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Portfolios to enhance multi-functions in agro-silvo-pastoral systems

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1 Introduction

FUNCiTREE has studied the production priorities and preferences of the local rural communities in Rivas, (Nicaragua), Potou (Senegal) and Segou (Mali) using various approaches. We have also gathered the knowledge farmers have of the dominant trees in these areas, and the functions they play in their socio-economic system. At the same time, the trees were characterized by a series of traits, plant functional traits, with fair predictive power of some ecological functions that underpin the production system.

An important message that emerges from the studies about the use of trees by the different social groups is the large variety of benefits that local communities derive from the trees, and that despite many trees being multi-functional, no single tree fulfills all functions. Many trees have various uses, only a few fill single functions, and these are often related to medicinal use (Ickowicz et al. 2013). However, even if many tree species are multi-functional, their uses are often complementary to each other, and no single tree species fulfills all functions. For instance, in Senegal, several trees are used to feed livestock, but the species that provide good fodder for cattle differ from those that provide fodder to goats (Rusch & Pugnaire 2013, Carmona et al. 2013). Also, different social groups value the tree species differently and make different uses of them (Cisse et al. 2010, Clinquart et al. 2010). Consequently, it is critical that modern agro-silvo-pastoral systems are viewed and designed as functionally diverse systems.

Many challenges are still ahead in order to implement functionally diverse and flexible (that can persist through changing and fluctuating conditions) agroforestry systems. Challenges include knowledge gaps on the biology of the species, technical aspects related to propagation, the need of capacity building and out-reach and the magnitude of the economic risk to adapt current practices.

Based on the knowledge gathered during the project, a series of field trials and small-scale implementation of improved agro-silvo-pastoral systems have been established to gain and communicate experiences about how to enhance multi-functionality in these systems, while taking into account the production priorities in each case. The following sections describe how these production priorities have been translated into portfolios of trees and functions in each case.

2 Rivas

2.1 Current silvopastoral practices and potential for adaptation

In Rivas, scattered trees in pastures and live fences are the main elements of the silvo-pastoral system in the area. Trees in pastures are most commonly remnants after the clearing of the forest when livestock ranching was established, and possibly a result of natural regeneration, although grazing and browsing, and trampling and weeding generally hinder natural establishment of trees in the pastures in these areas (Esquivel et al. 2008). Consequently, trees in pastures are generally not managed actively as an agroforestry practice (i.e. planting and management). To achieve the necessary protection actions against browsing and trampling would require considerable changes in current livestock and silvicultural management practices.

These conditions are reflected in the studies that identified the socio-economic characteristics of farmers, and the species and silvopastoral arrangenments with highest likelihood of being adopted (Salazar 2012, Salazar et al. 2013). Farmers prefer to increase tree cover more in live fences than in the pasture area. Farmers wished on average to increase the tree cover in live fences and paddock borders by ca 200%, and by 57% the density of trees in pastures. The farmers preferred species such as *Cordia dentata, Gliricidia sepium, Cordia alliodora, Diphysa robinioides, Guazuma ulmifolia, Pachira quinata, y Enterolobium cyclocarpum*. The farmers could also increase the potential income with US$2948 per ha in 25 years, if these changes were implemented. Small-hold farmers chose trees based on their belief that they provided shade for the animals, improved the soils, provided firewood, and protected water sources. Less importance was given to animal nutrition and the fact that the trees could be tolerant to drought.

The study on multi-funcitonality of the silvopastoral system shows that the level of service provision and the degree of multi-functionality can be significantly enhanced by increasing tree species richness and with an appropriate choice of species. Hence, there is a substantial potential for improvement by managing live fences more actively. Live fences can provide shade for the animals, fruits, firewood, timber, and capture considerable amounts of carbon. Recent studies in Central America (Honduras) show that 70% of the firewood used in the livestock farms are produced in live fences and in pastures (Rivera 2013). In Rivas, on the other hand, the use of live fences is limited; generally fences are constructed with poles. With an adequate design and management, live fences have the potential to provide all year fodder, but currently this resource is under-utilized.

2.2 Fodder banks

The limitation of dry season feed supply is a major constrain in the double purpose (milk and meat) livestock production in Rivas. Pastures and grasslands almost entirely stop growth and dry back in the dry season. The remaining standing biomass is scarce and of low nutritious value.

FUNCiTREE studies on the use of water sources by trees show that some trees species can continue growth during the dry season because they change from shallow to deeper soil water sources. Some species also have as yet unexplored fodder value (Pérez Almario 2010, Pérez Almario et al., 2013) and may also tolerate repeated harvesting (Lombo 2012).

The cafeteria experiments of ten common trees in Rivas, showed different preferences by cattle. The descending order of consumption was *Samanea saman, Leucaena leucocephala, Albizia niopoides, Cordia dentata, Moringa oleifera, Guazuma ulmifolia, Gliricidia sepium, Brosimum alicastrum, Mimosa pigra* and *Acacia farnesiana*. The preference by cows was associated with several whole-tree and leaf traits. The first three species are legumes which generally have higher leaf nitrogen content; and these species had large and soft leaves. However, the least consumed trees were also legumes. The low preference in these cases is due to the presence of thorns and high concentration of condensed tannins. Many forage species present condensed tannins that can poison livestock if consumption is high (Mueller-Harvey 2006). This usually occurs when cattle have only this food in their diet. This seldom happens in a pasture where there is a variety of forages.

Figure 1: Fodder bank of Gliricedia sepium in Rivas, Nicaragua. Photo: Pere Casals.

In addition to fodder quality, biomass production and regrowth capacity after harvesting or browsing are important traits in trees supporting the fodder production function. Our experiments indicate that *Cordia dentata* and *Pithecellobium dulce* had the highest edible biomass, and both species have potential for cattle feeding in the dry season, either under the cut-and-carry system or by cutting and offering the fodder on the ground near the tree. However, to propose these species as important fodder providers, the effect of prolonged pruning on the response of *Cordia dentata* and *Pithecellobium dulce* needs to be determined. Several woody species such as *Cordia dentata, Gliricidia sepium, Guazuma ulmifolia, Albizia saman and Albizia nipoides* that currently occur in pastures in the area of Belén, Rivas, seem currently undervalued in terms of their potential to provide fodder.

Our studies indicated that species like *Leucaena leucocephala*, *Cordia dentata*, *Gliricidia sepium*, and *Guazuma ulmifolia* have important advantages as on-farm feed resources. The combined use of the species such as *A. saman* + *C. dentata*; *L. leucocephala* + *C. dentate*; *A. niopoides* + *C. dentata* to supplement the basal diet in the dry season (*Pennisetum purpureum*, molasses and minerals) can improve an average milk production of 6.5 kg / cow / day when based only on grazing of dry grassland and with supplement of manure, molasses and mineral salt, to between 6.7 and 7 kg / cow / day. The best response is due to the associative effect of mixed browse material (at least 2 woody species such as *L. leucocephala* + *C. dentata*) that enhances nutrient availability.

2.3 Field trials

Based on the assessments of tree traits and on the farmers' production priorities and preferences, field trials were designed to show how current silvopastoral practices in the area can be adapated to enhance multi-functionality, and production and economic yield (Villanueva et al. 2012).

We selected two typical farms that were easily accessible, and where the famers were open to collaboration and willing to share the experience with neighbours and other stakeholders. In the first farm a plot of 0.7 hectares with SPS cut and carry fodder bank of *Gliricidia sepium* and *Cratylia argentea* was established. The incorporation of these trees into the pasture system constitutes an alternative of fodder supply throughout the year, and particularly in the dry season. The tree richness of the plot was 12 species, at a density of 37 individuals/ha and a density of 23 trees/100 meters.

In the second farm 3.1 hectares with SPS- *Andropogon gayanus*, *Cynodon plectostachyus*, *Digitaria decumbens* and *Panicum maximum (cv mombasa),* associated with *Leucaena lecucocephala* were established to be used for grazing and browsing of woody species. The tree richness of the plot is 33 species, and tree densities of 109 individuals/ha and 9 trees/100 meters. In both farms, scattered trees with light to moderate canopy cover predominate and will require pruning to reduce shading effect on the pasture.

Also, the diversity of live fences was reinforced by increasing species richness and density (at least 25 individuals/100 meters, almost uniformly distributed). The woody component fulfils several functions as timber products, fruit for human consumption, feed resources, shade for livestock, soil conservation, carbon sequestration, provision of habitat for wildlife, among others. The richness and abundance of species reflect the multi-functionality of the silvopastoral system, improving the productivity and ecological performance and the potential for adaptation to climate variability.

3 Potou

The rural communities in Leona use several agroforestry practices to manage soil fertility, control soil erosion (water and wind), produce fodder and food, for medicinal purposes, and for firewood and timber production. Livestock production on rangeland is essentially the rule in the rural community of Leona, Potou, and the scarce grass vegetation in the dry season (8 months) forces the use of woody species. This situation leads often to an abuse of the tree fodder (pruning and sometimes immoderate cutting trees) that destroys the agricultural landscape, thereby enhancing precarious living conditions of agro-pastoralists.

Thus, trees are very important resources in rural livelihoods. Although most of the trees in the area are multipurpose species (Ickowicz et al. 2013), planted trees are often a response tospecific objectives such as the management of soil fertility and the provision of forage for animals, in addition to many other economic and social benefits, including human nutrition (Ickowicz et al. 2013). Thus, the benefits of trees and shrubs have to be understood not only as the potential to increase crop or grassland yields (Rusch & Pugnaire 2013) and the management of soil fertility, but also other economic and social well-being dimensions.

Further analysis of the species used in agroforestry together with the studies on ecological functions of AF trees led to the selection of species based on functional trais trees according to the constraints on each site.

To encourage adaptation of agro-technological practices, a series of field trials were established. These tests are based on a participatory approach to research and development enabling farmers to learn about the positive effects of integrating trees according to their functional roles in the production system.

3.1 Animal nutrition

Trees and shrubs are already a very important source of feed for livestock in the Sahel during the dry season, when several species maintain leaves and fruits. However, there are considerable indications of over-use; i.e. that the rates of consumption appear to be higher than tree and shrub productivity and recruitment. Fodder banks of trees can improve the availability of dry season resources for livestock considerably, and thereby they could be a palliative to the unsustainable use of natural resources in the village lands. Hence, field trials on fodder banks have been one priority activity in FUNCiTREE.

In the area of the Millennium Villages Project, mixed fodder banks have been established at two sites using combinations of four woody species (*Moringa oleifera*, *Ziziphus mauritiana*, *Bauhenia rufescens* and *Leuceana leucocephala*). The establishment of fodder banks was conducted with agro-pastoralist households practicing semi-intensive farming and the plots were arranged near water points (Figure 2). The species differ in their nutritious value and suitability for the different livestock species. Therefore, the use of a variety of species enables both enhancing the value of the feed offered, as in the case in Nicaragua, and also permits different mixtures that suit the dietary requirements of the different livestock species kept in the region. The leaves of the trees are harvested and dried before being distributed to animals in the form of balanced ratios composed of the fodder species for cattle and sheep. In both sites, seedling survival has been higher than 50%. The survival rate of *L. leucocephala* has been higher than that of other species (more than 98%) and that of *Z. mauritania*, the lowest (50% and 68% in each site, respectively).

These extension and demonstration activities have been planned and implemented under the guidance of FUNCiTREE researchers, to ensure that the procedures and conditions necessary for statistical analyses are followed.

Figure 2: Fodder bank Leuceana leucocephala established in the area of Wékhé, Potou, Senegal. Photo: Dioumacor Fall.

3.2 Other benefits provided by agroforestry trees

Other important functions of AF trees identified in Potou are soil erosion control and the protection of crops. In the communal production sites that have been promoted by the Millennium Villages Project (MVP), two main constraints have been identified, one related to the exposure of soils and crops to wind erosion and the other, the damage to crops caused by stray animals. The communities have expressed interest in setting up live fences and windbreaks using multi-function drought-resistant species in 2 parcels mainly used for horticulture, one managed by the community (30 households) and one by a women group (70 households).

In Potou, current fences against stray animals are mainly formed by *Euphorbia* spp. which is a spiny group of species, suitable to deter animals but which provides little additional benefits. We have promoted the the introduction of diverse live-fences around community arable areas. The species used (trees and shrubs), in addition to their role in the protection of crops and soils will provide other services (fruits, firewood and fodder).

Two species have been chosen, *Ziziphus mauritiana* and *Acacia mellifera*. They have been planted in two village areas, Wakhal Diam (2 ha) 400 plants and and in Syer, ca. 700. During the establishment of the live fences, leaders of peasant organizations were involved to ensure proper monitoring of irrigation and protection of plants to ensure survival. In both sites, survival rates have been low, but new trials will be conducted at a nursery established in Wakhal Diam by the Millennium Villages Project to grow live fence trees which will be planted during the rainy season 2013.

4 Segou

4.1 Assessment of tree production functions

The area of the Millennium Villages project has nine geomorphological units, with a dominant unit consisting of sand dunes and inter-dune. It was identified 11 types of parkland, the one dominated by *Acacia albida* occupies largest area (13.97% of the project area, followed by *Sclerocarya birrea* parkland with 10.93% of the area).

Determining the constraints and priorities of the users of the agri-forestry-pastoral area has laid the foundation for a sustainable exploitation of agro-forest parks, at the same time showing the need for an integrated approach that takes into account the interests of different social groups. Taking into account the functions of trees and shrubs in the agro-forestry park is essential in the process of diffusion and adoption of agroforestry technologies, as is the importance of attending the interests of various social groups. The main factors determining the adoption of agroforestry technologies are socio-economic, technical, environmental and cultural, and these factors vary depending on the particular technology. There is an impending need to implement accompanying measures, some of which fit into the overall policies or agricultural development programs.

Faidherbia albida, Adansonia digitata and *Tamarindus indica* were the most preferred species for planting by the farmers. These are feed and food provision species. Priority functions of trees and shrubs as perceived by people in the area are food, fodder and fuelwood, and it is necessary to disseminate relevant species for these functions in the entire area of the Millennium Villages Project. Sixteen species with a potential to provide fodder have been identified as a result of the surveys to assess local knowledge of the species. These species will be in the future tested as animal feed in the dry season (Table 1).

Table 1. List of woody species with potential for fodder provision identified in the area of the Millennium Villages Project in Segou, Mali.

N°	Fodder species	Part of the plant used
1	*Acacia seyal*	Leaves
2	*Adansonia digitata*	Leaves
3	*Anogeissus leiocarpa*	Leaves
4	*Balanites aegyptiaca*	Leaves
5	*Combretum glutinosum*	Leaves
6	*Faidherbia albida*	Leaves, fruits
7	*Ficus gnaphalocarpa*	Leaves
8	*Piliostigma reticulatum*	Fruits
9	*Prosopis africana*	Leaves
10	*Pterocarpus erinaceus*	Leaves
11	*Sclerocarya birrea*	Leaves
12	*Terminalia laxiflora*	Leaves
13	*Vitellaria paradoxa*	Leaves, fruits
14	*Zizyphus mauritiana*	Leaves

4.2 Implementation of planting and reforestation

The overall objective of the trials has been to contribute to improve the socio-economic and environmental conditions of rural populations in the project area of the Millennium Villages Project through the adaptation of current practices to those that promote multiple functions. Two kinds of practices have been identified as having the potential to fulfil these functions:

- Plantation of woody species in crop systems to increase the production of forage, firewood, improve soil fertility and contribute to food security, and
- Increase the diversity and cover of parkland woody species by promoting Assisted Natural Regeneration (ANR).

The main criterion for selection of woody species to be planted in crops has been the priority usages by the local communities (forage, timber and fruits). To assess these prioritized functions, focus group surveys were directed to different social groups (farmers, herders and women) from the area of the Millennium Villages Project. Sixteen priority functions fulfilled by agro-forestry trees and shrubs were identified, within three major categories, food production for humans, and the production of fuelwood and fodder. Nine different woody species, with different characteristics have been selected to be promoted for planting.

The supply of seeds was made by the Unit and Forestry Seed Herbarium of the Forest Resources Program CRRA in Sikasso and by own collections made by private nurseries. The production of nursery plants was made by a private nursery which was established by a collaborative program between the Institut d'Economique Rurale (IER) and the World Agroforestry Centre (ICRAF). In 2012, plants of all species, except for two (in total 5215) have been produced.

4.3 Plantation of preferred species

Within the Millennium Villages Project action area, and through community meetings, a planting scheme for 2012-2013 was established by which households decided about the species and number of trees to be planted. In total 1469 trees of 7 different species have been planted by 44 households in 7 villages. The majority of the trees were of *Faidherbia albida* (45 %) and *Adansonia digitata* (38%). The benefits provided by *F. albida* are provision of fodder (leaves and fruits) and improvement of crop yield. *A. digitata* is an important resource for human nutrition (leaves and fruits) and for the provision of fibres used in hand-crafts. By August 2013, 87% of the planted trees had survived, and approximately 3 800 new nursery plants of 6 species are ready to be planted. Fourteen species with a role in fodder provision during the dry season have been identified in the area.

5 Analysis of agroforestry functional portfolios with Bayesian Belief Networks

Bayesian Belief Networks (BBNs) are a generic modelling tool both for exploring data structure and for decision analysis under uncertainty; and are increasingly being used in ecological, environmental and resource management modelling**.** BBNs enable modelling of complex data structures, including (i) multiple practices implemented jointly on farms, (ii) correlation between probabilities of implementation of those practices, and (iii) correlation between household and farm characteristics.

Our studies have demonstrated the use of BBNs for 'deductive' reasoning regarding adoption practices, answering questions regarding the probability of implementation of combinations of practices, conditional on household characteristics. More uniquely, we show how BBNs can be used 'inductively' to answer questions regarding the likelihood of certain household characteristics conditional on certain practices being adopted. Adaptation of silvopastoral practices on farm is a multi-dimensional problem in which the farmers knowledge and preferences combines with scientific and technical knowledge through agricultural extension.

Diagnostics and systematic updating of knowledge are particularly interesting features of BBN not shared with other types of models. Particularly interesting is the possibility to specify a 'profile' of desired ecosystem services or functional traits of trees and to identify the likelihood of a 'portfolio' of trees corresponding to these characteristics. This is the essence of a so-called multi-functional approach to silvopastoral systems.

FUNCiTREE used Bayesian Belief Networks (BBNs) as an integrative framework for diagnosis and inference that linked ecological functions of agro-silvo-pastoral systems with the benefits received and perceived by the farmers. BBNs are graphical representations of conditional probability distributions which can be easily explored. This accessible way to visualize probability distributions enables a better understanding of the degree of uncertainty associated with different options, which makes the BBN approach an increasingly popular tool for decision-making support.

5.1 Steps to identify agro-silvo-pastoral tree portofolios using BBNs

We used BBNs to model the farmers' preferences for tree species, and their particular functions and uses, in other words, the functional portfolios selected by the farmers. For instance, in Rivas, Nicaragua, we obtained networks showing the likelihood that farmers would select a certain level of tree density, in live fences and in pastures, as well as the kind and proportion of different tree species, based on the production functions they wished to enhance, or on their belief about the benefits provided by the trees (Barton et al. 2013). These networks were built on the farmers' stated preferences to adapt their current silvo-pastoral system into an improved system in which several functions would be enhanced. For instance, one can ask, given a list of uses preferred by the farmer, what is the portfolio of species most likely to provide them? The BBN model 'answers' this question as likelihoods defined by the conditional probability tables in the network.

In Rivas, Nicaragua, through interviews, we collected information on farm and farmer characteristics and in particular, on the present and ideal composition of trees in the pasture according to farmers. Obtaining detailed information on the current and desired state of the pasture was facilitated by the use of a board representing a typical pasture on the farm. Using markers specific for the common tree species in the area, the farmer illustrated the current composition of the typical pasture. The farmer was then asked to modify the composition and abundance of trees until he obtained what he considered to be an "ideal" pasture. (Fig. 3.)

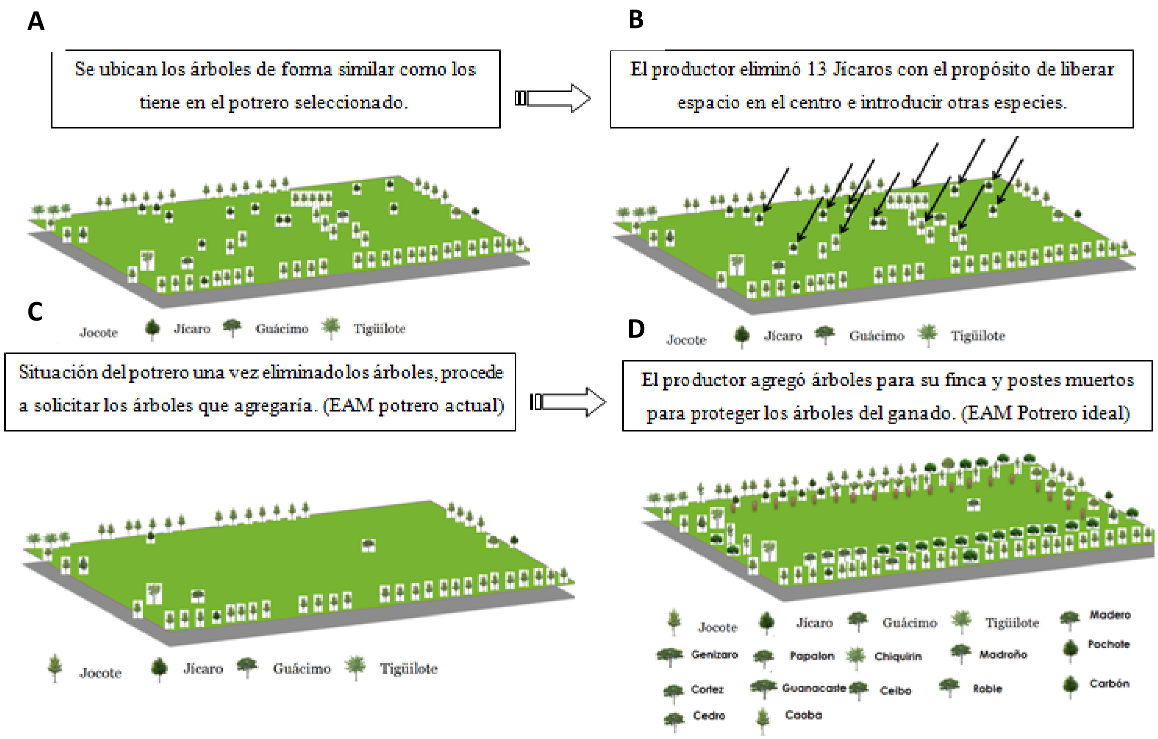

Figure 3: Example of the process of defining the current pasture and adaptation to the ideal pasture. ***A****: Trees are arranged on the board similarly to the position in the pasture .* ***B:*** *The farmers eliminated 13 'jícaro' (Crescentia alata) trees in order to introduce new species.* ***C****: Pasture without 'jicaro' trees.* ***D****: The farmer added trees and poles along the fence to protected the trees from livestock (Salazar 2012)*

Survey data and interviews showed that farmers prefer increasing tree density in live fences before doing so in the pasture area (Figure 3). They prefer trees that grow easily, with economic benefits and want to eliminate species with few uses and those which reduce pasture productivity due to excessive shading. In these general terms the results confirm that farmers prefer planting trees that provide direct ecological benefits, for example to soil fertility (Cerdán et al. 2012). The ecosystem services most often referred to are ensuring dry season fodder for animals, diversifying farm products such as fence posts, construction materials and firewood and providing scenic beauty to the surroundings.

According to Esquivel (2007), pasture productivity may start to decline as crown cover exceeds 30% or more. Tree cover in current pasture is around 15% on average, while farmers indicate in the simulation exercise that they would like tree cover of around 42% on average. An average farmer in the sample has 12 trees/ha in live fences, but would add 36 trees in an ideal plot. An average farmer currently has 7 trees dispersed in the pasture and would add 18 in an ideal pasture.

En live fences, the most common species are *Cordia dentata, Gliricida sepium* and *Spondias purpurea.* In improved live fences farmers would add mostly *Pachira quinata*. Currently, the most common trees scattered in pasture are *Guazuma ulmifolia* and *Cordia alliodora*, while the farmer would add *G. sepium, P. quinata, C. dentata*.

Crown size is an important factor when considering changing tree density in pasture. For example, species such as *Enterolobium cyclocarpum* and *Albizia saman,* provide ample fruit for animal fodder, but are not preferred by farmers due to their wide crown, since it is believed that species with a wide crown reduce pasture productivity. On the other hand, hardly any farmers chose to eliminate *E. cyclocarpum* and *A. saman* from their current pastures. Species with a crown size above average represent 20% of the trees chosen by farmers for the ideal pasture, including *Cassia grandis* (255 m^2), *A. saman* (175 m^2), *E. cyclocarpum* (130 m^2), *P. quinata* (122 m^2), *Leucaena* sp (102 m^2), *G. ulmifolia* (75 m^2). For example, despite its crown size *P. quinata* is the third most common species in pastures in the area. Farmers mention other characteristics that outweigh the disadvantages of shading such as good survival rates, rapid growth, commercial demand for wood and use as fenceposts. It is also believed to have great landscape value.

At a second stage in the study, the BBN model was validated with the farmers in a workshop, which provided the opportunity to demonstrate graphically linkages between the farmers' decisions, preferences, wishes and production priorities, and the probability of occurrence of different farm functions and of ecosystem service provision. These activities were part of the demonstration package implemented in Rivas.

The studies using BBN in FUNCiTREE are planned to be published in a featured issue in an international peer-reviewed journal (e.g. Ecology and Society) and the interactive models will be uploaded on a FUNCITREE page on the Hugin Expert webpage. This page will be open to the public.

6 Risk factors in adaptation of sylvo-pastoral technologies

In Nicaragua, the use of incentives (seed, labour and technical assistance), and of field trips in communities where there are ongoing activities that promote practices in sylvo-pastoral systems are considered critical. Also, the selection and design of the sites and the AFSs established was done in conjunction with the farmer and in accordance with the specific benefits sought by that farmer. This process also provided the opportunity to build farmers' decision-making skills and ability to adapt information to his/her own needs. It is also important to stress that the production of fodder and feed for the animals provided by the AFS is one component of the production system and that needs to be improved alongside with other factors. For instance, in order to reach the best relationship between animal production and multi-functional SSP it is necessary to consider the animal genetic potential, animal health and water availability (quality and free access). If these factors are not considered, they become bottle-necks that will impair the benefits obtained from the new technologies proposed which could even show a lower performance than the traditional system.

The farmers take risks when they adapt their production system by incorporation new technologies. It also takes time before the improvements result in higher production. Some values of multi-functionality, such as the insurance against drought spells and climatic variability, increase resilience of the system, but will likely not increase short-term productivity. Small-holder farmers may have limited economic capacity to take these kinds of risks. These matters need to be taken into account when promoting new technologies. Extension and demonstration activities should take into account the need of capital and labour, the long period of time expected from establishment to production, and the erratic rainfalls during the year that may hamper the establishment of trees from seed or seedlings.

In Mali, determining the constraints and priorities of users of agro-silvo-pastoral system in the study area has laid the foundation for a sustainable exploitation of agro-forest parks, and has highlighted the need for an integrated approach that takes into account the interests of different focus groups. It has also shown the need for the implementation of accompanying measures, some of which fit into the overall policies or agricultural development programs. The factors determining the adoption of agroforestry technologies are socio-economic, technical, environmental and cultural, and vary depending on the kind of technology that is promoted.

7 Extension strategy

The field trials are representative of the conditions faced by producers in the area, so they can be used as demonstration sites to generate motivation among neighbouring farmers and as centres of information exchange with public institutions and local universities. Neighbours and producer groups have come to know the process of the establishment, management and use of the sylvo-pastoral system, which is necessary to achieve the adaptation of current practices among other producers. However, this requires monitoring by local institutions to help with questions from farmers and sustainable replication in time.

In Senegal, the trials are based on a principle of participatory approach in research and development, with the aim to enable farmers to learn about the positive effects of the including trees into their AFS, according to the trees' functional characteristics. The participatory approach will promote ownership of the results in the target populations with the intention of promoting a wider dissemination.

Both in Mali and Senegal, FUNCiTREE activities have been integrated into the Millennium Village Project (MVP) extension program. This concerns the improvement and enhancement of agroforestry technologies (TAF) including fodder banks, life fences and windbreaks, assisted natural regeneration, the domestication of fruit trees. MVP will contribute to the dissemination of research results by integrating into its program activities within "Sustainable Land Management" (SLM), "Agroforestry and land restoration". At the end of FUNCiTREE, MVP starts a major reforestation program, dissemination and consolidation of achievements in the field of agroforestry technologies.

In Senegal, ISRA, through FUNCiTree, has been heavily involved in the implementation of the reforestation program in the choice of species, seed collection, the domestication of trees. ISRA is also a prime contractor in the following programmes in the area of Potou: «Tree Seed Program, and partners in the «Planning Program for Economic Development in the Niayes Zone».

In Segou, Mali, factors that determine the adoption of agroforestry technology include the enhancement of production functions (wood, fodder, food) and service functions (fight against erosion, maintain soil moisture, soil fertility improvement), the organization of farmers in associations, the support to farmers by extension services, land ownership and the level of land degradation. It is therefore necessary to take account of these factors in the development of agroforestry technologies to promote their adoption in these rural areas.

7.1 How can change be encouraged?

A synopsis of characteristics of extension programs for multi-functional sylvo-pastoral systems would include:

- Scale-up from plot to entire farms
- Identify farms with pastures that are highly multi-functional
- Farmers need to see concrete examples in order to trust new technologies; exploit positive linkages in farmers networks
- Farmers need to see tangible results on animal production associated with multi-functional AFS
- It is important to recognize farmers' priorities, needs and access to resources
- Use of co-existing crops during the tree establishment period

7.2 Lesson learned

The transition from research to experimentation has positive outcomes with regard to demonstrating that more trees in pastures leads to increased benefit provision all year long. The adoption process is slow and gradual (step by step), but farmers recognize the value of the trees and the services they provide to the farm. There is growing interest among farmers to retain and manage trees in pastures, both as individual trees in pastures and as live fences.

To increase multifunctionality in sylvopastoral systems it is necessary: 1) to recognize priorities, needs and access to the resources of the producers, 2) to identify and learn how the producer manages a portfolio of species that offer various services according to the farm production objectives, 3) use of co-existing crops during the tree establishment period.

In Potou, Senegal, despite a difficult environment, agro-pastoralists remain receptive to the views and experiences gained through the project. They are determined to integrate into their farming operations production systems that not only improve their income and living conditions, but also to reduce the risk of environmental degradation. The communities in Leona, Potou, however are poorly armed for the sustainable management of agroforestry systems due to many technical limitations such as the choice of species and inadequate knowledge about their biology, including the best seed collection periods, how to produce saplings and not least the management of the AFS. In FUNCiTREE, the MVP and Institut Senegalese de la Recherche Agronomique (ISRA) cooperated in the holding a series of capacity building sessions on technical seed collection, nursery and plantations.

While economic incentives are often mentioned by farmers, they do not seem crucial to successful adaptation of new species and sylvo-pastoral practices. When the system is multi-functional, options are many; when outcomes are also risky, copying successful practices on demonstration farms is a dominant extension strategy which takes advantage of positive linkages in farmers' networks.

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Based on the principles of functional ecology, FUNCiTREE addresses the provision of multiple services of silvopastoral systems (SPS) in semi-arid regions in Africa and Central America. FUNCiTREE aims to provide farmers in the regions with a portfolio of regionally suitable tree species that are capable of providing multiple services. The project integrates theories and concepts from agroforestry and ecological science and will provide a scientifically based model for the design of modernized SPS.

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