and jack fruit trees at the boundary in the lower catchment in Keroni, Plate B shows mixed plot of taro, maize, banana, sweet potatoes enclosed in live fence of *Gliricidia sepium* and *Pterocarpus indicus*

Figure 6: *Syzygium aromaticum* (Clove tree) on plots below the village down towards the ocean (Nangani) associated with *Musa acuminata, Cocos nucifera* and *Artocarpus indica*

vi. Bandani- Croplands located in the valleys

The most important practice here was gardening associated with banana and taro enclosed by live fences of *Gliricidia sepium* and *Pterocarpus indicus* for protection of crops from stray animals, fodder, protect the animal from bad weather, maintain humid microclimate and act as wind breaks, act as source of income when shoots are sold.

These fast growing species were also planted at the riverbanks to prevent erosion. Here maize was intercropped with sweet potatoes and cassava. *Moringa oleigfera, Gastonia duplicata, Eucalyptus sp.* were found dispersed on Bandani cropland.

b) Settlement area

Common to all homes is the presence of live fences of *Gliricidia sepium and Pterocarpus indicus* reinforced with bamboo, which equally marks the limit of the plots. The main characteristic of this land use is the occurrence of fruit trees in orchards around these homesteads. The fruit trees found include *Artocarpus heterophyllus, Artocarpus indicus, Mangifera indica, Carica papaya, Persea americana, Musa sapientum.*

4.1.2 Agroforestry practices

Trees and agroforestry practices are managed differently based on these different land uses. From the transect walks, focus group discussions, seven different types of agroforestry practices from the different land use categories were identified (Table 2) and the corresponding tree species on different farms and landscape niches. The variation of these practices is an indication of diverse needs and opportunities around the Adda-Daoueni village. The trees were of native and exotic origin and exotic species were dominant and more diversified than the native species (Appendix I). Different tree species varied with different farms and landscape niches. This was due to the fact that some tree species are more suitable to particular locations and also the functions of trees in locations influenced the farmers' decision to plant or maintain them. Some species were found in all the different land uses either planted or maintained from natural regeneration.

Table 2: Various agroforestry practices identified in Adda-Daouneni

Agroforestry practice	**Tree species**	**Land use category**	**Observation**
Live fences	**Exotic***: Pterocarpus indicus, Gliricidia sepium, Phyllostachys spp*	Croplands in the lower catchment, homesteads	Fast growing multipurpose tree species
Scattered trees in cropland	**Exotic:** Citrus spp., *Syzygium aromaticum*, Pterocarpus indicus, Persea americana, Cocos nucifera, *Artocarpus heterophyllus, Artocarpus indica*	Cropland, forest periphery, Bandani	Used for timber, firewood, shade, flowers and fruit
Boundary planting	**Exotic**: *Artocarpus heterophyllus, Artocarpus indica, Persea Americana, Moringa olifeira Phyllostachys spp., Ceiba petandra, Cinnammomum verum, Citrus sinensis, Coffea Arabica, Eucalyptus sp, Magnolia champaka, Malus pumila, Mangifera indica, Moringa Oleifera, Persea Americana, Pterocarpus indicus, Syzygium aromaticum* **Native:** *Anthocleista grandiflora, Weinmannia comorensis, Chrysophyllum gorungosanum,*	Homestead, cropland	High value trees (Fruit trees, shade, timber)
Terraces	**Exotic***: Pterocarpus indicus, Gliricidia sepium*	Cropland	On slope contours (the gradient of slope was reduced by digging and trees planted on the contours)

Hedgerows	**Exotic***: Pterocarpus indicus, Gliricidia sepium, Magnolia champaka, Phyllostachy spp.*	Cropland, Bandani	on contours on farms on slopes(trees planted directly on contours)
Collection of tree fodder from natural forests	Exotic*: Flueggea virosa*, Mtsongori **Native:** *Anthocleista grandiflora, Aphloia theiformis, Dracaena xiphophylla, Ficus lutea, Phyllantus comorensis, Tambourissa leptophylla*	Forest (Mparoni, Chitsahani)	Most of tree species used as fodder are evergreen, but a few deciduous species resist dry season due the presence of humidity provided by other forest tree species
Orchards	**Exotic:** *Artocarpus heterophyllus, Artocarpus indica, Persea Americana, Citrus spp, Syzygium aromaticum*	Homesteads, Nangani, Bandani	For fruits, flowers

4.1.3 Livelihood activities

Farming was the dominant livelihood activity and involved cultivation of the cropland in the lower and upper catchment areas, forests and valleys (Bandani) in the landscape (see Figure 7 below). In addition to dairy cows, goats, sheep and chicken were also present on farms in Adda**.** A tethered cow was central to the farming system for soil fertility and fodder was cut and carried to the plot by all household members from all parts of the landscape.

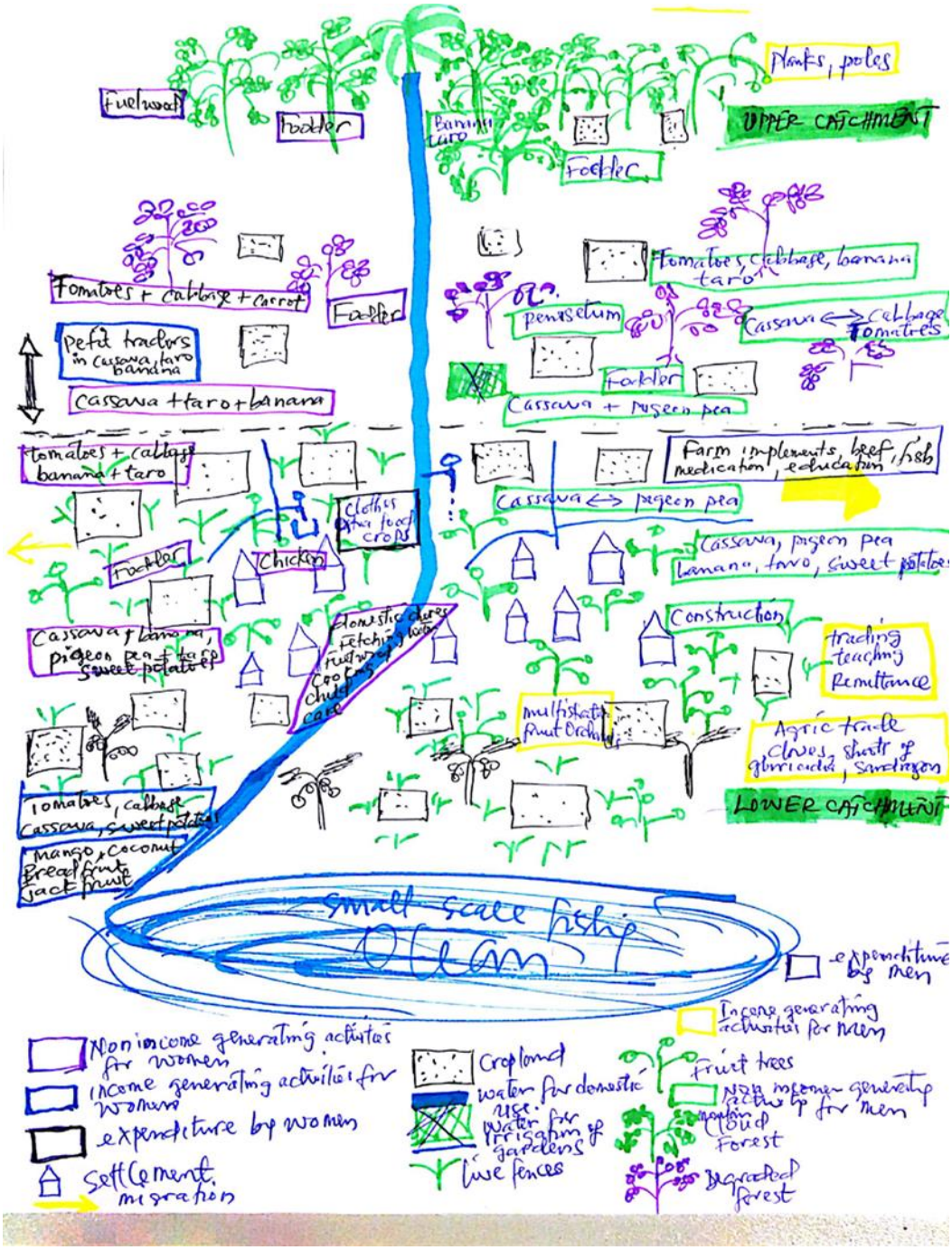

Figure 7: Livelihood representation at catchment level drawn by the author

Crop cultivation in the upper catchment was done mainly for subsistence. In the lower catchment area, above the village (Jumoidago) garden crops (e.g. tomatoes, cabbage) and below the village towards the ocean (Nangani), Syzygium *aromaticum* cultivated as a cash crop mainly for commercial purpose. *Artocarpus heterophyllus, Artocarpus indica and Cocos nucifera* are fruit trees associated with all cropland in the lower catchment purposely for household consumption but also excess sold.

Men play a central role in the farming system as they are responsible for preparing and feeding tethered cow on farm with fodder transported by all members of household, fell trees and transport timber planks for construction or maintenance of the house, and plant, manage and harvest timber, tree crops and some annual crops such as taro, cassava. But the annual crops are mostly cultivated and managed by women. Women sold tree products harvested by their husbands or elderly boys in the markets, they assist in ploughing, weeding and feeding the cattle in the absence of men. The male dependents contribute to weeding, soil tillage, transport fodder and harvesting of crops (Figure 8). The female dependents equally assisted the parents on the farm to till the soil, weed, transport fodder and sell harvested tree crops (*Artocarpus indica, Citrus reticulata, Cocos nucifera*) and food crops (cassava, green banana, pigeon pea, tomatoes and nsososti) on road sides in the village.

The farming system is composed of crops mostly intercropped, livestock (tethered dairy cow as the central element and sometimes other small ruminants and poultry) and a diversity of it trees used in live fences, hedgerows on contours, scattered on plots and boundaries with a large diversity and frequency of fruit trees in all landscape niches. Plots are privately owned and sizes varies from 0.0075 to 1 hectare. On the average, farmers own 4 plots dispersed in the landscape. Most of the farmers had plots in the lower catchment near the village, towards the valleys, below the village, and also owned croplands in the upper catchment in the degraded and dense forest. Farms on the slopes are distinguished from those on the flat surface (Figure 9) by the presence of hedgerows on contours but live fences are found in all. Crops are intercropped on the same plots in association with fruit trees and other valuable trees. The main crops cultivated are:-garden crops (tomatoes, eggplant, cabbage, carrot) and food crops

(pigeon pea, taro, banana, cassava, sweet potatoes, Irish potatoes and maize). The crops are cultivated at different times of the year and some crops cultivated up to 3 times per year (see Appendix II for farming calendar).

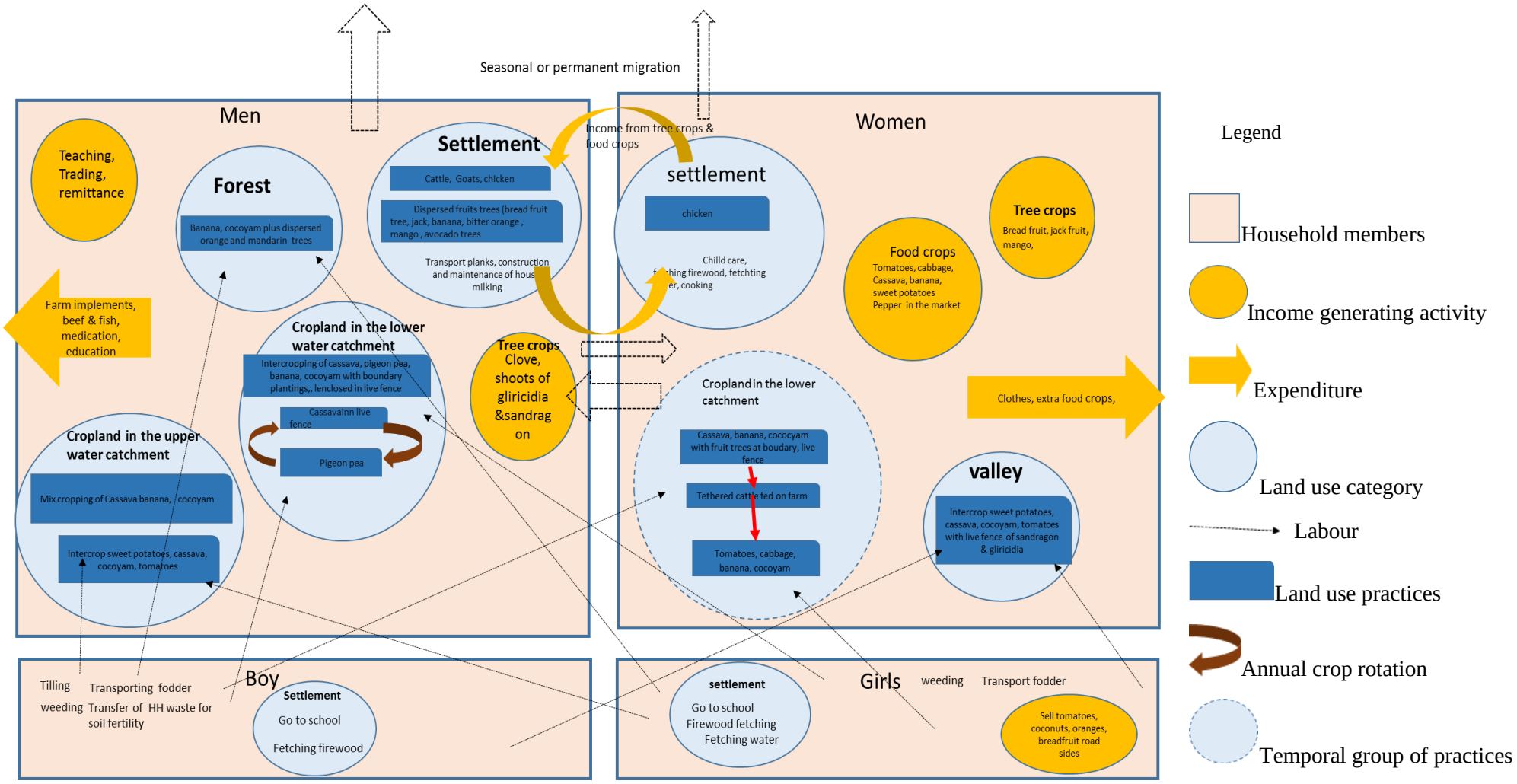

Figure 8: Land Use and Livelihood diagram of a typical farming household in Adda-Doueni, catchment

Figure 9: Plate A, cropland on a flat surface in Keroni, Plate B, cropland on a slope in the Jumoidago

4.2 Utilities, products and services of trees

Depending on the needs of the farmer certain species of trees were planted or retained on farm. Provisioning and environmental services of trees were highly valued by the farmers. Table 3 below shows the tree species recorded during the study along with their utilities, products, services and the different locations in which there were found. Trees provided key products which were either sold to raise the income levels of the households or used directly. A majority of the trees identified performed multiple functions.

Table 3: Tree species discussed with farmers around Adda with utilities, services and products of tree species

Botanical Name	Local Name	Origin	Products							Environmental/Agronomic services					Common locations on farm			
			Fuelwood	Fodder	Timber	Fruits	Medicine	Charcoal	Food	Windbreaks	Soil Erosion control	Nutrient cycling & fertility	Humidity & shade	Source of Water	Cropland	Boundaries	Forest	homestead
Pterocarpus indicus	Mbarti	Ex.	X	X	X						X	X				X		
Tambourissa leptophylla	Mbwomo	N	X		X								X		X	X		
Coffea arabica	Mcafe	Ex.				X										X		
Cinnammomum verum	Mdaracine	Ex.					X									X		
Piper sp	Mdawa	N					X										X	
Artocarpus heterophyllus	Mfanassi	Ex		X					X	X			X			X		X
Chrysophyllum gorungosanum	Mfuantsi	N			X							X	X			X		
Gliricidia sepium	Mgliricidia	Ex.		X							X	X				X		
Eucalyptus sp	Mkalkisse	Ex.	X		X											X		
Syzygium aromaticum	Mkarafu	Ex.	X		X										X	X		
Weimania comorensis	Mkindrinkindri	End.	X		X			X		X		X	X			X	X	

Citrus reticulata	Mkinga	Ex.				X								X	X		
Citrus reticulata	Mlandsie	N				X								X	X		
Litchi sinensis	Mlechi	Ex.				X									X		
Mangifera indica	Mmanga	Ex.	X	X		X									X		X
Cocos nucifera	Mnadzi	Ex.				X								X	X		
Anthocleista grandiflora	Mpapa	N	X	X	X			X				X	X		X	X	
Khaya comorensis	Mpori	End.			X					X		X	X		X		
Ocotea comorensis	Mrobwe	End.			X											X	
Pyllantus comoriensis	Mroundrasole	End.		X												X	
Citrus sinensis	Mroundra demu(bitter)	Ex.	X			X								X	X		
Citrus sinensis	Mroundra ngizi(sweet)	N				X								X	X		
Spondias mombin	Msakua	Ex.				X									X		
Jatropha curcas	Msumu	Ex.													X		X
Gastonia duplicata	Mtrengemoi	N								X					X		
Khaya comorensis	Mtrondro	End.			X					X		X			X	X	
Psidium cattleinum	Mtsongoma	Ex.				X										X	
Flueggea virosa	Muhamba	N		X	X											X	
Ficus lutea	Mvuvu	N		X									X		X		
Moringa oleifera	Mvunge(wachizungu)	Ex.			X							X			X		
Moringa sp	Mvunge	N			X	X						X			X		
Psidium guayava	Mvwera	Ex.				X									X		
Nuxia pseudodenta	Mwaha	N															

Persea americana	Mzavoka	Ex.				X	X			X					X	X		X
Citrus limon	Mlimu	Ex.				X									X	X		
Dracaena xiphophylla	Mtsanga	N		X		X											X	
Malus pumila	Mpomo	Ex.				X									X	X	X	
Citrus hystrix	Mkomvava	Ex.				X									X	X		
Averrhoa bilimbi	Muaju	Ex.				X									X	X		
Averrhoa bilimbi	Muaju	N				X									X	X		
Ceiba petandra	Mpambafuma	Ex.		X	X					X			X			X		
Magnolia champaka	Shampaka	Ex.		X	X											X	X	
Aphloia theiformis	Mfantrabo	N					X									X	X	
Strychnos mitis	Mkomolasua	Ex.						X									X	
Annona muricata	Mkonokono	Ex.				X	X									X		
Artocarpus indica		Ex.		X		X				X						X		X
Phyllostachys sp	Bamboo	Ex.		X			X									X		
Myristica fragrans	Mkunku manga	Ex.				X											X	
	Mewani					X											X	
	Mtrule					X											X	

Ex. refers to exotic, End. = Endemic, N= native

4.2.1 Key tree products

The key tree products included firewood, timber, food (fruits, leaves, condiments), medicine, fodder for livestock, charcoal, dead fence and source of revenue (sales of fruits and timber). Fruit trees, fodder trees, timber trees and have been discussed below as major ones.

4.2.1.1 Fruit trees

The study identified 25 species of fruit trees in the Adda- Daoueni area (Table 3). In the study area, exotic fruit trees were ubiquitous and present with a high diversity of species on almost all cropland types in the lower catchment (jumoidago, nangani, kayansini and keroni, had *Citrus sinensis, Artocarpus heterophyllus, Artiocarpus indica, Persea americana , Mangifera indica, carica papaya* trees and the density and diversity increases on plots towards the settlement area. The most diverse number of tree species was observed in the homestead's orchards. *Cocos nucifera* were found mostly in farms towards the ocean (nangani). *Psidium cattleinum, Tamarindus indica* were mostly observed on farms in the plateaux and of the upper catchment area. The diversity of fruit trees permit fruitification at different periods of the year (Table 4). Some fruit trees like *Artocarpus indica* does not only produce fruits but the tree was equally used to produce mortar and pistle which fetches more income for the households. Also the leaves of *Cocos nucifera* were used for house construction (Figure 10) and making of mats. *Citrus Sinensis* (sweet and bitter) fruit trees are planted or maintained on plots for their flowers and oranges. The flowers are exported for the distillation of essential oils. The bitter oranges are equally useful because the juice is used as a condiment.

Table 4: Fruiting period of different fruit trees within the year in Adda-daoueni

Fruit trees		**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Ananas comosus										x	x	x	
Annona muricata							x	x	x	x			
Artocarpus heterophyllus		x									x	x	x
Artocarpus indica				x	x	x							
Averrhoa bilimbi							x						
Carica papaya	*Green*	Harvested all year round											
	Ripe						x	x	x				
Citrus aurantium							x	x	x	x			
Citrus hystrix							x	x	x	x			
Citrus reticulate(Ex)					x	x							
Citrus reticulate(N)						x	x	x	x				
Citrus sinensis	*Flower*									x			
	Oranges				x	x	x						
CitrusAurantifolia										x	x		
Cocos nucifera		Harvest all year round but abundant in October and November(Kashkasi)											
Litchi sinensis												x	
M'boiramati		Harvested all year round											
M'sossoti		Harvested all year round											
Malus pumila					x								
Mangifera indica		x	x	x	x	x				x	x	x	x
Musa paradisiaca		Harvested all year round											
Persea americana				x	x								
Psidium cattleinum		x				x	x						x
Psidium guayava						x	x						
Spondias mombin						x	x						
Sysydium aromaticum								x	x	x	x	x	x
Tamarindus indica		Harvested all year round											

Figure 10: Plate A, a house constructed using fronds of Cocos nucifera, Plate B, jack tree (Artocarpus heterophyllus) bearing fruit

4.2.1.2 Fodder trees

Since the tethered cow is central to the farming system and there is a lot of pressure on land for food crops, farmers depended on forest tree species for fodder during the six months of dry season to feed their livestock. Most of these trees were found in the mountain cloud and degraded forests and the rest planted on croplands. The following tree species *Anthoclesita grandiflora*(mpapa*)*, *Ficus lutea*(mvuvu), Mtsongori, Mbuishi, *Phllantus comorensis*, *Aphloia theiformis* (mfantrobo), *Flueggea virosa* (Muhambo) and *Dracaena xiphophylla* (mtsanga*)* were species found to grow naturally in the Mountain cloud and degraded forests (mpapani) identified as important sources of fodder for livestock. Few *Ficus lutea* trees were found dispersed and maintained on few farms. Anthocleista grandiflora were found in some plots planted at the boundaries by farmers. Other trees like *Gliricidia sepium* and *Pterocarpus indicus* are being promoted by Dahari for fodder and as control against erosion. They were planted as hedgerows at contour lines and live fences around cultivated farms. They have been integrated in most farms in the lower catchment and around settlements. Fruit trees like *Artocarpus indica* and *Artocarpus heterophyllus* were equally identified as important sources of fodder. They were planted at the boundaries of most farms in the croplands in the lower catchment and few dispersed on farms.

4.2.1.3 Timber trees

Due to the durability of certain tree species and the market value of timber, farmers integrated these on their farms. They are used in the construction or maintenance of their houses and moreover sell to increase the revenue level of the family. Some of the timber species trees found on farmers' plots were *Tambourissa leptophylla, Weimania comorensis, Ocotea comorensis, Anthocleista grandiflora, shivundze, Khaya comorensis, Chrysophyllum gorungosanum, mvunge, Gastonia duplicate, Ceiba petandra, Magnolia champaka.* Because of limited availability of timber at all times, *Syzygium aromaticum* and *Pterocarpus indicus* trees are used as poles in construction in the case where they become very tall. They are advantageous because of their fast rate of growth.

4.2.1.4 Medicinal trees

Some trees species were identified in the study area to have medicinal value (see table 3). The leaves of *Persea americana* and mdaracine were used in tea for blood cleansing and treatment of cough in humans. Based on knowledge of farmers, *Persea americana* are widely used and this was mentioned by all the farmers. Bamboo leaves are used to excite cattle for mating. The leaves of *Annona muricata* were used to treat nausea and Mewani treats body pains. The leaves of mtrule are used in tea, hot water for body massage to ease pains. *Persea americana* was recorded on farms dispersed and on boundaries in the croplands and in orchards in homesteads. Phyllostachys sp was observed on farms above the village at contour lines to reinforce the live fences around homesteads. All the medicinal tree species excluding *Persea americana* and *Phyllostachys sp* were found in the forest only.

4.2.1.5 Firewood

A number of trees as were identified used as firewood (see Table 3). The time invested in fetching firewood is variable depending on the location in the catchment. Can take 20 mins to fetch from the cropland around homesteads and up to 7 hours from the mountain cloud forest. Farmer's knowledge indicates preference of tree species used as firewood. They were aware of the duration of the wood takes to burn or the how long the charcoal burns (30 minutes to 3 hours), the species that burn so well even when the moisture content is high.

Amongst these species, recorded *Moringa olifeira, Weimania comorensis, Eucalyptus sp* were found in most farms in the landscape. *Moringa oleifera* is much loved for its high energy content and longer burning time. The trees are not primarily planted on farm for firewood but used on condition when trees are felled for timber (*Tambourissa leptophylla, Weimnia comerensis, Eucalyptus sp, Anthocleista grandiflora, Mvunge, Hadza, Filao*), aged or dry up (*Sysygium aromaticum, Citrus sinensis*), pruned before crop cultivation (*Mangifera indica, Pterocarpus indicus)* or when generally brought down by wind.

4.2.2 Environmental services

The environmental services identified were nutrient cycling and soil fertility, soil erosion control, windbreaks, humidity and shade and role in the water cycle. Only the main services are discussed below

4.2.2.1 Soil erosion control

Based on farmers' knowledge, the roots of trees open up the soil thereby increasing infiltration of water into the soil. This reduces the water flowing on the soil surface. They also mentioned that trees act as wedge against soil being carried down the slope by rain water. Out of the total number of informants interviewed, 11 farmers provided information on tree and other species used in erosion control (Table 5). Results based on local knowledge show that the most important tree species used in erosion control is *Gliridia sepium* and *Pterocarpus indicus*. Some farmers further integrate *Pennisetum purpureum, Brachiria decumbens, Phyllostachys spp* and banana to increase the effectiveness in erosion control.

Table 5: Number of farmers that use different tree species for soil erosion control

Tree species	**No. of farmers that planted on farm**
Gliricidia sepium	8
Pterocarpus indicus	8
Banana planting	4
Pennisetum purpureum	2
Phyllostachys spp.	1
Magnolia champaka	1

Mangifera indica	1
Mrouva	1

4.2.2.2 Humidity and shade

Based on local knowledge of the farmer, tree canopies provide shade to the farm that enable crop growth during the dry season. The food crops (banana, taro and cassava) very important for diet in the study area profit from the humidity and shade provided by trees. Information on humidity and shade was provided by 11 informants. The results show that tree species such as *Moringa oleifera, Artocarpus heterophyllus, Anthocleista grandiflora, Khaya comorensis, artocarpus indica and Mangifera indica* provide shade and humidity to banana, taro and other crop s(table 6). Also leaf litter from trees provide mulch that conserves soil humidity.

Table 6: Farmers' perception of the positive functions different tree species play in soil moisture conservation on different crops

Tree species	Banana	Taro	Cassava	Crops in general	Total number of farmers
Moringa oleifera	**2**	**2**		**6**	**10**
Artocarpus heteropyllus	**4**	**3**		**2**	**9**
Weinmannia comorensis	**2**	**2**	**1**	**3**	**8**
Anthocleista grandiflora	**1**	**1**		**4**	**6**
Khaya comorensis	**2**		**1**	**1**	**4**
Artocarpus indica	**1**	**2**		**1**	**4**
Mangifera indica	**1**	**2**		**1**	**4**
Gastonia duplicata	1		1		2
Eucalyptus sp	1	1			2
Chrysophyllum gorungosanum	1	1			2
Tambourissa leptophylla	1	1			2
Citrus spp.				2	2
Annona muricata	1	1			2
Persea americana	1				1
Ocotea comorensis				1	1

Ficus lutea				1	1
Annona muricata					0
Mshimbui				1	1

Despite the positive effect of trees in providing moisture conducive for growth of crops, there equally exist some negative effects of shading and competition at root level on crops. Knowledge was gotten from 16 farmers and presented table 7 as below. *Citrus sinensis, Syzygium aromaticum, Pterocarpus indicus and Litchi sinensis* are major trees in the study area that negatively affect crops.

Table 7: Farmers' perception of the negative function of shading by different tree species on different crops

	Taro	**Cassava**	**pigeon pea**	**Banana**	**Tomatoes**	**Cabbage**	**Irish potatoes**	**Sweet potatoes**	**Total no. of farmers**
Citrus spp.		4	2	2	1	1	1		**11**
Syzygium aromaticum	1	4	2		1	1			**9**
Pterocarpus indicus		4			2			1	**7**
Litchi sinensi	1	1	1	1	1	1	1		**7**
Artocarpus heteropyllus					2	2			4
Tambourissa leptophylla					2				2
Persea americana		1							1

4.2.2.3 Nutrient cycling and soil fertility

Farmers understood very well the role of trees in nutrient cycling and fertility. They identified the various species of trees that improve soil fertility. Based on the knowledge of 22 farmers, the rate of decomposition of leaf litter and the biomass quantity determine largely how good a tree species is in improving soil fertility. Table 8 below summaries the major fertilising tree species. They identified *Pterocarpus indicus, Gliricdia sepium* and *Weinmannia comorensis* as the species with leaves that decompose rapidly and constitute best fertilising species. Farmers' knowledge equally

suggested a species like *Artocarpus indica* as non-fertilising tree species because it's leaves take a very long time to decompose.

Table 8: Trees species most mentioned by farmers as having positive soil fertility benefits (in decreasing frequency)

Tree species	**Number of farmers (des Comores, 2006).**
Pterocarpus indicus	**13**
Gliricidia sepium	**9**
Weinmannia comorensis	**8**
Anthocleista grandiflora	**5**
Artocarpus heteropyllus	**4**
Artocarpus indica	**4**
Persea americana	**4**
Chrysophyllum gorungosanum	3
Ocotea comorensis	2
Malus pumila	1
Mangifera indica	1
Moringa oleifera	2
Tambourissa leptophylla	1

4.3 Local knowledge about tree management

Based on the knowledge of farmers, tree management practices were meant to maintain, improve growth and development functioning of different components on the farm and to reduce competition with crops. The different practices identified by farmers were nurturing, planting, cutting and pruning.

4.3.1 Nurturing trees from natural regeneration

These were the tree species identified that farmers maintained from natural regeneration on the croplands. They are either are selected and maintained dispersed in the cropland or in the boundaries for different reasons. Table 9 shows the different species that were nurtured on the cropland. Information was provided by six farmers.

Table 9: Tree species most commonly nurtured on cropland from natural regeneration

Tree species	**No. of farmers**
Anthocleista grandiflora	3
Gastonia duplicata	3
Khaya comorensis	2
Tambourissa leptophylla	2
Chrysophyllum gorungosanum	1
Citrus sinensis	1
Nuxia pseudodenta	1

4.3.2 Tree planting

These are trees that were planted on the cropland by farmers for erosion control, timber, fuelwood, fruits, fodder, and cash crops. Information on tree plantation was provided by 25 farmers in the study area and presented below in table 10.

Table 10: Trees most commonly planted by farmers in the Adda-Daoueni landscape

Tree species	**No. of farmers**
Pterocarpus indicus	**11**
Moringa Oleifera	**10**
Gliricidia sepium	**9**
Syzygium aromaticum	**8**
Citrus sinensis	**7**
Artocarpus indica	**5**
Weinmannia comorensis	**4**
Phyllostachys spp.	**4**
Persea americana	3
Coffea arabica	2
Eucalyptus sp	2
Mangifera indica	2
Artocarpus heterophyllus	2
Ceiba petandra	1
chrysophyllum gorungosanum	1
Cinnammomum verum	1
Anthocleista grandiflora	1
Magnolia champaka	1
Malus pumila	1
Msaki	1

Terminalia catappa	1

4.3.3 Roots pruning

The farmers understood well there is below ground competition between roots and tubers like cassava. Their knowledge suggest they fully understood the difference between deep and shallow root systems associated with tree species and which ones compete with crops. They managed this by cutting the roots of the trees before cultivation each season. The trees managed this way in the croplands are presented in Table 11 below.

Table 11: Trees subjected to root pruning on cropland mentioned by farmers in Adda

Tree species	**Cassava**	**No. of famers**
Gliricidia sepium	**8**	**8**
Pterocarpus indicus	**4**	**4**
Mangifera indica	**1**	**1**
Moringa Oleifera	**1**	**1**

4.3.4 Branch pruning

Farmers had deep explanatory knowledge about the negative effect of tree shade on crops across the landscape. Pruning was a key field preparation activity and was done before crop cultivation starts to reduce competition with crops. Below in table 12 are the tree species in croplands in the landscape that are repetitively subject to pruning to limit light competition between crops. The major source of fuelwood from croplands was obtained from pruning branches.

Table 12: Trees species regularly pruned in the cropland mentioned by farmers in Adda

Tree species	Crops	Cassava	Tomatoes	Cabbage	Sweet potatoes	Pigeon pea	Total No.
Artocarpus heterophyllus		1	1			1	3
Citrus sinensis		1	2	1			4
Gliricidia sepium	1		1				2
Khaya comorensis			1				1
Moringa Oleifera			1		1		2
Pterocarpus indicus	1	2					3
Weinmannia comorensis	1						1

4.4 Field management and agrosilvopastoral interactions

4.4.1 Field preparation and the central role of the tethered cow

i. **Field preparation**

Generally field preparation takes up to 3 months (figure 11). The first step involves the clearing of shrubs and other grasses in the case of a short fallow. Secondly the cleared plot or plot previously cultivated is ploughed using a local implement. First ploughing is very important for plots on the slopes. After ploughing for the first time the tethered cow is introduced and rotated on farm until whole farm is covered. The manure is manually spread to other parts of the farm where the tethered cow could not reach. The ploughing permits proper mixing of dung with soil and prevents dung swept away during rain as most farms are on the slopes. First ploughing distinguishes preparatory activities on plots on slopes and flat areas. When cow is removed, the farm is allowed for two weeks to permit complete decomposition of dung. The final tilling is done and mounds produced to permit deep rooting of tubers.

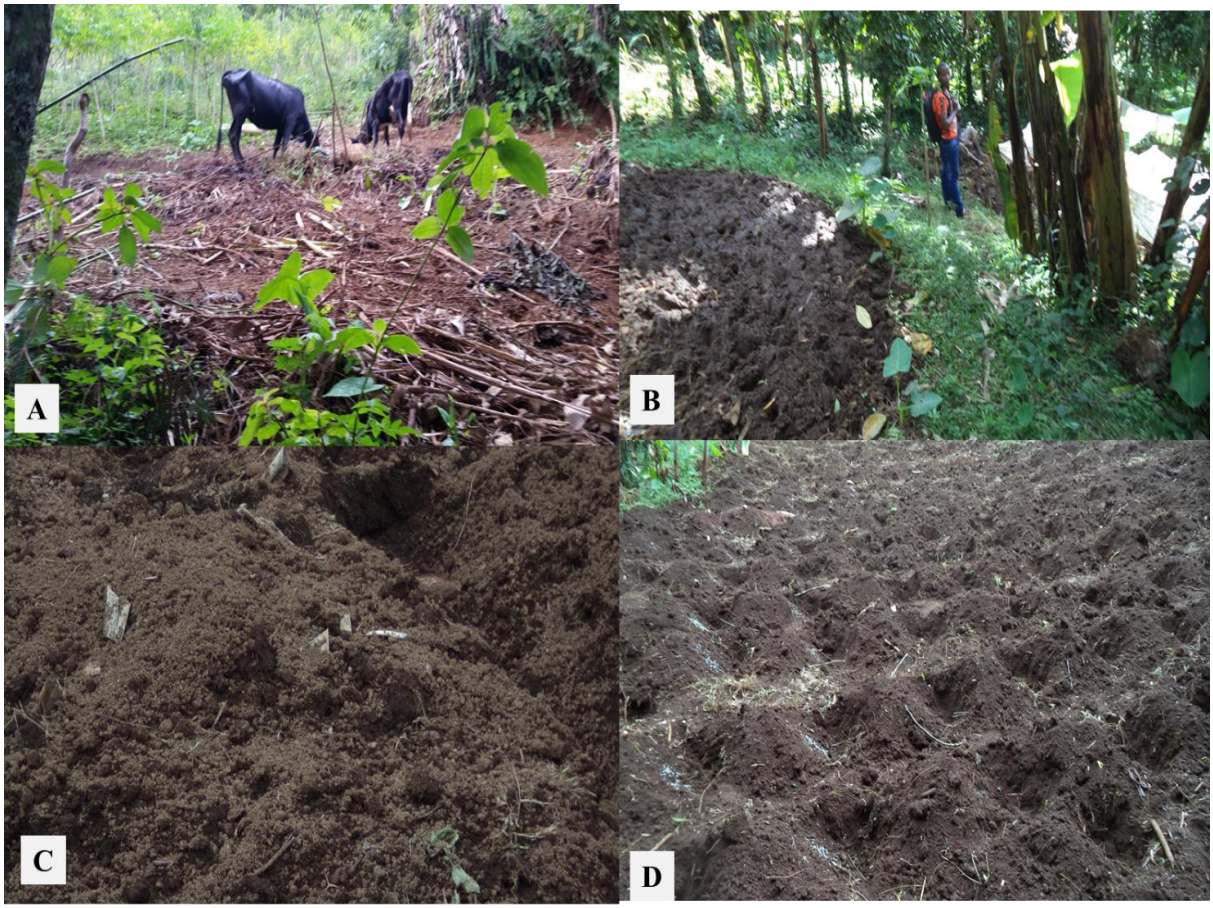

Figure 11: Plate A: Tethered cow on plot. Reddish-brown soil indicating decline in fertility; Plate B Cow removed and plots allowed for dung to decompose; Plate C: Plot hand ploughed after complete decomposition of cow dung; Plate D. Cropland ready for plantation, Presence of organic manure indicated by dark soil.

iii. The tethered cow practice

Due to the demographic pressure on land and decrease in farm size, fallows were increasingly rare and their duration shorter, cattle rearing has changed from the extensive traditional system that took advantage of fallow as grazing land, to the present system wherein the cattle are tethered on a defined plot and cut fodder from a range of sources (forests, cropland, kitchen waste) is carried and fed to the cattle. Others reasons have equally led to this that include decreasing yields due to decrease in soil fertility of plots, increased destruction of crops in fields by grazing animals, and lack of wood to construct fences around plots..

The tethered cow now provides the main source of soil fertility in the system. Generally, the cows are tethered and rotated on farm for a period of up to 3 months on

different parts of the plot depending on the overall size of the farm and the number of cows. The types of crops to be cultivated determine the duration of time a cow is stationed in a particular sub-plot

4.4.2 Livestock nutrition and fodder management

There exist different sources of fodder for livestock at different times of the year (table 12). The important sources are natural graminae from croplands in the upper and lower catchments, cultivated graminae (*Tripsacum laxum, Brachiaria decumbens and Pennisetum purpureum*), crop residues, kitchen waste (banana and cassava peelings) and planted or natural fodder trees. Usually harvested transported over long distances. Can take an hour to harvest from nearby crop land and up to 4 hours from the forest (see Figure 12). All the above mentioned sources excluding fodder trees were available only during the rainy season (kashkasi) and transition periods between dry and rainy season (kusi). Fodder trees and banana stem remains the most important and only available source of fodder for livestock during the dry season (shilimoni). Table 5 shows fodder sources and availability in the landscape throughout the year. Most of fodder during the dry season comes from the forest (degraded and mountain cloud forest) and the rest from from fruits trees (*Artocarpus heterpphyllus* and *Artocarpus indica*) and live fences (*Gliricidia sepium* and *Pterocarpus indicus*) on crop fields and around homesteads.

Fodder trees used during the dry months from June to October as indicated in the table 4 are evergreen and semi deciduous. The knowledge of farmers suggest that *Pterocarpus indicus, Artocarpus indica, Artocarpus heterophyllus, Persea Americana*(wild type), *Ficus lutea* and *anthocleista grandiflora* are the major tree species used during this period in deceasing order.

Figure 12: Transporting fodder is a key activity for all household members in the Adda catchement. Plate A: a child transporting sweet potatoes residues, Plate B shows a farmer looping leaves of Gliricidia sepium; Plate C Researcher helping a farmer with his load of Gramineae harvested from the Jumoidago plots (above the village); Plate D: a child transporting banana stem as fodder and water source

Table 13: Sources and availability of fodder throughout the year in Adda-Doueni

Tree Species	Source	J	F	M	A	M	J	J	A	S	O	N	D
Anthocleista grandiflora	MC						x	x	x	x			
Pterocarpus indicus	PF						x	x	x	x			
Gliricidia sepium	PF						x	x	x	x			
Bamboo	PF							x	x	x			
Artocarpus indica	PF							x	x	x			
Ficus lutea	MC				x	x	x						
Musa sapientum	PF				x	x	x	x	x				
Mtsongori	MC						x	x	x	x	x		
Mbushi	MC							x	x	x	x		
Phyllantus comorensis	PF							x	x	x	x		
Flueggea virosa	MC							x	x	x	x		
Dracaena xiphophylla	MC							x	x	x	x		
Tambourissa leptophylla	MC								x	x	x		
Mfantrabo	MC												
Grasses													
Kunu	HN	x	x	x	x	x	x						
Pennisetum purpureum	HN	x	x	x	x	x	x						
Brachiaria decumbens	PF	x	x	x	x	x	x						
Tripsacum laxum	PF	x	x	x	x	x	x						
Commelina benghalensis	HN	x	x	x	x	x	x						
Shitatsi	HN	x	x	x	x	x	x						
Kangoju	HN	x	x	x	x	x	x						
Shifundankole	HN	x	x	x	x	x	x						

CN=Harvested gramineae and shrubs from uncultivated land and cropland,

MC= Mpapani/Chitsahani, Planted on farm=PF

4.5 Local knowledge of tree-crop-livestock interactions and agro-ecological intensification

The management processes and practices of trees, crops and livestock by smallholder farmers is geared towards stabilising, promoting development and functioning of the farming system. Some of the management activities recorded or observed in the study area included soil erosion control, soil fertility and cattle management and fodder.

4.5.1 Knowledge and practices about cattle management and fodder

The key finding indicates there is a high need for tree fodder species on plots closed to the settlement area during the dry season.

One of the major problem encountered in cattle management is the availability of fodder during the dry months of the year from July to October. During this period the forest (Degraded and mountain cloud forest) serves as an important source of fodder. They equally know exactly what species they need as they access these from the forest. Farmers have a detailed knowledge of fodder species and based on this knowledge, fodder species were classified into 3 categories (Table 14) as follows: -

- High quality fodder- this type of fodder increases milk production and generally makes cattle stronger
- Low quality fodder-this type reduces milk production, makes milk bitter, equally makes cattle weak or have diarrhoea when fed to cattle without associating with other fodder species. E.g the young leaves of *Gliricidia sepium* renders milk bitter, *Commelina bengalensis* gives diarrhoea to cattle.
- Standard fodder- this has no negative effect on cattle or milk quality and quantity.

It was noticed that older farmers have richer and detailed knowledge about different categories of fodder than the younger farmers. This was observed in the case where 4 older farmers stated that it were only young leaves of *Gliricidia sepium* makes milk bitter as opposed to the common knowledge that *Gliricidia sepium* leaves in general make milk bitter.

Table 14: Different categories of fodder based on local knowledge of farmers in Adda

Species	**Quality**			**Comments**	**Number of sources**
	High	Standard	Low		
Dracaena xiphohylla		x			
Pterocarpus indicus			x	Reduces quantity of milk production if given alone to cattle	15
Gliricidia sepium			x	Makes cow weak and milk bitter	15
Commelina bengalensis			x	Causes diarrhoea to cattle	12
Artocarpus indica			x	Worst fodder can provoke anthrax in cattle due to presence of small insects on leaves	11
Kangaju			x	Makes milk very bitter	8
Pennisetum purpureum(over mature stems)			x	Wounds cows mouth or break the teeth	7
Dindrolashinzugu			x	People avoid it because it gives anthrax to cattle	7
Ficus lutea	x			Makes cow strong and increases quantity of milk	5
Aphloia theiformis	x			Makes cow strong and increases quantity of milk	5
Anthocleista grandiflora	x			Makes cow strong and increases quantity of milk	5
Phyllantus comorensis		x			
Gliricidia sepium (young leaves)			x	Makes milk bitter if given alone. Must be associated with other fodder types to neutralize effect	4
Gliricidia sepium (mature leaves)		x		Good as fodder	4
Mbushi		x			
Pennisetum purpureum(young stems)	x			Makes cow strong and increases quantity of milk	
Brachiaria decumbens	x				
Tambourissa leptophylla		x			
Tripsacum laxum	x				

Musa acuminata		x			
Mtsongori		x			
Digitaria celari	x				
Videns pilosa		x			
Sida rhombifolia		x			

4.5.2 Knowledge about soil conservation processes

i. *The first key finding here was that the agro-silvo-pastoral integration with tethering of dairy cows on cropland is pivotal to the productivity of farming system in the Comoros.*

Farmers' had detailed knowledge on the soil fertility requirements of different food crops and garden crops. Of the 30 farmers interviewed, 22 farmers mentioned this indicating the importance of the knowledge in the system. Farmers have detailed knowledge about the fertilisation ability of cow manure and can generate different prescriptions for different crops. To support this statement, their knowledge suggested tubers (taro, cassava and sweet potatoes) need less fertility compared to garden crops and other food crops. Specifically, in the case of tubers, tethering the cow on the farm for 15 days will provide manure sufficient for its growth for more than 15 days will favour only the development of the vegetative parts than the tubercules. And for the better growth of other food crops including banana and garden crops, cattle are left on farm for 1 to 2 months.

Soil fertility improvement between project trained and untrained farmers are different. The cow dung and household waste are widely applied by all farmers (project trained and untrained) on their farms for soil fertility improvement. They all have similar knowledge about the processes and application, advantages and disadvantages of cow dung and household waste manure. In addition to the tethered cow and household waste as source of soil fertility, farmers under project training use compost manure as well to fertilise their plots. Out of the 13 project trained farmers interviewed, 6 confirmed using compost manure because of the advantages they have. They were perceived to be advantageous because it was easy to make and had little cost. In

addition they were observed to lead to more tasteful products than those grown with inorganic manures.

ii. *The second key finding is that farmers want trees more trees for fertilisation, timber, fruits and firewood. Erosion is no longer an important need to address anymore.*

In the past, soil erosion was a severe problem in the past but 25 out of 30 farmers interviewed said they were successfully controlling erosion on their farm. This was attributed to strategic tree management in the landscape but was not representative to the island of Anjouan. This was first initiated in 1960 by the BPDA project and in 1980 by CADER. Presently Dahari have assisted farmers to plant hedgerows of fast growing trees species of *Gliricidia sepium* and *Pterocarpus indicus* at contour lines on slopes for control against erosion.Farmers under Dahari project assistance have integrated *Brachiaria decumbens,* and Banana at the contours to increase the efficiency of the hedgerows in controlling soil erosion (Figure 13) while non project trained farmers use the standard hedgerows (Figure 14). Their knowledge shows that banana planted at the contour does not only improve the effectiveness of the hedgerow but also profit from the nutrients washed down the slope by rainwater. This was ascertained by 10 out of the 13 farmers interviewed under Dahari training.With a fully integrated anti-erosive infrastructure on plots, farmers have shifted their needs to timber, fruits; fertility and firewood. Table 15 below gives a summary of the trees farmers want add on their farms. This was cited by 25 out of 30 interviewed farmers. The species cited are represented in the table 6 below with their utilities.

Figure 13: Banana and Brachiaria planted on contours with *Glicicidia sepium* and *Pterocarpus indicus* to reinforce hedgerow against soil erosion

Figure 14: Simple hedged of Glicicidia sepium *and* Pterocarpus indicus *against erosion control by non -project trained farmer.*

Table 15: List of trees farmers want to increase on their plots

Tree species	**No. of farmers per species**	**Fruits**	**Firewood**	**Fertility**	**Timber**
Weinmania comorensis	15		✓		✓
Khaya comorensis	13		✓		✓
Citrus spp.	11	✓			
Phyllartron comorense	10	✓			
Chrysophyllum gorungosanum	10		✓	✓	✓
Citrus reticulata	9	✓			
Syzygium aromaticum	9	✓			
Artocarpus heterophyllus	8	✓		✓	
Artocapus indica	8	✓			
Flueggea virosa	7	✓			
Ocotea comorensis	6	✓			
Mjitabo	5				✓
Moringa oleifera	4				✓
Cocos nucifera	3	✓			

4.6 Opportunities, constraints and trade-offs in managing different trees and agroforestry practices

4.6.1 Opportunities

Due to diverse needs of farmers, they plant or maintain more and different trees on their farms. They are conscious of the loss of fertility and need more trees to improve soil fertility, need more tree fruits for food security, more fodder trees to use during the dry season, timber for construction and sale and the growing demand of Firewood for distillation of ylang ylang and use in homes for heating.

Even though plot sizes are small and not sufficient for cropping and trees also have their inconveniences (negative interaction with crops, some hardens the soil and inhibit crop growth). They need the products and services so they prefer to take the risk and integrate the trees on farms.

4.6.2 Constraints

There are a couple of factors that hinders the management of trees and and agroforestry practices in the landscape of Adda that were identified by farmers and included the following:

- Limited land holdings. This was a factor that was raised by almost all the framers that hinders the integration of trees on farms and landscape. Because of this some farmers ended up with small plots with high tree densities (especially fruit trees)

- Poor access to markets. This greatly influenced the integration of fruit trees as they complained of lack of markets to sell their fruits. There exists the main market in Mutsamudu that always have abundance of garden and tree crops during respective fruiting seasons, leading to low and discouraging prices and consequently dumping at the end of the day.

- Stealing**.** This is major concern as all the farmers did mention. This involves not only tree crops but also food crops. Farmers feel reluctant planting trees because they will serve as fodder to livestock as livestock owners cut or harvest anything belonging to anybody. As explained by a farmer, "*this has made us to plant most of our fruits trees closed to the village or around homes for better monitoring"*. The stealing of food crops such as taro, cassava and banana is also very rampant around and done especially in the night.

- Lack of desirable varieties of seedlings in the nursery. There exists a nursery ran by Dahari but tree species to suit the farmers' diverse needs are lacking. Some few farmers interested in planting particular tree species have to walk for hours to search in the forest. Some species are becoming rare in the forest.

- Most trees have very slow growth rates**.** Most farmers complained about the slow growth rate of most trees. They are reluctant to plant they feel they will not live to reap the benefits as they are already getting old. Due to the fast growth rate of *Moringa oleifera* (mvunge) almost all famers planted the tree on their plots.

- The composition of agroforestry trees in the Adda-Daoueni system does not have fodder species to get farmers through the dry season. This poses a serious

cattle management problem which is the main source of fertility in the Adda system.

- Limited labour. Farmers stated that tree planting requires much labour and attention. They did mention that looking after the cattle already occupies the time and planting more trees is extra work to the men.
- Most farmers that planted *Syzygium aromaticum*, *Citrus sinensis* etc complained of negative effect of shades on crops and corresponding decrease in crop yields.

4.7 Opportunities and constraints for agro-ecological intensification by improving tree-crop-livestock interactions.

In the tree-crop-livestock system there is exchange of products between the three components. The constraints as identified by the farmers were linked to competition for natural resources and opportunities for more incorporation of the three elements

4.7.1 Opportunities

- There is the movement of nutrients from the forests (degraded and dense), and other fodder sources to the farms through manure that immensely contribute in maintaining the fertility of the soil needed for the growth of crops.
- Trees on farms on the slopes reduces the speed of runoff and increases water infiltration into the soil.
- The already existing tree nursery should contain diversified species to meet the requirements of the farmers of fruit trees, fodder trees and timbers.

4.7.2 Constraints

- The forest is continuously degraded as farmers harvest fodder for cattle
- Lack of credit to finance agricultural activities
- The cattle trample and degrade the soil through compaction that favours erosion.

- The slow growth rate of trees before production discourages farmers planting trees
- Cattle diseases and non-availability of veterinary personnels
- Increasing the density of trees on farms increases the competition for sunlight between trees and crops leading to decreasing crop yields e,g cloves with a dense crown down to ground level do not favour growth of all crops, also *Moringa oleifera* hardens the soil and inhibit the growth of tubercules.

5. Discussion

5.1 Local knowledge of tree management for products and services

This research suggests that despite having small farm sizes, farmers still integrated trees on their plots as they recognised that these trees have multiple functions which benefit their farms and households. Because of the value of these functions they plant, protect, select and domesticate trees as discussed in Schroth & Sinclair (2003). Discussions with farmers revealed that agroforestry systems occupy key niches and that these were generally planned. A few tree species were scattered on farms but the majority were found on the boundaries of farms and hedgerows on contours (Sinclair, 1999). These special niches limit competition between trees and crops.

5.1.1 Products provided by trees

As has been recognised in many other studies the key products from agroforestry systems in the Comoros includedfuelwood, fodder, timber, medicine, charcoal, poles, mats and food (leaves and condiments) (see for example Scherr, 1995; Schroth & Sinclair, 2003. See also Table 3 above). In the Comoros these products are harvested at different times of the year. The diversified number of trees recorded provide different tree products that contribute in sustaining the household economy. Most important in this area are fruit trees. In this environment they are all exotic and quite diversified and play a very important role in the livelihood of the inhabitants of Adda especially as back up during months of nutritional stress as seen in other studies (see for example, Bell, 1995, Hunter et al., 2009). It is likely they also contribute to diet diversity in this area (FAO, 2005). They constitute a source of high value nutrients and have different fruiting periods within the year (as described in Table 4) making fruits available for household consumption throughout the year – and the local knowledge work suggests that they contribute to overall household security in a significant way). Once subsistence demands have been met, they also provide a source of income to most households when fruits are sold. Apart from serving as source of food, income, fruit trees also serve other functions like fodder, fuelwood, construction material and medicines that fulfil famer's needs.

5.1.2 Key services provided by trees

In addition top production benefits the farmers identified described a range of regulating benefits provided by trees on their farms such as erosion control, windbreaks, humidity and shade and nutrient cycling and soil fertility performed by the presence of trees on plots these are discussed below.

5.1.2.1 Erosion control

This constitute one of the most important benefits of trees in the study area because most of the plots are found on slopes. Good anti-erosion structures have been put in place by farmers on their plots with the assistance of past projects (BDPA and CADER) and currently Dahari. It is thanks to these structures that farmers are able again to cultivate their formerly degraded croplands.

Amongst all the trees used in erosion control, *Gliricidia sepium and Pterocarpus indicus* were the most important ones as shown in table 5. These trees were integrated on almost all plots on slopes by project trained and non-project trained farmers as hedgerows on contours. They were initially promoted by BDPA in the 1960s and later by CADER in the 80s. The planting of trees as live fences and hedgerows on plots by farmers was successful in this area unlike in other villages. This was due to a secured land tenure system and this confirms the assertion by Walters *et al*. (1999) that successful adoption of these practices over time by farmers is due to a secured land tenure system. This greatly influenced the adoption of trees on farm. The multi-purpose function of the trees species and the fast growth rate of these trees did encourage most farmers to integrate them on farm. Apart from being used in erosion control, they constitute the most widely used sources of fodder during dry season, windbreaks, poles when allowed to grow to a certain height. These trees also sustain or improve the fertility of the soil, crop yields and contribution to increase in income of the farm (Leakey 1996). Banana, *Pennisetum purpureum and Brachiaria decumbens* were integrated on the contours of some plots in association with *Gliricidia sepium* and *Pterocarpus indicus* hedgerows by project trained farmers. This was done to increase the effectiveness of the hedgerows against erosion control. This confirms to the results of a study by Angima et al., 2000, combining calliandra and napier grass, simple hedge of calliandra, a grass hedge and a control with no hedge. It was observed that the combined hedge of calliandra and napier grass registered the highest percentage in slope reduction implying that there was more accumulation of upslope

soil at the contours indicating its increased effectiveness when combined with the napier grass.

On some plots with hedgerows established a long time agoin Adda, terraces were observed resulting from a gradual accumulation of soil from the upslope at the foot of the hedgerows and this corresponds to a study by Young & Sinclair (1997). Though some few terraces were manually dug by farmers to reduce the steepness of the slopes on plots.Because banana requires much soil fertility to growth, farmers have integrated them at the contours to profit from the accumulated fertile soils from upslope.

As was hypothesized, the results indicates there exist differences in knowledge and practice with erosion control between projects trained and untrained farmers. Farmers under Dahari project assistance have integrated *Brachiaria decumbens,* and banana on the contours to increase the efficiency of the hedgerows in controlling soil erosion while non project trained farmers use the standard hedgerows. Their knowledge shows that banana planted at the contour does not only improve the effectiveness of the hedgerow but also profit from the nutrients washed down the slope by rainwater. The results also show that a only few project trained farmers integrated tree species such as *Magnolia champaka*, *Mangifera indica* and Mrouva on contours in combination with *Gliricidia sepium and Pterocarpus indicus*.

5.1.2.2 Humidity and shade

Soil moisture conservation falls amongst the highly recognised functions of trees based on farmers' local knowledge. The results showed that humidity and shade both affect crops positively and negatively. The effect varies with different tree species. This knowledge will help Dahari or other projects to promote trees that are less comnpetitive.

Tree shade is important as it provides the best growing environment for some crops, especially those originating from the forest understory such as taro and banana. Tree shade on croplands is equally of importance as it provides moisture on plot beneficial to crops especially during the dry season. Of all the trees integrated on boundaries and on farm *Moringa oleifera to Mangifera indica* indicated in table 6 are most identified by farmers to provide a positive environment for the growth of crops on plots and forest understorey. The most staple crops (banana, taro and cassava) crucial to diet in

the study area profit from the shading effect of trees (*Moringa oleifera, Artocarpus heteropyllus,Weinmannia comorensis, Anthocleista grandiflora, Khaya comorensis, Artocarpus indica and Mangifera indica*) needed for their growth. In this farming system crops are cultivated under different light intensities that ranging from full sunlight to heavy shading (as decribed in Rogers & Losefa (1993). Planting crops during the dry season makes use of tree shade to get fully established. The results show that the effect of shade on crops vary with different types of crops and their moisture requirement. Shade requirement by a particular crop can be manipulated by pruning or reducing the density of the crown of the tree (Rogers & Losefa, 1993). Shade tolerant crops such as banana and taro require heavy shade and mostly cultivated in the mountain cloud forest even though are cultivated in all the croplands in the landscape. Garden crops like tomatoes, cabbage etc need light shading. It can be seen from the results (Table 6) that *Moringa oleifera, Artocarpus heterophyllus, Weinmannia comorensis and Anthocleista grandiflora* are the most important species that provide shade to all crops at varying intensities due to its less dense and small crown widths.

Even though shade provided by trees are important for the growth of shade tolerant crops, and the improved establishment of planted crops during the season, the shade of some trees negatively affect a variety of crops. The results of such trees have been summarised in table 6. Based on the local knowledge of farmers, *Citrus spp, Syzygium aromaticum, Pterocarpus indicus* and *Litchi sinensis* was recorded as the major trees whose shades negatively affect crops. *Citrus spp., Syzygium aromaticum and Pterocarpus indicus* were identified by many farmers to negatively shade cassava. The shading effect was manifested by thin and slender stems of cassava with yellow leaves. The reason given by farmers was that these trees have very dense crowns which descended right to the ground level that permitted no light to reach the crops. Gardens crops such as tomatoes and cabbage were equally affected. The shading led to excess moisture to garden crops which provoke their rot.

5.1.2.3 Nutrient cycling and soil fertility

Farmer's knowledge about fertiliser trees was quite detailed. They distinguished fertilising trees based on the rate of decomposition and the organic content of leaves. *Pterocarpus indica, Gliricidia sepium, Weinmannia comorensis and Anthocleista*

grandiflora are the main trees species that contribute to fertility of the soil. *Pterocarpus indica* and *Gliricidia sepium* are nitrogen fixing trees, established at no cost that restores soils deficient in nitrogen across the landscape (Young, 1997). The number of knowledge base sources indicates their wide recognition in improving soil fertility compared to other species identified. As stated by all farmers (project trained and non-project trained) fertility from trees can last for a year depending on the types of crops cultivated. The duration of soil fertility of one year is dissimilar from that suggested by Kang et al (1990) where they mentioned that fertility from leguminous trees such as *Glricidia sepium* and *Leucaena leucocephala* can last for 2 to 3 years. Nevertheless integrating these into the farming system improves soil fertility, productivity and makes the system sustainable (Schroth & Sinclair, 2003). *Pterocarpus indicus* contribute to nutrient cycling due to its tap root system that descends deep into the ground and make use of the nutrients which are later on retain to the soil when leaves fall and decay (Faleyimu & Akinyemi, 2010). There was no distinct difference in knowledge on fertiliser trees between projects trained and non-project trained farmers.

5.2 Farmers needs for trees on plots

Based on the results in table 15, it is clear that farmers need more trees is driven by need for fruits, timber, and firewood and soil fertility. This will increase and diversify productivity and most probable relax the pressure on the forest (Ndayambaje et al., 2012). Generally, most solicited are fruit trees and timber tree species. The obvious reason is food security throughout the year and diversification of income Ndayambaje et al., 2012).

5.3 Livestock nutrition and fodder management

There exist a multiplicity of fodder sources and availability at different times of the year as shown in table 13. Fodder is abundant during the rainy season, the period when cultivated gramminae and natural growing graminae are available including fodder from the live fences of *Gliricidia septum and Pterocarpus indicus*. The trees that provide fodder during drying are evergreen and semi-deciduous, thus retaining or losing some of its leaves during dry periods. During the dry season farmers depend on

the degraded forests and mountain cloud forests for fodder since other sources cannot survive during this time.

All the farmers have a much detailed knowledge of fodder types and based on this, categorised into high, standard and low qualities (see table 14). This classification is based on the effect of the various fodder types on the quality or quantity of milk produced by cattle lactation, taste of milk and dung (watery or solid). The number of sources indicates the number of sources of knowledge base about the different types of fodder. The basis of classification is similar to the one in a study in Nepal carried out by Thapa et al., (1997), wherein farmers classified fodder into 2 categories, known as "posilan" (nutritious fodder) and "Obanopan". Posilopan increases milk production with a high butter content. Obanopan made of "obano" (dry and warm) and "chiso" (cold and wet). The basis of classification of fodder in the two contexts makes cattle nutrition identical.

Despite the fact that farmers are aware of the poor quality of *Pterocarpus indicus and Gliricidia sepium* and their effect on the quality and quantity of milk and the general health of the cattle, they are still the main fodder as shown on table 14 fed to cattle during the dry season. This is because most often they don't have much time to go to the forest to fetch for fodder during the dry season when other fodder sources are all dried up. This ties with study by Thapa et al, 1997 in Nepal where farmers are very well informed about the low quality of obano as fodder but still its given to cattle to fill them up. The farmers have detailed knowledge about fodder and because members of the household have to walk as long as 3 to 4 hours in search of fodder from the degraded and mountain cloud forests during the dry season, they expressed their need to have high quality fodder trees on their croplands in the lower catchment closed to homesteads. This is comparable to the results obtained by Roothaert et al. (1997) in Kenya where farmers in an agro-ecological zone desired fodder trees on their farms against the seasonal scarcity and for animal satisfaction.

5.4 Farmers' ecological knowledge on tree management practices

Trees are generally managed in different niches such as cropland, boundary, forest and around homesteads in Adda landscape (Buyinza et *al.*, 2015).

Different tree species are maintained or planted for different reasons. According to Schroth & Sinclair (2003), farmers plant or nurture trees for timber, fruits for nutrition,

shade, control against soil erosion, fodder and soil fertility. In Adda a total of 9 tree species were maintained on plots from natural regeneration. The species include *Anthocleista grandiflora, Gastonia duplicata, Khaya comorensis* and *Tambourissa leptophylla.* All of these trees are of multiple functions in provisioning and environmental services (see table 3 for tree utilities). Equally 21 tree species were planted on plots across the landscape with most important ones being Pterocarpus indicus, *Moringa oleifera, Gliricidia sepium, Syzygium aromaticum, Citrus sinensis, Artocapus indica, Weinmannia comorensis and Phyllostachys spp.*

In the study area, distance is a factor that negatively affects planting or growth of trees (Schuren & Snelder, 2008). This was particularly observed in Adda with fruits trees that were planted in plots closest to and around homesteads. This was for better surveillance for growth and from thievery (Schuren & Snelder, 2008) because stealing is a major problem in the study area.

Despite the fact that trees are planted or maintained for wide range of benefits there exist negative interactions with crops. Above and below ground competitions were identified on plots based on farmer's knowledge. Above ground interaction as Shading was identified with some trees as shown in table 7 that negatively affect crops by reducing the light intensity required by crops for growth. Farmers knowledge suggest that trees characteristics such as large tree crown, crown density and crowns that descend to the ground level increase the tree competitiveness with crops for sunlight. *Citrus spp, Syzygium aromaticum, Pterocarpus indicus* and *Litchi sinensis* were identified to have these characteristics and had a major negative effect on food and garden crops. Below ground competition, i.e. competition between tree roots and crops for water and nutrients in the soil was identified with some trees. Such trees have shallow root systems and compete more with crops for limited nutrients. The roots of *Gliricidia sepium* mentioned by almost all the farmers when in contact with cassava, it becomes bitter. Some tree species such as *Moringa oleifera* based on local knowledge of farmers makes the soil dry and hard. This hard soil and hinders growth and development of tuber crops.

In order to manage the trade-off associated with tree management farmers adopted practices such as roots pruning and pruning of branches. The roots of a total of 3 tree species are pruned on plots with main ones being *Gliricidia sepium and Pterocarpus indicus* to minimise the effect on cassava. This ties with a study by Siriri et al (2013)

which revealed that competitive effects of tree roots with crops is limited by regular root or shoot pruning. This was usually done during land tillage. The importance trees whose branches are pruned are *Citrus sinensis*, *Artocarpus heterophyllus and Pterocarpus indicus.* Pruning is usually done during field preparation.

6. Conclusion and Recommendations

6.1 Conclusion

The findings of this study concludes that local knowledge of farmers is very important in the management of trees on farms and in the in the Adda-Daoueni landscape. Farmers have a wealth of knowledge about trees-crop-livestock interactions, trees and the various ecosystem services provided by trees. This coupled to their household needs greatly influence their planting and retention on their plots. There is a variation in the need of farmers and as a result farmers adopt different species of trees on their plots ranging from fertilising trees, fruit trees timber species and fodder trees. Also, all farmers had detailed knowledge about fodder trees, fodder quality and the effect of fodder on the quality of milk and the general health of the cow.

There is a difference in perception, knowledge and practice between Dahari supported and non- supported farmers in managing trees for erosion control. This leads to the conclusion that that erosion practice by Dahari supported farmers is more efficient in retaining soil and nutrients on plots on slopes.

Despite the fact that farmers have detailed knowledge about the utilities of trees, their plantation or retention on plots is constrained by a number of factors such as poor access to markets, limited landholding, theft, lack of desirable varieties of seedlings in the lone existing nursery, slow growth rate of trees, limited labour and competition of valuable trees such as *Syzygium aromaticum* and *Citrus sinensis.* Equally, improving tree-crop-livestock interactions to achieve agro-ecological intensification comes with challenges such as continuous degradation of forest as farmers harvest for cattle, increased cattle on farm favours erosion through soil compaction, cattle diseases due to lack of veterinary personnel and increased competition for nutrients and sunlight between trees and crops.

6.2 Recommendations

- The community should liaise with the law enforcement officers as back up to creat an anti-gang group that patrols round the village in the night in order to reduce

or stop stealing. This will encouraging more tree planting especially further away from homesteads.

- The farmers should be schooled on the management of any exotic tree species introduced in the area in relation to other crops on the farm. This will permit a win-win benefit. An example are trees *like Sysygium aromaticum* and *Citrus sinensis* which farmers adopt because of it economic value but its presence on farms reduce crop yields.

- The farmers' local knowledge on trees is very important and should not be neglected when making tree species choices in the nursery. This will lead to a targeted and successful adoption of trees on farms.

- Fodder trees such as *Anthocleista grandiflora, Aphloia theiformis, Ficus lutea, Fluggea virosa* and *Phyllantus comorensis* should be included in nurseries and farmers encouraged to plant on plots for use during dry periods when fodder for lisvestock becomes scarce.

- The association of graminae and banana with other hedgerow species at contours should be encouraged to all farmers in the landscape as this has proven to be more efficient in with farmers under Dahari support in controlling erosion on plots on slop

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APPENDICES

APPENDIX I: List of trees recorded in the Adda landscape

Vernacular Name	**Scientific Name**	**Origin**
Dzimbouchi	*Cyathea boivini*	*N*
Hadza		
Mbarti	*Pterocarpus indicus*	*E*
Mbuyu	*Adansonia digitata*	*E*
Mbwomo	*Tambourissa leptophylla*	*N*
Mcafe	*Coffea arabica*	*E*
Mdaracine	*Cinnammomum verum*	*E*
Mdawa	*Piper sp*	
Mfanassi	*Artocarpus heterophyllus*	*E*
mtrule	*mohumbo*	*E*
Mfuantsi	*Chrysophyllum gorungosanum*	*N*
Mgiricidia	*Gliricidia sepium*	*E*
Mkalkisse	Eucalyptus sp	E
Mkarafu	*Syzygium aromaticum*	*E*
Mkindrinkindri	*Weinmannia comorensis*	*N*
Mkinga(exotic)	*Citrus reticulata*	*E*
Mlandsie(indigenous)	*Citrus reticulata*	*N*
Mlechi	*Litchi sinensis*	
Mmanga	*Mangifera indica*	*E*
Mnadzi	*Cocos nucifera*	*E*
Mpapa	*Anthocleista grandiflora*	*N*
Mpoirimpoiri/mvoivoiri	*Carica papaya*	*E*
Mpori	*Khaya comorensis*	*N*
Mrobwe	*Ocotea comorensis*	*N*
Mroudrasole	*Phyllantus comoriensis*	*E*
Mroundra demu(bitter),	*Citrus sinensis*	*E*
Mroundra ngizi(sweet)	*Citrus sinensis*	*N*
Msakua	*Spondias mombin*	*E*
Msiro	*Pterocarpus erinaceus*	

Msumu	*Jatropha curcas*	*E*
Mtrengemoi	*Gastonia duplicata*	*N*
Mtrondro	*Khaya comorensis*	*N*
Mtsongoma	*Psidium cattleinum*	*E*
Muhomba	Flueggea virosa	*N*
Mvuvu	*Ficus lutea*	*N*
Mvunge wachizoungou(introduced)	*Moringa oliefera*	*E*
Mvunge(indigenous)	*Moringa sp*	*N*
Mvwera	*Psidium guayava*	*E*
Mwaha	*Nuxia pseudodenta*	*N*
Mzavoka	*Persea americana*	*E*
Shivundze	*Phyllartron comorense*	*N*
Trindri	*Musa sapientum*	
Mtsanga	*Dracaena xiphophylla*	*N*
Mpomo	*Malus pumila*	E
Mkomvava	Citrus hystrix	E
Muaju(exotic and indigenous)	*Averrhoa bilimbi*	E
Mpambafuma	*Ceiba pentandra*	E
Shampaka	*Magnolia champaka*	E
Muhamba	*Flueggea virosa*	E
Mtsongori		
Mfantrabo	*Aphloia theiformis*	N
Mkomolasua	*Strychnos mitis*	E
Mkonokono	*Annona muricata*	E
Mlimu	*Citrus Lemon*	E

APPENDIX II: Farming calendar in Adda-Daoueni

		J	F	M	A	M	J	J	A	S	O	N	D
Tomatoes (Early planting)	Field prep.	x	x	x									
	Planting				x								
	Weeding					x							
	Harvesting						x						
Tomatoes (Regular planting)	Field prep.				x	x	x						
	Planting							x	x				
	Weeding								x	x			
	Harvesting									x	x		
Tomatoes (Late planting)	Field prep.							x	x				
	Planting										x	x	
	Weeding											x	x
	Harvesting												
Irish potatoes (Regular planting)	Field prep.			x	x	x							
	Planting						x	x					
	Weeding						after 15 days	after 15 days					
	Harvesting								x	x			
Irish potatoes (Late planting)	Field prep.								x	x	x		
	Planting											x	x
	Weeding											(15 days)	15 days)
	Harvesting	x	x										
Cabbage (Regular planting)	Field prep.				x	x	x						
	Planting							x	x				
	Weeding							(15 days)	(15 days)				
	Harvesting									x	x		
Cabbage (Late planting)	Field prep.							x	x	x			
	Planting										x	x	
	Weeding										(15 days)	(15 days)	

		J	F	M	A	M	J	J	A	S	O	N	D
	Harvesting	x											x
Aubergine	Field prep.			x	x	x							
	Planting						x	x					
	Weeding							x	x				
	Harvesting									x	x		
Pepper (Regular planting)	Field prep.			x	x	x							
	Planting						x	x					
	Weeding							x	x				
	Harvesting									x	x		
Pepper (Late planting)	Field prep.							x	x	x			
	Planting										x	x	
	Weeding											x	x
	Harvesting	x	x										
	Field prep.				x	x							
	Planting						x						
	Weeding						after 15 days						
	Harvesting							x					
Petsaille (Regular planting)	Field prep.					x	x						
	Planting							x					
	Weeding							after 15 days					
	Harvesting								x				
Petsaille (Late planting)	Field prep.							x	x				
	Planting									x			
	Weeding									after 15 days			
	Harvesting										x		
Pigeon pea	Field prep.								x				
	Planting									x			

		J	F	M	A	M	J	J	A	S	O	N	D
	Weeding											x	
	Harvesting						x	x					
Taro	Field prep.							x					
	Planting									x			
	Weeding											x	
	Harvesting						x	x					
Cassva	Field prep.							x					
	Planting									x			
	Weeding											x	
	Harvesting						x	x					
Sweet Potatoes	Field prep.											x	x
	Planting	x											
	Weeding			x									
	Harvesting						x	x					
Maize	Field prep.						x						
	Planting									x			
	Weeding											x	
	Harvesting	x											
Igname	Field prep.							x					
	Planting								x				
	Weeding											x	
	Harvesting						x	x					
Carotte (Regular planting)	Field prep.			x	x	x							
	Planting						x	x					
	Weeding								x	x			
	Harvesting									x	x		
Carotte (Late planting)	Field prep.							x	x	x			
	Planting										x	x	
	Weeding											x	x
	Harvesting	x	x										
Cucumber	Field prep.			x	x	x							

(Regular planting)		J	F	M	A	M	J	J	A	S	O	N	D
	Planting						x	x					
	Weeding						15	15					
	Harvesting								x	x			
Cucumber (Late planting)	Field prep.					x	x	x					
	Planting								x	x			
	Weeding								after 15 days	after 15 days			
	Harvesting										x	x	
Onion	Field prep.					x	x	x					
	Planting								x	x			
	Weeding										x	x	
	Harvesting	x	x										

APPENDIX III: Semi structured interview guide

Introduction

1. Brief description of farming activities (15 min)

Number of fields, key crops, and number livestock -record precise information on the field visited but elicit information on other plots (location, key crops, and any trees they manage)

What types of trees do you manage on your farm? (Which ones are planted and which ones have been nurtured from NReg) and for what purpose (utilities for which they are planted).

2. Soil conservation management (20 min)

Do you have soil fertility problems on your farm? Where? Why?

Which crops are most affected? Where?

What are you doing to improve soil fertility?

Do you know any trees that improve soil fertility?

Explore knowledge of mulching? (Paillage/compostage)

What are the advantages and constraints of different methods? What other methods do they know that they may not be practising? Ask the reasons why they are not using that method? How did you learn this?

Do you have soil erosion problems in your fields? *If so where? How do you address the problems? Which other methods do you know to address the problem?*

Can trees help you address erosion problems? Which ones?

4. Cattle management (20 min)

What are the advantages of having cow(s)?

What difficulties do you face in managing your cows?

What are the fodder sources you know that can help you at different time of the year?

How do you manage these resources? do you plant them? Harvest them?

In what ways can you improve the situation? What could you plant where? What would you do differently?

5. Opportunities and constraints to increasing tree diversity and cover (10 min

Would you want to plant more trees on your farm? Is no why? If yes? Which ones? Why? Where?

Probe: Are t*here any tree species that have disappeared that you wish you had more of*?

Do you have any ideas on how you could increase the number of these useful trees on your farm?