FARMERS' KNOWLEDGE OF TREE ATTRIBUTES AND SHADE CANOPY MANAGEMENT OF COCOA AGROFORESTRY SYSTEMS IN WASLALA, NICARAGUA

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ABSTRACT

The research was carried out in the Waslala Province of Nicaragua during June-August 2010. The purpose of the study was to assess the local knowledge about positive and negative attributes of shade trees in cocoa agroforestry systems, with reference to their spatial and temporal placement and to gender and time working with cocoa related perceptions. The methods comprised semi-structured interviews, were computer generated images were used as visual aid; ranking exercise of the use-value of trees; focus group meeting with members of the CACAONICA cooperative and three feedback sessions held towards the end of the research with farmers and extension workers of the community. Cocoa agroforestry was found to be a good production system for the region, with economical, ecological and social strengths and with a series of products and services coming from the shade canopy that were recognized by farmers as beneficial for them. The main production issues were the impact of fungal diseases and low productivity of some of the plots, thus the need to invest more time in the management of the shade canopy and maintenance of the plantation was recognized. Farmers had detailed knowledge about management of the shade canopy in a temporal scale but geographical attributes such as slope and aspect proven to be complex and with many factors affecting farmers' perception. Training on technical aspects received over the last two decades has made the degree of knowledge among the farmers to be somewhat leveled, resulting therefore on differences expected according to gender and time working with cocoa undetectable for the span of this research.

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1. INTRODUCTION

1.1 Cocoa agroforestry

The cocoa tree is ecologically connected with the rain-forest of Mesoamerica, where it evolved as an understory tree, and is one of the oldest known cultivated crops from these forests (Kennedy, 1995). Thousands of years ago in the earliest harvesting of cocoa pods in Amazonia, native people used it not for chocolate but for the fruit pulp. Later on, interest centered upon its seeds which were mashed to make a crude, bitter tasting paste, mixed with water, chili peppers, vanilla and maize to prepare a revered beverage. This resulted in cocoa being considered a sacred tree in Mesoamerican society, representing a bridge between earth and the heavens and offered in rituals as food to the gods to control rainfall and ensure the success of their crops (Young, 1994).

Nowadays, cocoa has become one of the most important cash crops of the lowland tropics. Africa is the world's major producer, but an important heritage is still evident in Central America, where it has shaped the economic, social and political foundations of a great number of people (Young, 1994). Smallholder farmers often integrate trees to use as shade in these cocoa plantations. These trees are retained from the native forests, selected from the natural regeneration, or planted to produce, besides shade, different products and services. Timber, fuelwood, food and medicine, are the most important products, but farmers also recognize services as soil erosion control or improved water quality, among others, reflecting a deep knowledge of the interrelations between the different components of this agroforestry system (Rice y Greenberg 2000; Bentley *et al*., 2004; Somarriba *et al*., 2004).

Nicaragua, following the same tendency than the rest of Central America, experienced a high deforestation rate during the 60's and 70's. This declined during the war years of the 80's, but increased again after the mid 90's, causing erosion, flooding and contributing to global climatic change problems (Utting, 1993). As a result, conservation initiatives have been taken in the region, with agroforestry research and dissemination being promoted by government and non-government agencies (CATIE, 2009; Utting, 1993).

Agroforestry can be seen as an ancient land use system practiced and developed over thousands of years by farmers worldwide. Since the 70's, agroforestry has been considered as a science that promotes the use of trees in farming systems in order to increase the productivity of different goods and services (MacDicken and Vergara, 1990)

1.2 Social characteristics and farm description of the Waslala cocoa producers

Waslala is a municipality located in a mountainous region in the north-east part of Nicaragua. It has a humid tropical climate and 40,000 inhabitants living mainly in rural areas where agricultural production is the most common activity (Sandino et al, 1999). It is one of the oldest and biggest of the cocoa producing areas in the country (CATIE, 2009).

According to CATIE (2009), the production of cocoa is mostly from agroforestry systems in small family run farms. 53 % of the farms are less than 10 ha and the average household size is of 6-7 persons. The same authors report an illiteracy rate of 42 %, where adults have the lowest formal education level. Farmers however have a practical knowledge of the production system inherited from their families and received from technical assistance of public and private institutions. This traditional knowledge involves the use of shade trees in cocoa production and emphasises the use of multipurpose trees, providing fruit and timber for household use and local market retail as well as conservation practices such as planting trees in water catchments and river banks (CATIE, 2007; CATIE, 2009; Lock and Sandino, 1999). Other crops such as maize and beans may or may not be intercropped with cocoa, and pastures for cattle and other livestock such as poultry and equine also have an important role in household subsistence (CATIE, 2009).

Farming activities are often differentiated by gender, with woman and children taking care of trees and livestock for household subsistence and men and older sons involved with cattle and agricultural productivity. Horses, pack mules and donkeys have a role in the transportation of cocoa, which consist on more than 70 % of the income of the farm, and other crops to stocking facilities (CATIE, 2009).

According to Lok and Sandino (1999), Waslala farmers' have an average dry cocoa production of 416 kg/ha/year. Differences in production among farmers are usually related to the incidence of *Moniliasis* fungus, the geophysical characteristics of the farm and management practices such as a good canopy cover control, proper maintenance of cocoa tree and weed control, among others. Problems that threaten the sustainability of the farm are more related to external than internal factors, such as natural disasters, especially flooding, climate change, which has led to a warmer and longer drier period, governmental or policy changes and instability of market demand and price (CATIE, 2009).

1.3 Local Knowledge and its role in agroforestry

The knowledge that native or local people have acquired of their environment with generations living in direct contact with nature is referred to as local knowledge (Inglis, 1993; Rajasekaran *et al.*, 1991; Kolawole, 2001). This knowledge often relates to the culture, identity and spirituality of the people (Rajasekaran *et al.*, 1991) and includes in-depth information about plant, animals, natural phenomena and their interactions (Inglis, 1993; Ulluwishewa *et al.*, 2008; Eisold *et al., 2006*; Ross and Pickering, 2002), which has shaped the development and utilization of traditional land uses such as cocoa agroforestry systems. These system and the techniques used to maintain them are generally low cost, ecologically friendly and easily communicated, and their preservation and documentation are seem to be increasingly important (Kolawole, 2001; Boven K and Morohashi, 2002).

Local knowledge is constantly evolving and relies on three stages of development (Kolawole, 2001). Observation, experimentation and validation. These stages are manifested in the awareness and perception of a phenomena as a problem and the motivation to solve the problem, the evidence that comes from the approach to the solution and finally the utilization of the validated approach. The enrichment of this knowledge will depend on how it interacts with new information, leaving researchers and extensionists with the role to interact with farmers in an appropriate way (Ortiz, 1999). Interactions between farmers and scientific information can be classified in four main types (Ortiz, 1997; Ortiz, 1999): Formative, when new knowledge is formed; Modifying, when knowledge is adjusted; Reinforcing, when scientific information confirms farmers' knowledge; and Confusing, when there is a conflict with the knowledge and the new information. In view of the fact that previous top-down approaches have proven to be unsuccessful (Kolawole, 2001; Boven K and Morohashi, 2002), these interactions together with the cultural and socioeconomic background should be taken into consideration when working on rural development.

Assuming farmers' have considerable traditional knowledge of trees growing in their farms, this study was conducted in order to formalize existing knowledge about the most valuable attributes of trees growing in cocoa agroforestry systems. Furthermore, farmers' criteria and preferences over canopy shade management on different temporal scales and geographical situations was explored and incorporated into a knowledge base.

1.4 Aim

To assess the local knowledge about attributes of trees in cocoa agroforestry systems in the Waslala province of Nicaragua, with reference to their spatial and temporal placement and to gender and time working with cocoa related perceptions.

1.5 Objectives

1. To determine farmers' perceptions on the positive and negative attributes of trees.

2. To determine the factors affecting farmers' decision making regarding tree cover on different stages of cocoa management and considering geographical differences of slope and aspect.

3. To determine whether there are gender and/or time working with cocoa specific variations of perceptions about desirable tree attributes.

4. To determine the use value of the main trees found in the farms

5. To develop a knowledge base (KB) of the local knowledge on the interactions of trees with cocoa in this agroforestry system

1.6 Research Hypothesis

1. Desirable tree attributes and management differ according to spatial and temporal variations in placements

2. Farmers have a good understanding of the positive and negative interactions between the shade canopy and the cocoa crop

3. There are differences in the perception of tree attributes and benefits according to gender and age

2. LITERATURE REVIEW

2.1 Cocoa ecophysiology

Cocoa (*Theobroma cocoa* L.) is a tropical woody specie, from the Malvaceae family and a geographical origin from South America (Motamayor *et al.,* 2002). Regarding ecological requirements, cocoa grows well with temperatures between 19°C and 30°C, precipitations among 1,200 and 3,000 mm per year and a relative humidity over 70 % (Alvim and Kozlowski, 1997). Ideal soils should be well drained, with depth of 50 to 100 cm and good water retention capacity (Silva, 2001). In the wilderness the tree can reach heights up to 25 m in height, but when in cultivation, it is managed until heights of 3 to 5 m (Motamayor et al., 2002).

Cultivated cocoa represents one of the oldest agroforestry systems in tropical America, known since pre-Colombians times by the Mayas, where it was placed under the shade of selectively thinned forests (Bergman, 1969).

2.2 Trees on cocoa farms

Agroforestry systems are complex synergistic systems in which trees interact with other trees, crops, animals or shrubs, to provide a greater output of goods and services that are provided by either agriculture or forestry alone. Thus trees used in these systems differ from those used in agriculture or forestry in the sense that they are required to provide both products and services (Wood, 1990). According to Asare (2006), more often than not farmers disagree with researchers about the desirable traits for selecting trees for their cocoa farms, especially when undesired physiological or technical aspects of the management of a tree occur in species with high social, economical or traditional value for the farmer. The same author provides a descriptive list of multipurpose tree species adequate for use on cocoa farms in western Africa.

Diverse attributes has been mentioned as desirable for shade trees by the literature. Among these we can find crown architecture, phenology, compatibility with crops, growth rate, root architecture, leaf size and deciduousness as the most mentioned (Beer, 1987; Muschler, 2000; Bellow y Nair 2003). Medina (1950), also mentioned adaptability, easiness of propagation and reproduction method.

When farm activities are divided, for example when men are dealing with productivity of crops and woman with household subsistence, this may lead to different interactions with the products and services of agroforestry systems and may affect the importance that each group gives to specific species (Leach, 1994; Barret and Brown, 1995; Gausset *et al.,* 2005). Gender is therefore an important point to take into consideration when working with perception of tree attributes on farms.

A description of the most important tree products and services is given below.

2.2.1 NTFPs

Local communities around the world depend on trees and plants for a variety of goods and services such as provisioning services (food, medicine, fuelwood, fodder, construction, handicraft), regulating services (shade), supporting services (soil fertilization) and cultural services (ornamentation, rituals) among others. To have a quantitative and qualitative understanding of the uses to which local people have of these services can be useful not only to identify potential conservation issues (ie. overharvesting of some species), but also to recover and promote knowledge that could otherwise disappear from communities (Belem *et al.*, 2007)

One of the main direct concerns of women is the health of the family and especially of the children. This often results in a strong interest and knowledge on the medicinal properties of plants and trees and with products related to diet and cooking activities, such a firewood, leaves, flowers, oil and fruits which act as a supplement to cultivated staple crops and contribute to food security and the daily needs of vitamins and minerals (Thorsen and Reenberg, 2000; Gausset *et al*, 2005; Herzog, 2004). In rural areas fuelwood is often the main (or only) source of energy and timber with high calorific value is often highly appreciated by farmers (Herzog, 2004)

In an ethnobotany study on Burkina Faso, communities highlighted the extent to which tree species contribute to farmers' livelihood, and cited a number of examples where trees have traditional medicinal veterinary values, such as branches, barks, leaves and fruits of different local species being used to cure wounds, snake bites, diminish tooth pain, combat diarrhea, intestine parasites and increase milk production (Belem *et al.*, 2007).

2.2.2 Timber products

The wood taken from trees in agroforestry systems is a valuable asset for the construction of houses and fences and the production of tools and domestic utensils and farmers are often ready to accept a reduction in the crop yield if they value the tree products (Herzog, 2004). Nonetheless, damage of cocoa plants during harvest of timber trees should not be underestimated, given that the physical characteristics of the cocoa plant, which makes them susceptible to structural damage (Beer *et al.*, 1998).

When selecting timber trees for cocoa fields, farmers do not only look for the traditional desirable traits such as rapid growth, good form, high wood density and resistance to diseases and pests, but also place an emphasis on lowering competition and antagonism in cocoa by selecting trees that promotes complimentary or neutral interactions, for example considering traits including crown size and shape, root structure, leaf size, shedding rhythm and nitrogen fixation properties (Asare, 2006).

2.2.3 Environmental services

Growing cocoa in agroforestry systems is gaining attention as a means of improving biodiversity conservation in otherwise pure agricultural systems by acting as a buffer zone between protected areas and more intensive agricultural land, by providing a continuum of trees that act as wildlife corridors in fragmented landscapes and by providing a habitat for mammals, birds and other wildlife species of the region where they occur (Schroth *et al*, 2004; Sonwa *et al*, 2007).

A study done in Costa Rica (Reitsma *et al.*, 2001) showed little difference in the number and diversity of species between natural forests and cocoa agroforestry farms. Although this shows that cocoa farms provides a suitable habitat for bird species, and stop-over points for migratory birds (Wille, 1994; Beer *et al*, 1998) the conservation importance of some specialist birds could be higher for those found in the forest, suggesting that although shaded cocoa can support more diversity than other tropical crops it cannot substitute natural forests (Bentley, 2004).

Besides biodiversity, the highest services priorities that trees have on agroforestry systems are maintenance (or improvement) of soil fertility and microclimate amelioration (Wood, 1990) and an important reduction in the amount of fertilizers and pesticides use in comparison with shadeless plantations (Muschler, 2000)

2.3 Tree-crop interactions

Interactions between shade trees and crops in agroforestry systems have been widely reported in the scientific literature (Beer, 1987; Beer *et al*, 1998; Araya, 1994; Barradas and Fanjul, 1986). Although competition is inevitable when more than one species are sharing the same resources, it is believed that the system as a whole can benefit from their interactions (Somarriba *et al*, 2001). In the next section a review of the main benefits and drawbacks of tree-crop interactions in agroforestry systems is presented.

2.3.1 Physiological benefits from shade trees

From a physiological point of view, the main benefit that crops such as cocoa receive from shade trees is a reduction of the biotic stress placed on the plant due to an amelioration of climatic extremes, altered soil conditions and a reduction in light transmitted to the understory (Beer *et al*., 1998). By regulating microclimatic conditions, shade trees are known to stabilize and even out cocoa yields throughout the seasons, making planning and harvesting more efficient for the farmer and prolonging the life span of the crop. As a result of the reduced stress, crops can withstand physical conditions of lower quality or lower external inputs, such as fertilizer, and become a more suitable option for small scale farmers in tropical countries (Beer, 1987; Purseglove, 1968).

The main microclimatic conditions influenced by shade trees are presented below.

2.3.1.1 Light availability

According to Beer (1987) under a tree canopy there is a reduction of net radiation during the day, because less solar radiation reaches that surface, and according to Brenner (1996) this is particularly beneficial at the beginning of the season when soil can reach high temperatures causing crop damage.

The energy absorbed by shade trees can be considered as the balance of long and shortwave radiation, as pointed out by Brenner (1996), (equation1).

Equation 1:

$$Rn = S\,(1\text{-}a) + R_{1,d} - R_{1,u}$$

Where,
S: solar radiation
a: albedo
$R_{1,d:}$ longwave radiation absorbed by the surface
$R_{1,u:}$ longwave radiation emitted by the surface

The same author explains that with clear sky and no tree protection $R_{1,d} - R_{1,u}$ becomes negative, because at night the atmosphere becomes cooler than the soil or vegetation, potentially causing low temperature stress. Under tree canopy however, downward long wave radiation fluxes from the canopy would be similar to upward longwave fluxes from crops, thus the progression of understory cooling is considerably slower, explaining therefore why less frost is observed under trees than in open fields (Brenner, 1996).

The need for some degree of shade level is also supported by the fact that cocoa growth and pod yield decrease with high radiation intensity (Zuidema *et al.*, 2005; Isaac *et al.*, 2007).

2.3.1.2 T°, wind speed and Humidity

Trees can affect both the speed and turbulent structure of wind pattern in a field, reducing the susceptibility of crops to desiccation and damage (Beer *et al.*, 1998). Wind changes together with the changes that trees produce on radiation will have considerable effects on the energy balance of the plant, because shade trees affect all of the environmental variables to which stomata respond. They reduce vapor pressure deficit, leaf temperature and photosynthetic quantum flux density (Brenner, 1996). Competition for water between overstorey and understorey also influences stomatal response by changing leaf water status and microclimate. Therefore plants growing under trees may have different total conductance from those grown in monoculture, changing both their evapotranspiration and photosynthetic rates (Brenner, 1996).

Studies in Central America have show that coffee plantations under shade can reduce average maximum temperature by 5º to 6ºC, increase average minimum temperature by over 1,5ºC and substantially reduced vapor pressure deficit compared to unshaded plantations (Barradas and Fanjul, 1986). Reduced heat-load on coffee plants during daytime and reduced heat losses at night explain this effect (Somarriba *et al.*, 2001).

2.3.2 Soil conditions

2.3.2.1 Organic matter and nutrient cycling

The content of organic matter in the soil tends to increase over time in agroforestry systems with material added by leaf fall and pruning residues. In a study done in Costa Rica with cocoa and coffee (Beer *et al*., 1998), soil organic matter increased by 21 % in a system including pruned leguminous trees. According to Araya, (1994), agroforestry can also increase the number of bacteria and fungi in the rhizosphere and help stabilize nematodes populations below critical levels. At the same time, reduction of crop stress to environmental factors improves crop tolerance to infestation and diseases from these nematodes (Araya, 1994; Beer *et al*., 1998).

Nutrient cycling and nitrogen fixation will be strongly affected by the choice of the shade species, since different species have different production of below and above ground biomass and decomposition rates (Palm, 1995). The management of trees is another point to take into consideration, with practices as pruning, fertilization and residue management being tools for the control of nutrient transfer from trees to soil (Beer *et al*., 1998).

Isaac *et al.,* (2007) showed in an 8 years old cocoa plantation with neighbor trees that closeness to these trees increased cocoa biomass production mainly because of shading and nutrient manipulation. In particular the authors found that nutrient uptakes were higher closer to the trees, and that close to the trees, soil exchangeable K increased while available P decreased and N stocks were unaffected.

2.3.2.2 Erosion, runoff and soil structure

Runoff and soil erosion are lower when using shade tree systems, because accumulation of litterfall and pruning residues maintained as a mulch layer reduces the impact of raindrops on the soil, particularly during storm events (Beer *et al*, 1998; Ong *et al*, 1996). The mulch will also improve the retention of soil moisture during the dry season and improve infiltration rates, bulk density and water storage capacity (Ong *et al*., 1996; Rigui *et al*, 2008).

Root systems are involved in some of the major favorable effects on soil and crops resulting from the application of agroforestry techniques, especially if trees use soil resources not available to crops. According to Rigui *et al*., (2008) these include carbon enrichment of the soil through root turnover, interception of nutrients and improvement of physical properties such as aeration and structure.

2.3.3 Competition

Although it is suggested that competition may be more severe between similar species than between species with contrasting growth habits, the opportunity for complimentarity of resource use between species is restricted by the fact that all plants are competing for the same, usually finite, resources (light, CO2, water, nutrients); Thus there is extensive overlap between species in their resource requirements (Ong *et al*., 1996).

Competition for light is the primary limitation when water and nutrient are freely available. However in many tropical systems, water (eg. Semi arid regions) or nutrient availability (acidic, leached or degraded soils) rather than light is the major limiting factor (Ong *et al*., 1996), and roots from shade trees compete for moisture in the dry season and oxygen in the wet season (Vernon, 1967; Beer, 1987)

2.3.4 Pest and diseases

Schrot (2000), in a review of pest and diseases in agroforestry systems, conclude that due to the complex interactions between plants and pest or diseases (which is increased in diverse systems) "..agroforesters should integrate into their decisions the full range of traditional and scientific knowledge on the interactions between plant species, planting designs and management practices on one hand, and pests, diseases and their natural enemies on the other". The same author indicates that having a variety of species in the same area may reduce the risks of outbreaks simple by reasons of probability, even if a plant species has no effect on the pest or disease, and that good agroforestry designs can improve the tolerance of crops by reducing crop stress. It is also known that some tree species tends to attract certain pests or diseases, imposing therefore restrictions for their use in agroforestry systems, and the improved site condition can benefit the development of pests and diseases organisms as well as their natural enemies (Schrot, 2000).

Some fungal diseases of cocoa, such as black pod (*Phythphora palmivora*) or frosty pod (*Moniliophthora roreri*) are known to be favored by increased humidity as a result of an increase of shade (Smith, 1981; Somarriba *et al*, 2001). This variable becomes even more important if the site is naturally moist, such as river sides or valley bottoms, making a good management of the shade canopy of high significance for the health of the crop (Somarriba *et al*, 2001)

2.4 Shade canopy management

Understanding traditional techniques, management and use of trees on cocoa farms is essential if researchers and extension agents want to inform or promote agroforestry as a feasible way of production (Arnold and Dewees 1998; Bannister and Nair 2003; Garen *et al*., 2009) and has been pointed out by Lok and Sandino (1999) that farmers' tree management strategies include a thoughtful selection of shade tree species and a conscious approach to planting locations. This corresponds with recommendations given by (CATIE, 2007), on the improvement of cocoa production by choosing an appropriate botanical composition, spatial distribution and adequate management of the shade trees in the farm.

According to Somarriba (2005), shade levels and the botanical composition are in general inadequate on small scale farmers of Central America, so when trying to determine how much shade should have a given cocoa plantation, the following factors presented should be taken into account.

2.4.1 The temporal scale

2.4.1.1 Age-dependent changes

One of the key factors to consider for this point is the increase of the self-shading amount as cocoa grows older. As defined by Somarriba (2005), self shading comprises the shade cast by branches and upper leaves of the cocoa plant plus the shade cast by neighbor cocoa trees. When cocoa is young, the crown of the plant is small and it does not fully occupy the space available to grow nor the solar energy available for photosynthesis. Even more, they are sensitive to overheating and drying out, needing therefore a higher amount of shade from the tree canopy in these early years of the plantation (Somarriba, 2005). Other factors affecting the self-shading capacity are the frequency and intensity of pruning, the origin of the cocoa plant (grafted plants tends to be shorter and more open crowned than seed plants), and planting distance and planting configuration design (Somarriba, 2005).

Because of the greater sensitivity to light in young cocoa plants, the main role of canopy trees probably changes from light regulation to enhancing nutrient stability as the crop ages, thus management of the upper canopy trees is critical to the productivity of the crop (Isaac *et al.*, 2007). As Lok and Sandino (1999) pointed out, pruning of shade trees is a common practice done not only to increase cocoa productivity but also as a management activity to control fungal diseases such as *Moniliasis*, with a general recommendation of pruning twice a year.

2.4.1.2 Annual cycle

Variations in light requirements of cocoa are also dependant to its annual cycle, mainly in the stages of flowering and fruit development and filling. Though leaf flushing, fruit maturation, radial growth of stem, branches and roots and quiescent phase should also be considered (Alvim, 1984; Somarriba, 2005). For optimal cocoa performance, a good shade canopy should offer variable shade levels within a year, being adjusted to the phenological rhythms of the cocoa plant (Somarriba, 2005).

According to Somarriba (2005), farmers in Costa Rica tend to adjust the shade canopy to the cocoa needs by selecting shade tree species according to its deciduousness and physical characteristics; by managing the diversity of shade trees in the plot in order to adjust the canopy to the light needs of cocoa; by arranging the distribution and planting distance of shade trees and with management techniques as pruning or thinning.

2.4.2 Site characteristics

2.4.2.1 Slope

According to Somarriba (2005), the steepness modifies the speed at which the shade of a tree moves in the slope. In the morning, when the sun is in the lower part of the horizon, the tree projects the shade to the upper part of the slope with an elongated shape, then as the mooring advance, the shade will move slowly down the slope and will come closer to the tree, having by midday a more round shape; in the afternoon, the shade will move with increasing velocity to the lower part of the slope, becoming larger and therefore less intense (due to a bigger surface occupied by the same shade). Somarriba (2005), mentioned that cocoa farmers know this shade effects, therefore they tend to have a lower amount of shade trees up the slope, where shades move slower.

These steepness degree not only make this variations in the velocity of the shade movement more accentuated, but also projects shade as a geographical feature, increasing its effect on the amount and quality of light reaching cocoa (Somarriba and Quezada, 2005). According to the same author, these variations on the velocity of the shade caused by the steepness degree could be comparable with the effect on the shade velocity caused by different heights of trees located on flatlands, where taller trees produce a larger and less intense shade than shorter trees.

2.4.2.2 Latitude and aspect

The orientation of the mountain ranges determines whether different exposures will receives direct sunlight on different stages of the day (east exposure on the morning and west exposure on afternoon, if the mountain range has a north-south trend) or if it will be similar within the day but it will vary throughout the year (north and south exposure with a east-west trend of the mountain range); the sun movement over a year and the latitude where a plantation is located determine the angle at which the sun rays are reaching the ground and the maximum sun height for that place, causing that exposures facing the equator will receive for more months a higher amount of direct solar radiation (Somarriba, 2005), influencing therefore the management done to the shade canopy according to this variable.

2.4.2.3 Microclimate and adjacent features

Factors as prevalence of high cloudiness, which reduces solar radiation; morphology of the surrounding land, ie a valley surrounded by high mountains casting shade most of the day; the adjacent vegetation, affecting the lateral shade reaching the plot; the rainfall regime, which will determine the amount of trees to have without compromising cocoa productivity due to water competition; and soil fertility, that also determines the amount of shade to have, since under shade the demand of cocoa for nutrients is reduced and trees provide nutrients through litter and diminish erosion processes (Somarriba, 2005).

According to Somarriba (2005), all the factors previously mentioned, such as age of cocoa, annual phenology and the different site characteristics, are affecting the shade cast over a plantation, and even if they are independently analyzed, the combine effect of all of them should not be overlooked when designing the system.

3. METHODOLOGY

3.1 Study area

The study was conducted in Nicaragua, in a tropical cocoa-growing region of the Waslala municipality, located at the 13°20’ N latitude and 85°22’ W longitude (Figure 1) from June to August 2010. This region has an annual precipitation between 2000 to 2800 mm, with a dry period between February and May, annual temperatures between 18°C to 26°C and an average altitude of 420m. Ultisoles and Alfisoles are the predominant soil types (Sandino et al, 1999). By 2008, the population of Waslala district was 40,000 inhabitants, and there were more than 2,000 farmers for whom cacao was the main cash crop (CATIE, 2009).

Figure 3.1: Location of the study area, the community of Waslala in the RAAN province of Nicaragua.

3.2 Knowledge base system approach (KBS)

The Knowledge base system approach (KBS) (Sinclair and Walker, 1998; Walker and Sinclair, 1998), which was developed to address the need for systematic recording of qualitative knowledge through a formal method of knowledge acquisition and representation, has four phases for the process: a scoping stage; definition of domain stage; a compilation stage and a generalization stage. For a detailed account of the method proposed, see Walker and Sinclair (1998). This study completed the first three stages, with the final generalization phase as no part of the remit of this study.

3.3 Scoping and definition of domain

A first stage of scoping with a period of recognition and familiarization with the community and second stage of definition of domain where the setting of the preliminary boundaries to what the knowledge base will be about, with the areas to cover, the farmers to be selected according to their experience and availability and a stratification of the participants (Walker and Sinclair, 1998) was undertaken.

In these phases of the process farms were randomly visited in order to develop a general picture of the geography and production system of the area; members of the board directive and extension workers from the biggest cocoa cooperative in the region (CACAONICA) were met in order to explain the research objectives and methodology of the study. A presentation was given to them and good advices were received to improve some technical aspects of the interviews, such as key productive periods, temporal physiological changes of cocoa, some typical characteristics of the farms and local terminology, among them. Factors that may relate to differences in knowledge, such as time working with cocoa and gender, were identified for stratification purposes, and logistical support was gain to meet with the farmers.

3.4 Knowledge elicitation

A third stage of compilation, where iterative knowledge was elicited from the selected informants through interviews and other methods such as ranking exercises, group meetings and feedback sessions is presented in the following section.

3.4.1 Focus group meeting and annual cocoa forum attendance

From a focus group with the directives of CACAONICA cooperative and information gathered on the annual forum on “Alliance improvement for cocoa modernization in Waslala” the economical, social and historical context of cocoa production and evolution in this region was compiled. The forum gave the opportunity to meet with the main stakeholders of the cocoa sector in Waslala, such as farmers working with cocoa, representatives of the major buyer (Ritter Sport), coordinators of the CATIE project PCC (Central America Cocoa Project) and NGO’s promoting cocoa sustainable production.

As recommended by Huntington (2000) for these activities, collection of new data is not as important as trying to interpret what is already known and trying to better understand the informants’ perspectives, which for this research was helpful by putting in context the present reality of the production system in the region.

3.4.2 Semi-structured interviews

With this method, participants were guided in the discussion by the researcher but the scope and evolution of the interview followed the farmers’ train of thought. There were no fixed questions or time limits (Huntington, 2000), but a list of topics to discuss was used to help with the fluency of the interview (see appendix 1). This type of interview, which was more a conversation than a question-answer session, provided an opportunity for unexpected an important information to be discussed while at the same time providing structure to ensure that useful information is not missed (Huntington, 2000).

The 30 interviews done were held in the farmers’ field, since many of the questions were related with geographical attributes of the landscape, it was essential for the good development of the conversation to be able to point out specific features of the farm and explain processes onsite.

Plate 3.1. Interview with farmer on the field in the locality of Waslala arriba

3.4.3 Ranking exercises

A ranking of the use-value of trees was done using quantitative ethnobotany. For this method, informants were asked to describe the different uses of trees found in the farm and rank the importance of the tree for each use described. The values were then added giving a global value for each species and the results were compared by tree and use, producing in the end a ranking of trees according to their use-values (Phillips 1996; Gausset, 2004). According to Gausset (2004) with this method, problems of consensus and of comparability of data are minimized and can better account for a diversity of interests and opinions than the PRA matrix ranking, but are also more time-consuming. Ranking use value of trees also provides information on whether farmers rely on few multipurpose trees or on a diversity of specialized species (Gausset, 2004).

Women working in the farms gave to each tree a value from 0 to 1.5, for the following categories: wood, fuelwood, food, medicine, fertility and shade. An independent ranking was created for each one of these categories through the average given to the trees in all the farms; and with the added value received for each tree in all the categories, the total value was calculated.

When developing the rankings, if the specie had a value from 1.1 to 1.5 for an specific use, it was considered to be highly important for that use; if it was from 0.6 to 1, it was important; and if the value was from 0 to 0.5, of low importance. These values are presented in the ranking with the letters (a), (b) and (c) respectively. The reason for this classification is that some use categories (as wood, for example) have few desirable species; while categories as shade or fuelwood, have many species with the desired traits.

As explained before, the last column in the table, called total value, is the result of the addition of all the values given to a tree in the different categories. Thus, this category could be considered as the ranking of the best multipurpose tree.

3.4.4 Visual aids

Three dimensional computer generated images were created and used in the interviewing process, in order to facilitate the explanation and understanding on questions related with shade preferences for cocoa according to temporal variations and geographical differences. The images used showed different canopy shade covers on cacao plantations where farmers had to select from predetermined category ranges according to cocoa age, slope, aspect and preferred tree distribution (see appendix 1).

3.4.5 Feedback sessions

Three feedback sessions were conducted at the end of the interviewing process, two were held in selected farms of willingly farmers on the two villages with the highest number of interviewees, and the other one was in the cooperative offices with the extension workers. Posters with the principal results were shown and discussion was encouraged in order to clarify conflicting statements from informants and minimize any researcher bias. In these sessions new knowledge was elicited and an important part of the research was fed back to the community.

Plate 3.2. Feedback session with farmers of "Caño los Martinez" locality

Plate 3.3. Extension workers participating in the feedback session held on july 2010.

3.5 Data analysis

For the recording, management and representation of the knowledge gathered through the research, the Agroecological knowledge Toolkit (AKT5 for Windows Version 5) (Dixon et al, 2001) was used to create a knowledge base. This allowed a formal representation of disaggregated knowledge in the form of unitary statements and their translations into formal grammar, which was then represented in a hierarchical way and in diagrams as a visual representation of the knowledge (Walker and Sinclaire, 1998) (appendix 3).

4. RESULTS AND DISCUSSION

4.1 General aspects of the production system

4.1.1 Some History

The first productive variety of cocoa to come to Waslala was “forastero” in 1973. At that time farmers started to plant cocoa and a market for the seeds developed. This lasted until 1980, when the civil war brought economic and political instabilities, and reduced this new market to a minimum. At the end of the war (1989), a more secure and stable situation was formed, and former soldiers/farmers again looked for agricultural crops to produce.

Reintroduction of cocoa production among the farmers’ started in 1987 with a two year state project, called “Carlos Fonseca Amador” which brought in more productive hybrid seeds, and gave farmers seeds, plastic bags, and technical assistance for free.

In 1991 starts a program of genetic improvement in Nicaragua, with 70 ha planted with clones of the best genetic material in the locality of “El Recreo”, brought from the experimental site of CATIE in Costa Rica. In the same period, around 3.5 ha with material from el Recreo were planted in Waslala, which then increased to 22 ha by 2002. In 1992 a German NGO “Pro Mundo Humano”, expanded cocoa production in this region; planting 400 manzanas (280 ha) within 5 years.

Following the increase in production and supply of cocoa seeds in 1996, this NGO initiated a program with the purpose of producing export (i.e higher) quality cocoa by introducing training to improve the fermentation process, improve cocoa tree pruning, and improve management of the shade canopy.

The farmers that received this training got together and formed the CACAONICA cooperative in the year 2000, with 69 partners. By 2010 the cooperative had 446 partners and was the biggest cooperative in the region. In 2007 the cooperative became a partner with CATIE in the PCC (Central America cocoa project), formalizing and improving training with extension workers (among other objectives).

The training received by the farmers made the interview process much more fluent, since technical terms such as nitrogen fixation, pollination or erosion control were a common part of the interviewee's vocabulary.

4.1.2 Production, market and prices

According to some of the "forum" figures, the average cocoa area per household for the Waslala region is 1.7 ha, with a yield of 328 kg/ha/year. The price paid for cocoa depends on the production system, organic cocoa is sold for US$: 3,500/ton and traditional cocoa for US$: 3,150/ton. The yields and the price of organic cocoa in Nicaragua is the highest in Central America, and the demand for this product is increasing exponentially.

Compared to other crops in the region, cocoa is highly competitive due to its high price (the revenue per ha can be 4 times the one for coffee and 6 times the ones of crops such as maize and beans), low labor requirements, and year-round production, although there is a pick in production between October and January, cocoa plantations produce throughout the year, which is of great importance to small holders in subsistence production systems.

4.1.3 Production problems

The main problem affecting cocoa production is crop losses from pest and diseases. There are two main diseases affecting production in Waslala; frosty pod (*Moniliophthora roreri*) and black pod (*Phytophthora palmivora*), both are fungal diseases which increase their dispersion in highly humid and badly ventilated environments. These characteristics, together with the long rainy season of Waslala, make the area highly susceptible to these diseases, especially in lowlands with drainage problems.

Good management practices, particularly related to control of the shade canopy and the self-shading of cocoa trees, are therefore highly important.

A secondary problem is irregular production; 30 % of the cocoa trees account for 70 % of the total production. According to Somarriba *et al.* (2010), this is mainly due to a high genetic variability of cocoa trees in the same plot, incompatibility between trees, lack of pollination agents, and bad management or maintenance of the plantation.

4.2 Characteristics of farms in study

In Waslala, the land is privately owned, with a size of the cacao plots in the farms ranging between 1 mz (0,7 ha) and 7 mz (4,9 ha), and an average of 3 mz (2 ha) for the 30 farmers interviewed. Cocoa is the main cash crop produced, but the farms also produce beans, maize, poultry and products such as fruit, fuelwood and timber are taken from the shade trees.

The most common trees used for shade on the farm, were fruit trees such as *citrus* species, banana, plantain, avocado and mango; and service and timber trees as guaba (*Inga spp*.), laurel (*Cordia alliodora*), cedro (*Cedrela odorata*), poró (*Erithryna poepigiana*), mahogany (*Swietenia macrophylla*) and eucalyptus (*Eucaliptus spp.*).

Most of the farms visited were in a mountainous area, with the range running in a north-south direction, resulting in slopes facing east or west. Half of the farmers were in a steeply sloping land, while the other half were on more gentle slopes. This classification was done by the farmer's themselves, together with the researcher on the field, and steepness was not measured explicitly.

The period of time that the farmers have been working with cacao is in the range of 4 to 30 years, with an average of 18 years, coinciding with the time when training started in the beginning of the 90's. When asked about how many trainings sessions they had had, the most common answer where "uff, several" or "I think more than fifty", making it unfeasible to quantify this exactly. It is likely that this amount of training leveled farmers' knowledge, reducing differences related to age or time working with cocoa.

4.3 Waslala KB

This knowledge base consists of statements and causal diagrams obtained from 30 interviews to farmers working with cocoa, plus 11 interviews of the use value of trees conducted with women working mainly in the house. To refer to the "coco-nica" AKT5 knowledge base see appendix 3.

Out of the 30 farmers, 5 were women (widowers or divorced) and were managing the cocoa plots together with their children. The farmers covered 9 villages surrounding Waslala, and their age ranged from 23 to 65 years of age. The range of time that farmers had been working with cocoa is showed in table 4.1.

Table 4.1. Range of time that farmers in study had been working with cocoa

Farmers time working with cocoa (years)	n
1-10	12
11-20	10
21-30	8
average	17

4.4 Knowledge about shade trees advantages and disadvantages

Farmers were asked to mention and explain all the advantages and disadvantages of having shade trees on their farms, which are shown in a simplified way in figure 4.1.

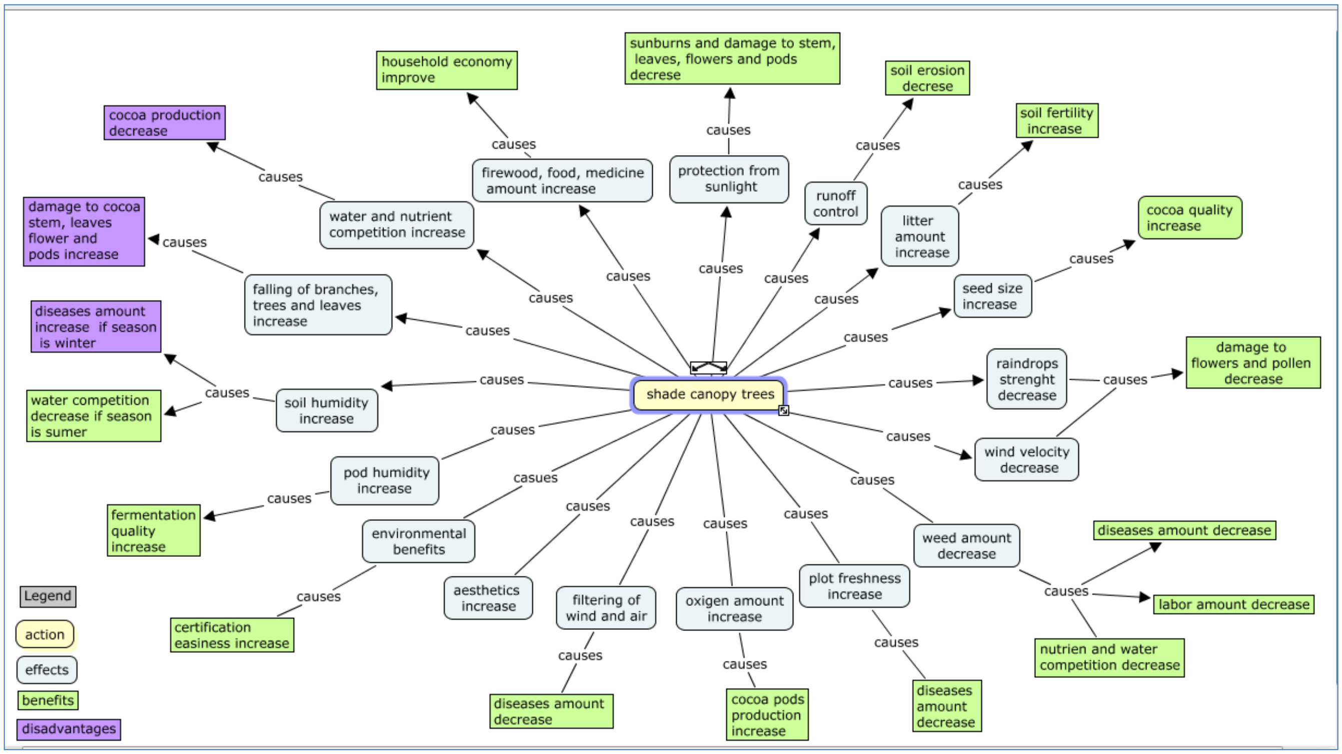


Figure 4.1. Diagram representing farmers' knowledge of the advantages and disadvantages of having shade trees with cocoa as an agroforestry system on their farms.

4.4.1 Advantages

The two more important benefits of the shade trees, mentioned by 100% of the interviewees, were the protection of the cocoa crop from the sun and the provision of different products such as wood, food, fuel and medicine. Temperatures are high throughout the year, especially in the dry period (26 °C average), and according to the farmers, the heat and direct sunlight damages young leaves, flowers and cocoa pods, and if it is too high, it can even kill the cocoa tree completely. Young cocoa trees are the ones how suffer the most from the sun.

Another benefit is a difference in the quality of the seeds, being generally bigger when they grow under shade. Moreover, shade improves fermentation by increasing humidity inside the pod. It is interesting to point out that when talking about the benefits of shade trees, all of the woman farmers mentioned an improvement in the quality of the product, while only 40 % of the male farmers did. This is probably due to the differentiation in work by men and women, with the women taking care of the processing of the seeds (fermentation and drying) and the men in charge of the plantation management. In the case of these women farmers, both activities were undertaken by them.

A high number (90%), of the interviewees mentioned an improvement in soil fertility due to litter decomposition. Erosion control through decreased runoff speed was mentioned by 72 % of farmers overall, but by 100 % of farmers on steeply sloping land. A decrease in the strength of the rain drops, which causes damages to flowers and pollen, was considered as a benefit by 69 % of the farmers, but with one of them pointing out that the effect is the opposite if the trees are too high. Protection from strong winds that damage cocoa directly through the destruction of flowers and breaking of branches, and indirectly through the falling of the branches or trunk of the shade trees, was mentioned by a 62 % of the interviewees.

Improved soil humidity and freshness of the farm was mentioned only by 55 % of the farmers, but the timing of the interviews (which was in the middle of the rainy season), could have been a factor of influence. Improved weed control was mentioned by 48 % of the farmers, although all the farmers who had cocoa plots under the age of 20 mentioned this benefit; one of the farmers said that when cocoa is mature, weeds are suppressed more by for the cocoa trees and litter than by the shade trees.

Environmental benefits, aesthetic value, oxygen production and control of diseases through filtering of air by the trees, were mentioned by less than 10 % of the farmers each.

Plate 4.1. 15 years of age cocoa plantation and its litter production

4.4.2 Disadvantages

28 % of the farmers said there were no disadvantages in having shade trees, and most of the farmers agreed that if the planting distance between cocoa and shade trees is adequate, competition for nutrient and water is low (depending also of the competitiveness of the tree species). Falling trees, branches and, according to one farmer, even leaves, produce damage to the cocoa trees in some way. According to the literature (Ryan, et al., 2009), this could be considered irrelevant on a large scale.

72 % of the farmers considered increased humidity in the rainy season a disadvantage of the use of shade trees; the main problem being the proliferation of diseases such as black pod and frosty pod. According to 80 % of the farmers this could be controlled by a good management (pruning) of the shade canopy.

4.4.3 Feedback on benefits and disadvantages

To compare the views of the extension workers with those of the farmers, an exercise of valuing the different advantages and disadvantages of shade trees were scored on a scale from 1 to 5 (with 1 as the most important) and this score was used in the three feedback session conducted for this study (table 4.2).

Table 4.2. Qualitative evaluation of shade trees attributes reported in the three feedback session

	Feddback sessions		
	extension workers	farmers group 1	farmers group 2
Benefits			
sun protection	1	1	1
rain protection	3	2	2
wind protection	2	1	2
litter production	1	1	1
erosion control	3	1	1
weed control	1	2	4
soil humidity	2	2	1
fruit quality	5	1	1
freshness	2	2	1
disease control	4	3	2
environmental aspects	1	1	1
Products			
fuelwood	1	1	1
wood	1	1	1
food	2	1	1
medicine	4	1	1
Disadvantages			
fell of shade trees	4	3	2
fell of trees branches	5	3	2
fell of trees leaves	5	5	5
water and nutrient competiton	4	4	4

The evaluation showed a general agreement between farmers themselves and with the extension workers, although with some slight differences for specific points. The main advantages of having shade trees said in the interviews were corroborated in the feedback sessions, such as protection from the sun and the wind, litter production, erosion control and the different products obtain from the trees. Is interesting to point out that improvement of environmental aspects did not came out regularly in the personal interviews, but when asked about it in the feedback sessions farmers were really keen to give a high importance to it, scoring higher than other advantages as rain protection or weed control that were more frequently mentioned in the interviews.

It is also noticeable that services and products provided by shade trees had much more importance for the farmers than the disadvantages, scoring the later ones very low in the three feedback sessions.

4.5 Importance of shade trees diversity

According to CATIE (2009), the use of a diversity of shade tree species in the cocoa plots in Waslala is part of the traditional management of these farms, and has a large significance in the livelihood of these people. This coincides with the responses given in the interviews; with 93 % of the farmers answering that they prefer to have a diversity of trees. Only two farmers replied that “as long as they give shade the species doesn’t matter”.

The benefits of tree diversity preference is explained by the different products and services obtained from different species, as shown in Figure 4.2.

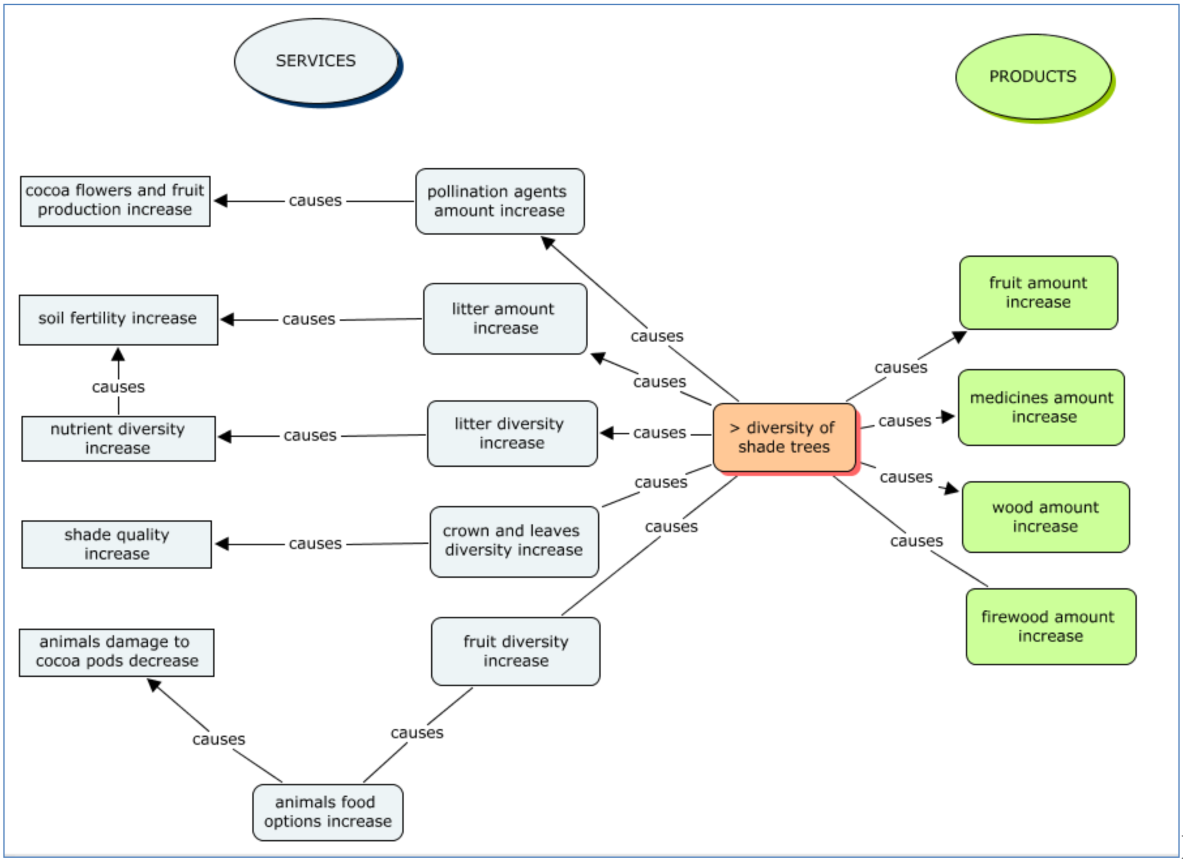


Figure 4.2. Farmers' knowledge on the benefits of having a diversity of shade trees on their farms.

After a deeper probing on the services provided by diversity of shade trees, some interesting reasons were given, especially in terms of soil fertility. Farmers explained that by having different trees, the soil receives different types of leaves, therefore receiving different types of nutrients, which improves the fertility of the soil. One of the woman farmers explained this effect relating it to cooking, she said, "It is like when you cook a soup, the more ingredients you put, the better it gets". Farmers also said that a diversity of trees shed leaves at different times through the year, so with a diversity of species the soil is protected throughout the year, and cocoa is never left without shade.

With a diversity of fruit trees, farmers not only have a greater variety of food for their own consumption and sale, but they also increase the amount of pollination agents reaching the cocoa plots, which helps increase pod production. Moreover, there is a great variety of fruit for animals to browse, reducing the number of cocoa pods they consume.

A variety of different qualities of construction and fire wood, and medicines for the family and the animals, were further stated benefits.

4.6 Knowledge about shade tree characteristics

4.6.1 Physical characteristics

According to farmers' criteria, retention of shade trees on their cocoa farm is done mainly for the provision of shade. The literature has described some morphological attributes of the shade trees that determine the level and quality of sunlight reaching the cocoa plants in the lower stratas. The most important of these are tree height, crown shape and density, leaf size, and phenological patterns (Somarriba, 2005). In table 4.3, farmers' preferences of these characteristics are presented.

Table 4.3. Preferences on morphological characteristics of shade trees on cocoa farms

Shade trees characteristics		Preferences (%)
deciduouness	*evergreen*	93
	deciduous	7
growth velocity	*fast*	90
	slow	10
height	*small (<15 m)*	0
	medium (15-25 m)	90
	large (> 25 m)	10
leaf size	*small*	21
	big	14
	doesnt matter	66
crown type	*open*	97
	close	3

Farmers' preference for evergreen trees over deciduous was noticeable, with only two farmers disagreeing. This result is the opposite to the preferences found in the Talamanca region of Costa Rica, where most of the farmers chose deciduous trees

(Vazquez, 2003). In the case of Waslala, this preference can be explained by the phenology of the deciduous trees found in the farm (cedro, laurel, madero negro (*Gliricidia sepium*)), which lose leaves in the dry season, leaving the cocoa tree with less shade when they need it the most.

Farmers also preferred fast growing trees, saying that with these have shade, and other products such as wood, sooner than with slow growing species.

Tree height was considered a factor with several implications for the farmer. Trees which are too small produce too much shade, causing more disease problems by increasing humidity and decreasing ventilation. Trees which are too tall were said to be more difficult and dangerous to manage, to cause more problems with falling branches, and were too susceptible to damage by the strong winds that are common in this region. The height preference also depended on the tree function, with farmers preferring smaller for easier harvest conditions and preferring taller timber trees in order to have more wood.

Leaf size proved to be a difficult question, with farmers explaining that there are too many sizes and they did not think that absolute leaf size was (66%). Farmers said that what they really want is a diversity of types of leaves because the smaller ones provide better shade but the bigger ones provide more organic matter.

Many authors recognize sparse or open crowns to be a desirable attribute (Beer, 1987; Bellow and Muschler, 1999; Muschler, 2000), which coincides with the preferences expressed by the farmers over this attribute, with 97 % of them choosing open crowns.

4.6.2 Indicators of good shade

When farmers were asked what indicators would they use to describe a good shade level, the majority implied that it was something they sensed and when they felt that it was neither too hot nor too humid. Other indicators mentioned were the good health of the cocoa trees, no diseases, good sized pods and seeds, been able to see the sunrays reaching the understory, and that the weed level was not too high.

Plate 4.2. Cocoa tree with a good pod production

4.7 Knowledge about shade management

4.7.1 Temporal scale

4.7.1.1 According to cocoa age

It is known that cocoa trees need more shade in their earlier stages of life, when the leaf area is small and young plants are more susceptible to desiccation and dehydratation. Farmers in Waslala deal with this issue by planting *musaseas* at high density for the first 4 or 5 years after establishing cocoa, to provide adequate shade for the young crop and generate money before cocoa starts producing. When the cocoa trees start self shading, these *musaseas* are partially or completely removed.

The results extracted from the computer-generated images showing different shade canopy densities through the life of the crop (see appendix 1), show a clear consensus on the need of diminishing the canopy as the cocoa advances in age. 83% of farmers chose to have a high density when cocoa is less than 3 years, the remainder found that the highest density image had too many trees so they chose a medium density. When cocoa was around 10 years of age, all of the farmers that had previously chosen high density shade trees, selected to go down to medium; while the interviewees that had chosen medium density, went down to low density canopy cover. Finally, when cocoa is over 25 years old, 79 % chose to have a low canopy density, while the rest chose a medium canopy with management to lower the shade intensity.

Plate 4.3. One year old cocoa plantation accompanied with *musaseas* as shade canopy

4.7.1.2 According to cocoa phenology

When farmers were asked about interventions done to the canopy to adjust to the phenological rhythm of cocoa (such as fruiting and flowering periods), they said that pruning, done to diminish shade tree cover and self-shading of cocoa, is done only once a year (occasionally twice, if the canopy grows too vigorously afterwards). This intervention is carried out just before the beginning of the rainy season (May), when the high temperatures of summer are over and the humidity starts to increase, and fungal diseases start to become an issue. A couple of farmers also pointed out that this is the best time for the interventions because after the rains the trees are slippery and pruning becomes more dangerous.

Muñoz and Beer (2001) showed that cocoa produce most of its fine roots at the beginning of the rainy season, while the shade trees do so at the end of the rainy season. Therefore if pruning of shade trees and fertilization of cocoa is done at the beginning of the rainy season, competition between trees and crop can be greatly reduced. According to Alvim (1984) and Somarriba (2005), trees and crops as cocoa required more sunlight in the flowering and fructification periods, and the shade canopy should be manage in order to synchronize the amount of shade with these annual phenological cycles. Even though farmers were aware of some of these aspects, they stressed more practical matters at the moment of explaining the timing of their interventions, such as easiness of pruning before the rains, custom, and trainings recommendations.

Plate 4.4. Farmer pruning cocoa tree in order to control self-shading in the locality of Zinica.

4.7.2 Geographical attributes

4.7.2.1 Plot slope

73 % of the farmers in Waslala said they prefer more shade in the steeper areas; 23 % were indifferent; and only one farmer said he preferred more shade in flatter areas.

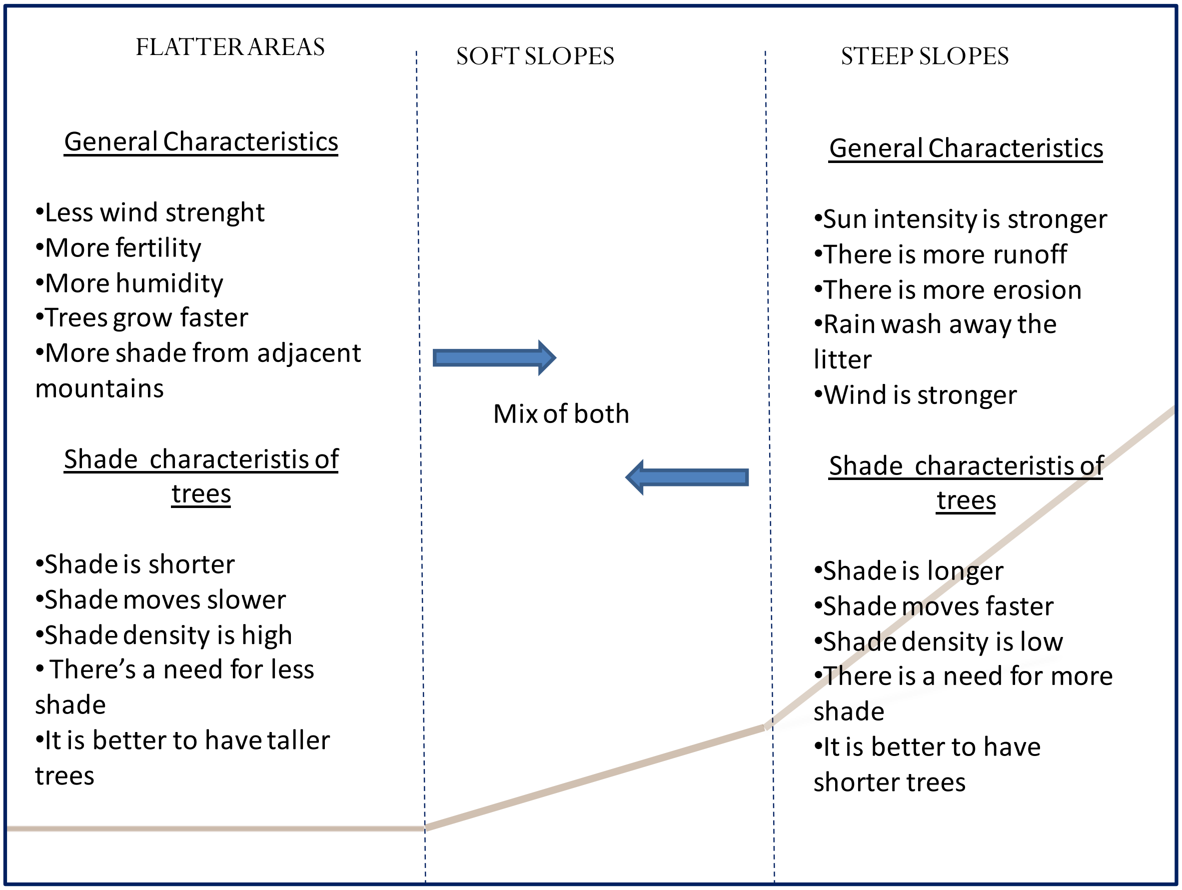
Farmers' preference for shade according to plot slope, and their specific situation (if they have one or more than one slope situation on the farm) is presented in table 4.4.

Table 4.4. Farmers' preference on shade canopy density according to plot slope

		Shade density		
Farmers plot slope	*n*	more in steeper areas (%)	more in flatter areas (%)	indiferent (%)
Steep slopes	*5*	80	0	20
Steep slopes with flatter areas	*10*	80	0	20
Soft slopes	*10*	80	10	10
Soft slopes with flatter areas	*5*	40	0	60

On farms that presented the situation of having cocoa plots in steep slopes there was a trend to prefer more shade in this situation than in flatter areas; while on farms with only gentle slopes or flatter areas, there is increasing indifference over the degree of shade required. In order to have a better understanding of the reasons given by the farmers for these preferences, more probing was done in further interviews about the site and shade characteristics occurring in different slope situations. These are summarized in figure 4.4.

Figure 4.4. Site and shade characteristics according to steepness degree.



Flatter areas were considered to be too humid, especially in the rainy season, with some farmers dealing with excessive moisture not only by controlling the shade canopy, but also using other techniques as drainage furrows. There was a general agreement that the shade of the trees in this area was more intense than on steeper slopes, where farmers felt that the shade went too far away from the tree. Farmers also pointed out that on steep slopes trees that are too tall can have problems with strong winds, and this had caused crop losses in the past. Steeply sloping ground was also considered to have fewer nutrients in the soil, and increased litter loss through surface runoff.

Farmers comments on shade characteristics according to slope showed that they perceive differences occurring in distinct site conditions, but many factors are acting together and a careful approach should take place when considering their responses. According to the literature (Somarriba, 2005), site characteristics, as latitude, slope, aspect, cloud prevalence and lateral shade from surrounding vegetation or geographical attributes, modify the quantity and intensity of the sunlight reaching the crops. Farmers mentioned shade of trees moving faster in steeply slope and being shorter in flatter areas, but because of the sun rotation and the effect of adjacent geography this is not so simple, and differences are occurring at an annual and daily basis (for more information see Somarriba, 2005). Waslala is located in a mountainous region, with farms having the cocoa plots with some degree of slopes and/or in flatter areas surrounded by mountains. It is possible that the perceived stronger intensity of shade from trees on flatter areas comes from the shade provided by geographical barriers and/or from a quicker recovery after pruning of the shade trees due to the better soil conditions than in steeply slopes. This factor wasn't mentioned neither by farmers nor extension workers, and therefore, more research could be conducted to understand the farmers point of view.

Farmers and extension workers said that in the rainy season there should be more shade on slopes than on flatter areas, mainly because of production losses through fungal diseases, which were greater in flatter areas due to its higher humidity and drainage problems. Farmers also pointed out that soils on steeply slopes had more fertility problems, and according to (Somarriba and Quezada, 2005), the higher the sunlight reaching a cocoa plant, the higher would be the need of water and nutrients for this plant to survive, needing therefore more shade on unfertile soils to balance the amount of light with nutrient availability.

4.7.2.2 Aspect

Farmers' were asked whether they have any shade preference on land with different aspects. Farmers did not recognized directions such as East or West, but they did identify which part of the cocoa plots were exposed to the sun in the morning or the afternoon.

The majority of the interviewees (53 %) stated that aspect did not make any difference, that both slopes receive sunlight, one in the morning and the other one in the afternoon. One farmer said that he preferred more shade on the east (i.e morning) slope, and the rest (43 %), preferred more shade where the sun heats in the afternoon (i.e west).

Differences on shade requirements according to aspect are more related to differences in latitude and north-south aspect (i.e. higher amounts of sunlight reaching north aspects in the southern hemisphere). For the characteristics of the farms in study, with farms having east and west sides, differences on shade preference were not expected, and when the farmers were asked to explain why did they choose to have more trees on the west side, the main response was “because it feels hotter”.

4.7.2.3 On farm tree distribution

A table with the characteristics of each one of three functional types: timber trees, fruit trees and service trees is given in figure 4.5.

Figure 4.5. Main characteristics given by farmers to the three tree type function

Timber trees	Fruit trees	Service trees
Characteristics:	Characteristics	Characteristics
•Trees are taller •In general: decidiuous •Small leaves •Give less shade •Are more competitive •In better sites can give valuable products sooner	•Are kept shorter so harvest is easier •Less pruning is done to them, in order to keep the fruits •Give more shade •Closeness to house is prefered	•Fixation of Nitrogen •Produce more litter •Are less competitive •In general: evergreen •Give good shade

Trees were found mixed all over the farm, but due to their specific attributes, some were found in specific areas. For example, timber trees seem to fit rather well for flat areas, where their high competitiveness is softened by the bigger amount of nutrients and water in this area. Moreover, they grow taller and give less shade than the other trees, which is what farmers want for flatter areas.

On the other hand, a higher proportion of service trees could be placed on steep slopes; they are in general easier to manage, because there is no need for them to grow as tall as timber trees and can be pruned without affecting fruit production. They also fix nitrogen and give more nutrients, which are needed more in this kind of areas.

Not all of the farms had all the situations described. Furthermore, some of the trees result from natural regeneration and the farmer only decides whether to keep them or not; this depends on the objectives of each farmer.

When farmers were asked over the preferred distribution of the shade trees on the farm: random, in lines or clumped (see appendix 1); 86 % of the interviewees chose in lines, in order to have a uniformly distributed shade and because is easier to do management operations afterwards. This coincide with the literature, since according to Somarriba (2002), when the shade canopy is found uniformly in the plot, the cocoa plants and the fruit production are developed more homogeneously. Only 4 farmers (14 %) chose a random distribution and no farmer selected a clumped disposition of trees.

Visual aids such as the computer generated images and diagrams showed in the feedback sessions proven to be useful when trying to explain the different geographical situations and spatial distribution of trees on the farm.

4.8 Use value of trees

From the interviews done to women working in the farms' houses, a table with the use value of trees was created (table 4.5). The diversity of trees found in some farms was considerably high, resulting in a large number of trees mentioned only by one or two farmers. In the other hand, tree species as guaba and laurel, were mentioned in all the farms. With this in consideration, only tree species that were mentioned more than three times were used to develop the rankings (15 species in total). To see the list of scientific names please refer to appendix 2.

Table 4.5. Ranking of the use value of trees.

	Use value of trees						
Ranking	wood	fuelwood	food	medicine	fertility	shade	total value
1	*laurel (a)*	*acacia (a)*	*aguacate (a)*	*eucalipto (a)*	*poró (a)*	*guaba (a)*	*eucalipto (5,1)*
2	*cedro (a)*	*guaba (a)*	*mango (a)*	*limon (b)*	*guaba (a)*	*poró (a)*	*guaba (4,8)*
3	*eucalipto (b)*	*eucalipto (a)*	*guineo (a)*	*madero negro (b)*	*guineo (b)*	*acacia (a)*	*aguacate (4,8)*
4	*zapote (b)*	*laurel (a)*	*pejibaye (a)*	*naranja (b)*	*acacia (b)*	*aguacate (a)*	*mango (4,6)*
5	*acacia (c)*	*guayaba (a)*	*naranja (a)*	*mango (b)*	*guayaba (b)*	*madero negro (a)*	*naranja (4,5)*
6	*aguacate (c)*	*cedro (a)*	*limon (a)*	*guayaba (b)*	*madero negro (b)*	*guineo (a)*	*limon (4,4)*
7	*madero negro (c)*	*aguacate (b)*	*zacote (b)*	*aguacate (c)*	*naranja (b)*	*eucalipto (a)*	*guayaba (4,1)*
8	*guaba (c)*	*zacote (b)*	*guaba (b)*	*laurel (c)*	*mango (b)*	*mango (b)*	*laurel (4,1)*
9	*mango (c)*	*mango (b)*	*guayaba (b)*	*zacote (c)*	*aguacate (b)*	*pejibaye (b)*	*zacote (4,0)*
10	*poró (c)*	*naranja (b)*	*poró (c)*	*guaba (c)*	*pejibaye (c)*	*laurel (b)*	*acacia (3,8)*
11	*naranja (c)*	*limon (b)*	*eucalipto (c)*	*guineo (c)*	*limon (c)*	*naranja (b)*	*guineo (3,6)*
12	*pejibaye (c)*	*madero negro (b)*	*acacia (c)*	*cedro (c)*	*zacote (c)*	*guayaba (b)*	*madero negro (3,6)*
13	*limon (c)*	*poró (c)*	*cedro (c)*	*acacia (c)*	*cedro (c)*	*limon (b)*	*cedro (3,6)*
14	*guayaba (c)*	*pejibaye (c)*	*madero negro (c)*	*pejibaye (c)*	*eucalipto (c)*	*zacote (b)*	*poró (3,5)*
15	*guineo (c)*	*guineo (c)*	*laurel (c)*	*poró (c)*	*laurel (c)*	*cedro (b)*	*pejibaye (2,8)*

Many of the trees had medicinal properties; with snake bite antidotes, tetanus antidote, animal insecticide, painkillers, and remedies for diarrhea, fever, headaches, vomits, gastritis, cold, sickness and premenstrual pains being some of those mentioned.

It was also observed that the further the town was away from a town or from the roads, the more the women new about homemade remedies. When commenting this to an especially knowledgeable farmer, she said that because of the distance to town, road conditions, availability of medical help, and money issues, knowing all these medicinal properties was the only way she had to help her family and herself.

Species that were mentioned only one time scored high values in some of the categories. For further research, could be useful to consider these species if diversification programs are aimed at. According to Gausset (2004) use-value rankings can document the potential importance that different trees are assigned by different people and give information on whether people rely on a few multi-purpose trees, or whether they rely on a diversity of specialized trees.

5. CONCLUSIONS AND RECOMMENDATIONS

For the area in study, cocoa agroforestry has been identified as a good production system for the farmers. The agroclimatic conditions of Waslala fulfill all the ecophisiologycal requirements of cocoa. The production system is organic and retention of trees growing naturally in the area is a common practice among the farmers, resulting in an ecologically sustainable system. The price of organic cocoa in Nicaragua is the highest in the Central American region. The labor required per ha is less than for any other crop produced in the area and cocoa is produced continually throughout the year (with some months more productive than others), which is a great advantage for small holders in subsistence production systems.

The tree canopy produced a series of products and services that were recognized by farmers as beneficial for them. The services were related with the amelioration of the site conditions through regulation of sunlight reaching the crop, wind control, litter production and runoff control. According to the farmers, these effects improved the quantity and quality of cocoa and helped control erosion in areas where steep slopes are predominant. The products taken from the shade trees were mainly timber, fuelwood, fruits and medicine, and from the results taken from the feedback sessions, all products were of great importance for the livelihood of the farmers. Farmers showed a clear understanding of the relationship between having a diversity of shade trees and the provision of products and services, giving interesting comments on how diversity can improve shade, litter and cocoa seeds quality, and protect from diseases and animal consumption.

Most of the farmers interviewed believed that disadvantages as competition for water or nutrients may exists in the system, but they don't consider it important for the production because it can be controlled by using an adequate planting distance, a good management of the shade canopy, by pruning or thinning, and the selection of the right species for the right places. On the other hand, they gave more importance to production losses from damage caused by felling of trees and branches than was expected from the literature, which largely considers these issues as insignificant.

Knowledge about the shade canopy management and silvicultural practices done to the cocoa plants over time were similar for all the farmers and congruent with the literature. This seems to have been highly influenced by the training received over the last two decades, due to the input of more and new resources coming from different institutions. Therefore, the degree of knowledge among the farmers on technical aspects of management has been somewhat leveled, thus one of the hypothesis of this thesis (differences in knowledge according to the amount of time of the farmers working with cocoa and gender related differences), was falsified.

When dealing with the management of shade according to differences in slope and aspect, farmers' knowledge also showed a practical component, giving more reasons and deeper answers when they had a variety of different situations on their farm, showing that practice and the specific reality that farmers have to face plays an important role in their understanding of certain cause-effect relations. More situations are generally found on bigger farms, but what seems to increase the level of experience is having different situations, not the farm size itself.

Differences between shade needs according to slope proved to be confused and complex even for the extension workers, with a lot of discussion and contradictions appearing in the feedback sessions. A high proportion of farmers stated a preference for having more shade when the slope is steep and, mostly due to high humidity levels, having less shade on gentle slopes. Extension workers agreed with this for the rainy period, but said it should be the opposite in the dry season. Although a consensus was reached among farmers and extension workers on the preference of having more timber tress on flatter lands and more service trees on steeply slopes, there was a lot of confusion to why. Many factors are known to affect the specific need of shade of a particular place, with slope (although important) only one of them, so a careful approach has to be considered when analyzing this data. As a recommendation, it can be said that more training on shade canopy management could be useful in this region.

Doing the interviews in the native language of the farmers proved to be of great importance, reaching deeper levels of discussion and exchange of ideas through a fluent conversation. It is recommended that further research in this field is done in the language of the people in study.

Even though one of the advantages of producing cocoa is a low labor requirement, there is a need to invest more time in the management and maintenance of the plantation in order to increase cocoa yields and production, with techniques such as grafting, manual pollination, sanitary pruning of cocoa pods and a good management of the shade canopy as primary recommendations.

REFERENCES

Alvim, P; Kozlowski, T. (1977). Ecophysiology of Tropical Crops. ACADEMIC PRESS. London, UK. p 279 –313.

Araya, M. (1994). Distribucion y niveles poblacionales de *Meloidogyne* spp. y *Pratylenchus* spp. En ocho cantones productores de café en Costa Rica. *Agronomia Costarricense*, 18:183–187.

Arnold, M. and Dewees, P. (1998). Rethinking approaches to tree management by farmers. ODI *Nat Res Perspec*, 26:1–9.

Asare, R. (2006). Learning about neighbour trees in cocoa growing systems: A manual for farmer trainers. *Development and Environment*. Vol 4.

Bannister, M.E. and Nair, P.K.R. (2003). Agroforestry adoption in Haiti: the importance of household and farm characteristics. *Agroforestry Systems,* 57:149–157.

Barradas, V.L. and Fanjul, L. (1986). Microclimatic characterization of shaded and open-grown coffee (*Coffea arabica* L.) plantations in Mexico. *Agric For Meteor* 38: 101–112.

Barrett, H. and Browne, A. (1995): Gender, environment and development in sub-Saharan Africa. Pp. 31-38. In: Binns, T. (ed.): *People and Environment in Africa*. Chichester, John Wiley.

Belem, B., Nacoulma, B.M.I., Gbangou, R., Kambou, S., Hansen, H.H., Gausset, Q., Lund, S., Raebild, A., Lompo, D., Ouedraogo, M., Theilade, I. and Boussim, I.J. (2007). Use of Non Wood Forest Products by local people bordering the "Parc National Kaboré Tambi", Burkina Faso. *Journal for Transdisciplinary Environmental Studies,* 6(1)1-21.

Beer, J.W. (1987). Advantages, disadvantages and desirable characteristics of shade trees for coffee, cocoa and tea. *Agroforestry Systems* 5:3-13.

Beer, J., Muschler, R., Kass, D. and Somarriba, E. (1998). Shade management in coffee and cocoa plantations. *Agroforestry Systems* 38: 139–164.

Bellow, J.G; Nair, PKR. (2003). Comparing common methods for assessing understory linght availability in shaded-perennial agroforestry systems. Agricultural and Forest meteorology. 114: 197-211.

Bentley, J.W., Boa, E. and Stonehouse, J. (2004). Neighbor trees: shade, intercropping, and cocoa in Ecuador. *Human Ecology*, 32:241–270.

Bergman, J.F. (1969). The distribution of cacao cultivation in pre-columbian America. Ann. Assoc. Geograph. 59:85-96.

Boven, K. and Morohashi, J. (eds). (2002). Best practices using indigenous knowledge (*The Hague: Nuffic / Paris*: UNESCO / MOST).

Brenner, A.J. (1996). Microclimate modifications in agroforestry. *In* Tree Crop Interactions – A Physiologycal Approach. Eds. Ong C K and Huxley P. Chapter 5, pp. 159–188. CAB International, Wallingford, UK.

CATIE. (2007). Competitividad y ambiente en los territorios cocoateros de Centroamerica. *Proyecto Cocoa Centroamerica*, *Documento de proyecto*, 166p. Turrialba, Costa Rica.

CATIE. (2009). Determinación del potencial de mantener, aumentar o adoptar diferentes sistemas de cocoa (*Theobroma cocoa*) con base en el rol relativo y absoluto que éstos juegan en las estrategias de vida de los hogares en el municipio de Waslala, Nicaragua. *Proyecto Cocoa Centroamerica,* 41p. Turrialba, Costa Rica.

Dixon, H.J., Doores, J.W., Joshi, L., Sinclair, F.L. (2001). Agroecological knowledge toolkit for windows: methodological guidelines, computer software and manual for AKT5. School of Agricultural and Forest Sciences, University of Wales, Bangor.

Eisold, J., Tonsjost, S., Bollig, M. And Lindstadter, A. (2006). Local and ecological knowledge on natural resource management- a case study from north western

Namibia. Abstract on Conference on International Agricultural Research for Development. Bonn, October 11-13, 2006. 6 p.

Garen, E., Saltonstall, K., Slusser, J., Mathias, S., Ashton, M. and Hall, J. (2009). An evaluation of farmers' experiences planting native trees in rural Panama: implications for reforestation with native species in agricultural landscapes. *Agroforestry Systems* 76: 219–236.

Gausset, Q. (2004). Ranking local tree needs and priorities through an interdisciplinary action research approach. *The Journal of Transdisciplinary Environmental Studie,* 3(1): 1-17.

Gausset, Q., Yago-Ouattara, E.L. and Belem, B. (2005). Gender and trees in Péni, south-western Burkina Faso. Women's needs, strategies and challenges. *Danish Journal of Geography,* 105 (1): 67-76.

Herzog, F. (2004). Multipurpose shade trees in coffee and cocoa plantations in Côte d'Ivoire. *Agroforestry Systems,* 27: 259–267.

Huntington, H. (2000). Using traditional ecological knowledge in science: methods and applications. *Ecologycal Applications,* 10(5): 1270-1274.

Inglis, J.T. (1993). Traditional ecological knowledge: concepts and cases. Canadian Museum of Nature, Ottawa, Ontario, Canada.

Isaac, M.E., Timmer, V.R. and Quashie-Sam, S.J. (2007). Shade tree effects in an 8-year-old cocoa agroforestry system: biomass and nutrient diagnosis of Theobroma cocoa by vector analysis. *Nutr. Cycl. Agroecosystems*, 78:155-165.

Kennedy, A.J. (1995). Cocoa. In: *Evolution of crop plants* J. Smartt and N. W. Simmons (de.) Longman Scientific & Technical. Essex. pp. 472-475.

Kolawole, O.D. (2001). Local knowledge utilization and sustainable rural development in the 21st century. *Indigenous Knowledge and Development Monitor,* 9(3): 13-15.

Leach, M. (1994). Rainforest relations. Gender and resource use among the Mende of Gola, Sierra Leone. Washington, D.C., Smithsonian Institution Press.

Lok, R. and Sandino, D. (1999). Traditional cocoa agroforestry systems in Waslala, Nicaragua: adoption of technology and adaption to local environment and priorities. In: International Symposium on Multi-strata Agroforestry Systems with Perennial Crops, CATIE, Turrialba, 22–27 Feb 1999, Extended Abstracts, pp 251–255. CATIE, Turrialba.

MacDicken, K.G. and Vergara, N.T. (1990). Introduction to Agroforestry. In: MacDicken, K.G., Vergara, N.T. (Eds.), Agroforestry. Wiley, New York, pp. 1–31.

Mekoya, A. Oosting, S. Fernandez-Rivera, S. and Van der Zijpp, A. J. (2008). Multipurpose fodder trees in the Ethiopian highlands: Farmers' preference and relationship of indigenous knowledge of feed value with laboratory indicators. *Agricultural Systems,* 96: 184-194.

Motamayor, J.C., Risterucci, A.M., Lopez, P.A., Ortiz, C.F., Moreno, A., Lanaud, C. (2002). Cacao domestication. I. The origin of the cacao cultivated by the Mayas. Heredity 89:380-386.

Muñoz, F. and Beer, J.W. (2001). Fine root dynamics of shaded cocoa plantations in Costa Rica. *Agroforestry Systems*, 51: 119–130.

Muschler, R.G. (2000). *Arboles en Cafetales. Modulo de Ensenanza Agroforestal No. 5.,* Proyecto Agroforestal CATIE/GTZ, CATIE, Turrialba, Costa Rica.

Ong C.K., Black, C.R. and Marshall. F.M. (1996). Principles of Resource Capture and Utilization of Light and Water. *In* Tree Crop Interactions – A Physiological Approach. Eds. Ong C K and Huxley P. Chapter 4, pp. 75–158. CAB International, Wallingford, UK.

Ortiz, O. (1997). The information system for IPM in subsistence potato production in Peru. Experience of introducing innovative information in Cajamarca Province. Ph.D. Thesis, Agricultural Extension and Rural Development Department, the University of Reading, UK.

Ortiz, O. (1999). Understanding interactions between indigenous knowledge and scientific information. *Indigenous Knowledge and Development Monitor,* 7(3):7–10.

Palm, C.A. (1995). Contribution of agroforestry trees to nutrient requirements of intercropped plants. *Agroforestry Systems*, 30: 105–124.

Phillips, O.L. (1996). Some quantitative Methods for analyzing ethnobotanical knowledge. In: Selected guidelines for Ethnobotanical research: A fi eld manual. Ed. M.N. Alexiades. The New York Botanical Garden, New York.

Purseglove, J.W. (1968). Tropical Crops: Dicotyledons. Harlow. Longman. 719 p.

Ryan, D., Bright, G. and Somarriba, E. (2009). Damage and yield change in cocoa crops due to harvesting of timber shade trees in Talamanca, Costa Rica. *Agroforestry Systems*, 77 (2): 97-106.

Rajasekaran, B.D., Warren, D.M. and Babu, S.C. (1991). Indigenous natural-resource management systems for sustainable agricultural development - A global perspective, *Journal of International Development,* 3(4): 387-401.

Reitsma, R., Parrish, J. D., McLarney, W., Muschler, R. and Beer, J. (2001). The role of cocoa pantations in maintaining forest avian diversity in southeastern Costa Rica. *Agroforestry Systems,* 53: 185–193.

Rice, R.A. and Greenberg, R. (2000). Cocoa cultivation and the conservation of biological diversity. *Ambio*, 29: 167-173.

Righi, C., Lunz, A., Bernardes, M., Pereira, C., Dourado, D. and Favarin, J. (2008). Radiation Availability in Agroforestry System of Coffee and Rubber Trees. *In*: Advances in Agroforestry- Toward Agroforestry Design. An Ecological Approach, Eds. Springer. Chapter 4, pp. 249-327.

Ross, A. and Pickering, K. (2002). The politics of reintegrating Australian aboriginal and American Indian indigenous knowledge into resource management: the dynamics of resource appropriation and cultural revival. *Human Ecology*, 30 (2): 187-214.

Sandino, D., Grebe, H. and Malespin, M. (1999). Desarrollo agroforestal con cacao en Waslala Nicaragua. Agroforestería en las Américas. Vol. 6 N° 22.

Smith, E. (1981). The interrelationships between shade types and cocoa pest and disease problems in Papua New Guinea. In: Proceedings of the VII International Cocoa Research Conference, Cameroun 1979, pp 37–43. Cocoa Producers Alliance, Lagos, Nigeria.

Schroth, G., Krauss, U., Gasparotto, L., Duarte Aguilar, J. and Vohland, K. (2000). Pests and diseases in agroforestry systems of the humid tropics. *Agroforestry Systems*, 50: 199–241.

Schroth, G., Da Fonseca, G.A.B., Harvey, C.A., Gaston, C., Vasconcelos, H.L. and Izac, A.M. (eds) (2004). Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington, D.C, 523 pp.

Silva, Neto PJ. (2001). Sistema de produção de cacau para a Amazônia Brasileira. Belem. CEPLAC, Brasil. 125 p.

Sinclair, F.L., and Walker, D.H. (1998). Acquiring qualitative knowledge about complex agroecosystems. Part 1: Representation as natural language. Agricultural Systems 56(3):341-363.

Somarriba, E., Beer, J. and Muschler, R.G. (2001). Research methods for multistrata agroforestry systems with coVee and cocoa: Recommendations from two decades of research at CATIE. *Agroforestry Systems*, 53: 195–203.

Somarriba, E., Harvey, C.A., Samper, M., Anthony, F., González, J., Staver, C. and Rice, R.A. (2004). Biodiversity conservation in neotropical coffee (*Coffea arabica)* plantations. In: Schroth G., Fonseca G., Gascon C., Vasconcelos H., Izac A.M. and Harvey C. (eds). Agroforestry and Conservation of Biodiversity in Tropical Landscapes. Island Press, Washington, pp. 198–226.

Somarriba, E. (2005). ¿Cómo evaluar y mejorar el dosel de sombra en cacaotales?. Agroforestería en las Américas. 41-42: 122-130.

Somarriba, E. and Quezada, F. (2005). El diseño y manejo de la sombra en el cacaotal. Serie Técinca, manual técnico N°59. CATIE, Turrialba, Costa Rica. 55 p.

Somariba, E., Cerda, R.,Astorga, C.,Quesada, F., Vasquez, N. (2010). Reproduccion sexual del cacao. En: Colección escuelas de campo. CATIE, Proyecto Cacao Cetroamerica. 48 p.

Sonwa, D.J., Nkongmeneck, B.A., Weise, S.F., Tchatat, M., Adesina, A.A. and Jansens, M.J.J. (2007). Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. *Biodiversty conservation*, 16:2385–2400,

Thorsen, D. and Reenberg, A. (2000). Marginal producers or breadwinners: Women's cropping strategies and access to agricultural key resources in Boulgou province, Burkina Faso. Geografisk Tidsskrift – *Danish Journal of Geography*, 100: 47-59.

Ulluwisshewa, R., Roskruge, N., Harmsworth, G. and Antaran, B. (2008). Indigenous knowledge for natural resource management: a comparative study of Maori in New Zealand and Dusum in Brunei Darussalam. *GeoJournal*, 73: 271-284.

Utting, P. (1993). Trees, people and power. London: Earthcan.

Vasquez, M. (2001). Selection criteria for shade trees in cocoa plantations in Talamanca, Costa Rica. MSc thesis, University of Wales, Bangor, UK. 60 p.

Vernon, A.J. (1967). New developments in cocoa shade studies in Ghana. *J Sci Food Agric* 18:44~48.

Walker, D.H., and F.L. Sinclair, (1998). Acquiring qualitative knowledge about complex agroecosystems. Part 2: Formal representation. Agricultural Systems 56(3):365-386.

Wille, C. (1994). The birds and the beans. The coffee fields of Mexico and Central America may be the last best habitat for migrating birds. Audubon Nov/Dec 94: 58–64,

Wood, P. J. (1990). Principles of species selection for agroforestry in: Macdicken, K.G.; Vergara, N.T., (Ed.) Agroforestry: Classification and Management. New York: John Wiley. p.290-309.

Young, A. M. (1994). The Chocolate Tree. A natural history of cocoa.Smithsonian Institution Press. Washington and London. 200p.

Zuidema, P.A. Leffelaar, P.A. Gerristsma, W. Mommer, L. and Anten, N.P.R. (2005). A physiological production model for cocoa (Theobroma cocoa): Model presentation, validation, application. *Agricultural Systems*, 84: 95–225.

APPENDICES

Appendix 1. Semi structured interview

a) Introduction and main characteristics of the farm and the household:
   - farm size
   - family members and their age
   - for how long have they worked with cacao
   - what variety of cacao do they have
   - plantation distance
   - slope and aspect faced by the plantation

b) preferences of shade tree characteristics
   - crown shape
   - leaf size
   - tree height
   - deciduous or evergreen (or combination of both)
   - origin (native, exotic, doesn't matter)
   - establishment method (natural or planted)
   - number of different species they like to have (>5, <5 or if doesn't matter)
   - life span and growth rate of tree

c) What are the benefits of using shade trees in cacao farming?

With relation to:

- light regulation for cacao
- soil fertility (n fixation, litter production)
- products
- health and pests
- quality of cacao fruits

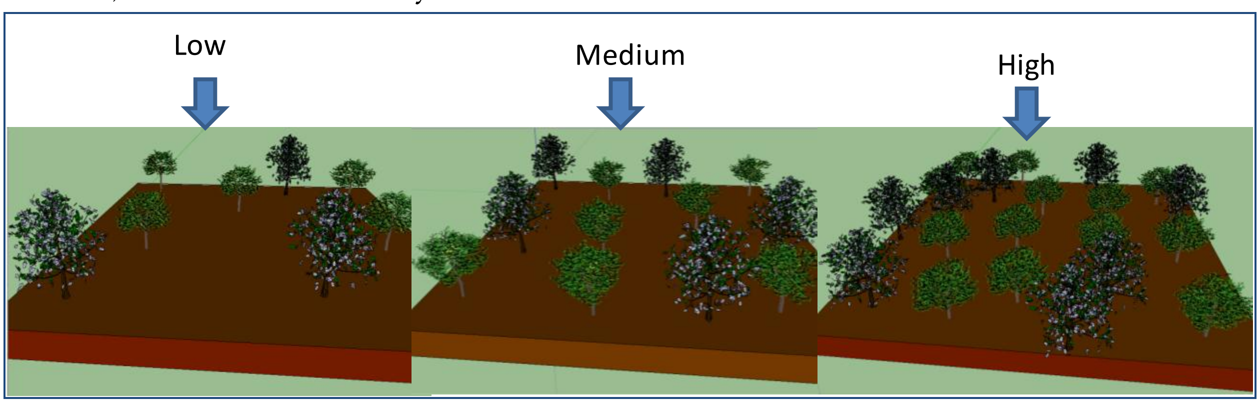
d) Do you see any disadvantages of using shade trees on your cacao?

With relation to:

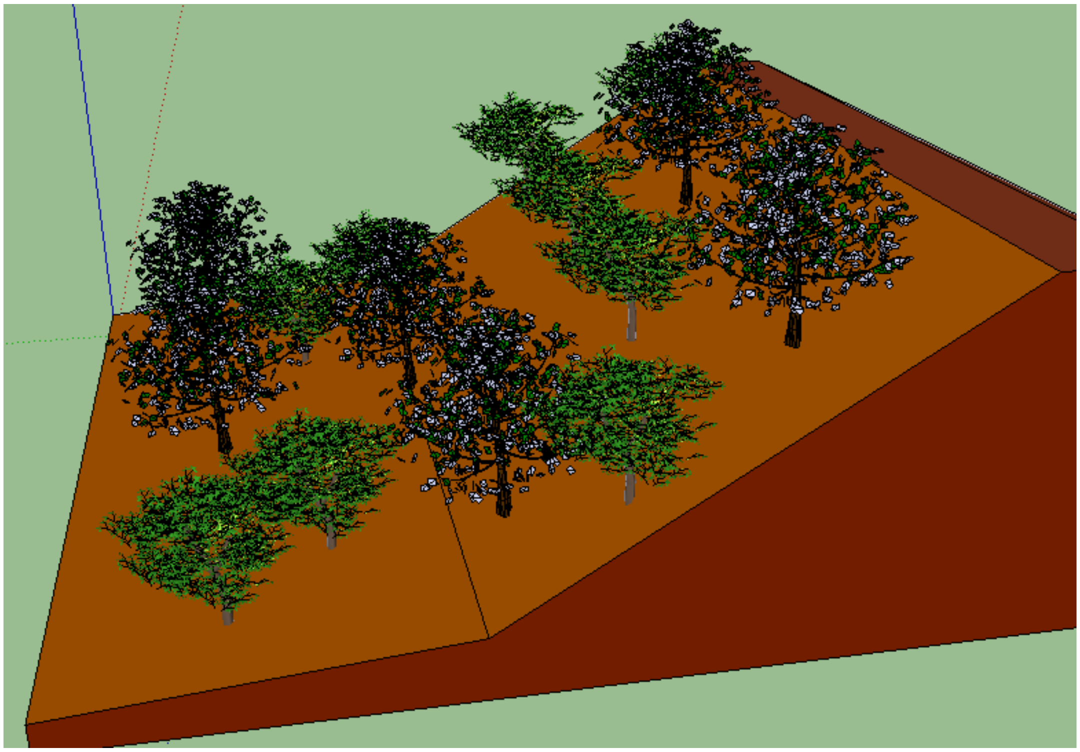
- loss of productivity
- water and nutrient availability
- health and pests
- difficulties on management practices

e) for preferences on shade cover related to age of cacao:

   a) When cacao is less than 5 years what kind of canopy cover do you prefer
   b) When cacao is 10-20 years?
   c) When cacao is >30 year?

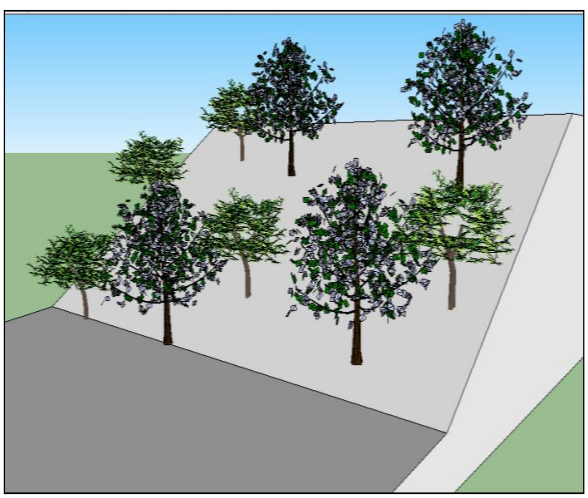


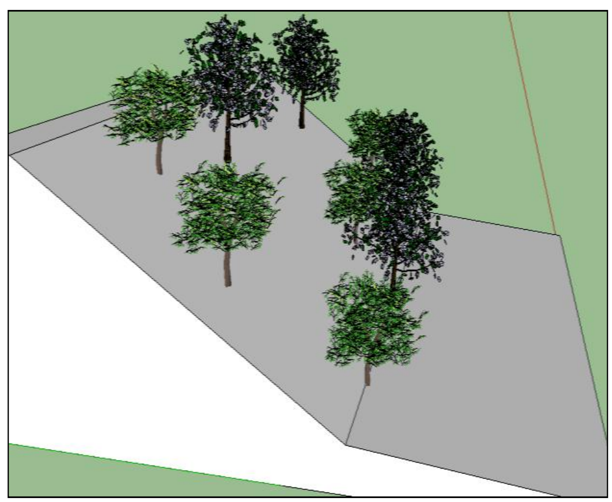
f) Preferences on shade cover according to plot slope



g) differences on shade cover preferences according to aspect

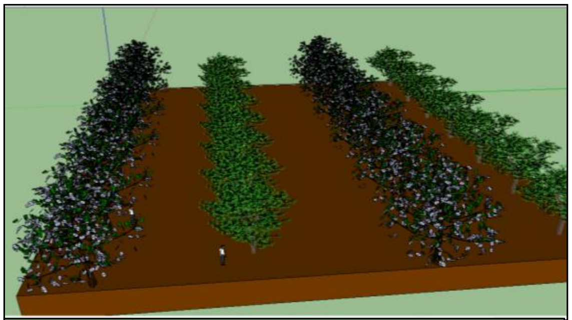
East aspect West aspect





h) Preferences on shade trees distribution

a)In lines b) Random c) in clumps



i) Cacao management

does the need of shade differ according to the distance of cacao planting?

have you done pruning?

since when did you start with the pruning?

the same for thinning

weed management

j) Use value of trees

With values as: 1,5 for very important; 1 for suitable; 0,5 for usable; 0 for no value

tree species	**fuelwood**	**poles**	**food**	**medicine**	**fodder**	**shade**	**fertility**	**total use value**
tree1								
tree2								
tree3								
tree4								
tree5								
tree6								
tree7								
tree8								

Appendix 2. List of scientific names of trees mentioned in the use value ranking

spanish name	**latin name**
laurel	*Cordia alliodora*
cedro	*Cedrela odorata L*
eucalipto	*Eucaliptus camaldulensis*
zapote	*Pouteria sapota*
acacia	*Cassia siamea*
aguacate	*Persea americana*
madero negro	*Gliricidia sepium*
guaba	*Inga spp.*
mango	*Mangifera indica L*
poró	*Erythrina poeppigiana*
naranja	*Citrus sinensis L*
pejibaye	*Bactris gasipaes*
limon	*Citrus limonium*
guayaba	*Psidium guajava L*
guineo	*Musaseas*

Appendix 3. AKT5 "coco-nica" Knowledge base (KB)