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A Participatory Approach for Tree Diversification in Cocoa Farms: Ghanaian Farmers' Experience

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Abstract

In Ghana, the diversity and density of non-cocoa trees in cocoa farms is primarily the result of farmers' managing natural processes of regeneration in forest-fallow systems. Tree diversity is therefore more a result of haphazard, uncoordinated decisions over a long period rather than advanced planning. Relying on natural regeneration processes greatly limits farmers' ability to select desirable species or arrange their distribution within farms. As a result, the potential of diverse cocoa growing systems is limited in its ability to make significant contributions to household incomes or conservation of biodiversity on farm and in the surrounding landscape. This paper presents a six step tree diversification process that was developed and implemented with farmers in Amansie West and Atwima Mponua districts of Ghana's Ashanti Region using a participatory action learning approach. In conjunction with 36 farmers in six farmer groups, a tree diversification framework was tested and implemented. Farmers used the framework to critically characterize and select desirable non-cocoa trees according to biophysical and socio-economic attributes, and then planted these species onto farms with the aim of providing favorable vegetative cover for cocoa, as well as securing valuable sources of timber and non-timber products. In total, 960 tree seedlings were planted on 31 farms using a designed 12 m x 12 m triangular planting arrangement with an initial planting density of 28 trees per acre. The value of this process is that it provides farmers with a flexible decision support tool for evaluating and integrating desirable trees into tree crop systems for increased diversity.

Key Words: Ghana, on-farm diversity, participatory action learning, smallholder farmer, tree crops, tree planting

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Introduction

In the tropics, perennial tree crop systems like coffee (*Coffea* sp.) and cocoa (*Theobroma cacao*) that were grown in shade-tree agroforestry systems have undergone a transition as some countries have promoted unshaded and more intensively managed plantations (Beer et al. 1998). With the increasing focus on the environment and biodiversity conservation in agroforestry, researchers are assessing the multiple values of these shade tree systems and encouraging more diversity in tree crop systems.

Smallholder cocoa farms in West Africa range in their structural diversity and species richness between highly diverse cocoa agroforests like those found in southern Cameroon (Zapfack et al. 2002; Gockowski et al. 2004; Nomo 2005; Sonwa et al. 2007), and relative cocoa monocultures which can be found in parts of Ghana and Côte d'Ivoire (N'Goran 1998; Padi and Owusu 1998; Ruf and Zadi 1998; Ruf and Schroth 2004). Tree diversity in cocoa farms offers farmers a range of agronomic, economic, cultural, and ecological benefits (Sonwa et al. 2001; Gockowski et al. 2006). In particular, multi-strata cocoa farms contain a horizontal and vertical distribution of crops, native forest trees, and fruit trees at different periods in the life of the cocoa. Each component plays an important role in sustaining the longevity and health of the cocoa farm by maximizing the productivity of all components within the system (Rice and Greenberg 2000). According to Obiri et al. (2007) shade increases the economic rotation age of hybrid cocoa trees. A diversified farm also enables farmers to exploit the different components in the system, as well as their interactions, so as to meet subsistence needs, maximize incomes, and reduce risks against fluctuations in world market prices of cocoa beans (Rice and Greenberg 2000; Duguma et al. 2001; DiFalco and Perrings 2003). Finally, multi-strata cocoa can help to protect forest patches, to regenerate and conserve particular forest tree species, and to provide agroforestry habitat for key animal species (Greenberg et al. 2000; Siebert 2002; Schroth et al. 2004) that play vital roles in maintaining and conserving forests.

In West Africa, the diversity of non-cocoa trees primarily results from farmer's harnessing the natural processes of regeneration within forest-fallow systems by preserving some mature trees and selecting certain seedlings and coppice sprouts to grow in tandem with the cocoa. Farmers also plant forest trees, although it is more common for farmer's to plant fruit trees. This practice of integrating food crops, native trees, and fruit trees into cocoa farms embodies a process of tree diversification - a reflection of cocoa agroforests. However, the ability of this diversification practice to achieve its potential in terms of significant increases in household incomes and conserving biodiversity on farm and in the managed cocoa landscape in general is limited by a number of institutional, technical, marketing and legal factors. For example, there appears to be a lack of emphasis or encouragement for tree diversity and diversification amongst national extension systems and cocoa projects. In Ghana, priority has instead been given to increasing cocoa bean production, and pest and disease control. Technology has also contributed to an overall reduction in shade cover for cocoa over time through the promotion of hybrid varieties which favor lower densities of shade (Padi and Owusu 1998; Asare 2005), and the widespread availability of chainsaws which facilitate removal of mature forest trees (Ruf and Konan 2001). Furthermore, there is neither a strong focus on understanding interactions between native species and cocoa, nor on simplifying and sharing the information between stakeholders on the importance of biodiversity conservation on farms (Asare 2005).

In addition, there exists wide variation in farmers' knowledge of the dynamics of different tree species as they occur in managed cocoa landscapes. This can be due to limited availability and/or a lack of dissemination of indigenous farmer and scientific knowledge, which adequately describe the characteristics and interactions of native and naturalized trees in cocoa farms. Thus, there is not a scientifically validated framework that provides technical information on how to combine different tree components in the cocoa farming systems to affect interrelationships in time and space to harness the full potential of tree diversification on cocoa farms. As a result, some farmers are not able to select compatible species for regeneration on cocoa farms, nor their spatial arrangements within the farm. Even if compatible trees do germinate farmers sometimes cannot differentiate between species during their seedling phase, and as a result weed them out in the management practices. This trend was also documented by Rolim and Chiarello (2004) in the 'cabrucca' systems in southeastern Brazil. Hence, diversification through natural regeneration of desirable forest trees in cocoa establishment is more a product of haphazard and uncoordinated decisions over a long period rather than advance planning

Mainstreaming tree diversification in cocoa

According to Leakey (1998), there is a need to help develop multi-strata agroforestry systems in West Africa. Specifically, he calls for the research and development of suitable systems that use commercial species, the development of an entrepreneurial mentality among rural communities, and research to identify how to best combine tree species into agroforestry systems. In response to these recommendations, and in an effort to specifically address some of the constraints to tree diversification in cocoa farms, Forest and Landscape Denmark (FLD), together with the Sustainable Tree Crops Program (STCP) and the World Cocoa Foundation (WCF) launched a collaborative effort to assist farmers in diversifying their cocoa farms through the integration of desirable tree species.

This collaborative effort was based on the recognition that while research has focused on documenting non-cocoa tree species diversity, richness, and structural diversity in Cameroon (Gockowski and Dury 1999; ASB 2000; Zapfack et al. 2002; Sonwa et al. 2007), Nigeria (Adeyemi 2000), Ghana (Asare 1999; Osei-Bonsu et al. 2003), and Côte d'Ivoire (Herzog 1994; Ruf and Zadi 1998), as well as cocoa-forest tree interactions and management options in Ghana and Nigeria (Manu and Tetteh 1987; Opoku et al. 2002; Osei-Bonsu et al. 2002; Anim-Kwapong 2003; Famaye et al. 2003; Anglaaere 2005), few efforts have been made to understand the social processes that create and/or sustain diversity in cocoa agroforestry systems (Amanor 1996; Oduro et al. 2003). In addition, there has been little effort to encourage and apply diversification methods that are based upon shade tree and tree crop spacing arrangements, shade tree compatibility, market and policy environments, and farmer preferences and planting material availability. These gaps can partially be attributed to the limited information available on either technical or local knowledge of the characteristics and interactions between native trees, naturalized trees, and cocoa trees. Also, few efforts have been made to foster intentional diversification of cocoa agroforestry systems because there is no participatory method available which merges farmer knowledge and forest tree preferences with scientific findings into a strategy to support and enhance the integration of non-cocoa trees on cocoa farms for increased financial and ecological benefits. Therefore, by testing and applying a diversification framework together with farmers, tree diversification can be mainstreamed into current cocoa farming practices in an effort to conserve, through their use, a diversity of forest tree species in the managed cocoa landscapes.

The overall objective of this paper is to present a participatory tree diversification approach and the experience of implementing it amongst cocoa farmers in Ghana, with the hope that the approach can be adapted and implemented in other perennial tree crop systems. Initially the paper describes the concept of diversification in cocoa farming, including the benefits and current practices of tree diversification in Ghana. The paper then introduces a tree diversification process that was carried out in two districts in Ashanti Region of Ghana. Specifically it describes the diversification framework that was developed and then adopted by farmers, citing specific examples from farmers' experience using the framework. Finally the paper concludes by outlining the way forward for tree diversification.

Tree diversification in cocoa

Diversification of agroforestry systems or tropical plantations reflects an effort to increase the diversity of species on a plot or across the landscape in order to improve economic returns, enhance agronomic productivity, increase socio-cultural benefits, and/or contribute to the conservation of biodiversity within managed landscapes. Specific to this work, tree diversification in cocoa farms is a process that involves the strategic integration in time (at various stages in the establishment and management of cocoa farms) and space (the three-dimensional arrangement of trees on the ground and into the canopy) of suitable and valuable non-cocoa tree species and other plants into a cocoa farm (Asare 2006). Species may include indigenous forest trees, fruit trees, common agroforestry species, food crops, shrubs, and/or herbs.

Tree diversification on farm may occur as a result of promoting a wider distribution of tree species that are already present somewhere in the landscape or introducing trees from outside the landscape (Asare 2006; Kindt et al. 2006). Species can be planted and/or preserved in mixtures or in sets of mono-specific plots in the cocoa system. Tree diversification can also occur through domestication—a process which enhances different species production of fruit, timber, medicine or environmental services, in order to meet farmer's functional needs or to take advantage of market opportunities (Simons and Leakey 2004).

Benefits of diversification

Numerous studies have documented the physiological, environmental, economic, and socio-cultural value of different shade or neighbor trees in cocoa growing systems (Abbiw 1990; Herzog 1994; Wessel and Gerritsma 1994; Rice and Greenberg 2000; Duguma et al. 2001; Anim-Kwapong 2003; Jeffrey and Schroth 2006). Therefore, from a largely social perspective, one proposed advantage of a tree diversification process is that it can result in a portfolio of different strategies to meet a diversity of needs. For example, given that farmers are not a homogeneous group, the process of diversification can lead one farmer to select only high value timber species for their future economic returns, while a second farmer might opt to integrate a mixture of fruit trees with native forest trees that are proven to enhance the overall health of the cocoa and reduce desiccation during the dry season.

Farmer-based diversification can also reduce exposure to product and income risks and provide greater profitability than a single cropping system. By diversifying cocoa production to focus on other short, medium, or long term products, and then bridging the whole system to opportunities in the market chain, diversification can help to stabilize or improve farm income and household welfare (Gockowski et al. 2006). Hence, it is assumed that diversification will allow more consistent performance under a wide range of conditions. In Cameroon, Duguma et al. (2001) argue that cocoa agroforests are more sustainable than annual food crop production systems, and in an economic productivity analysis of three different types of cocoa production systems (low input without fruit trees; low input with fruit trees; medium input with fruit trees) found that all three production systems were profitable under all of the scenarios they considered. Furthermore, the authors acknowledge that they incorporated neither timber nor medicinal species into their analysis, which can further bolster economic returns.

A third benefit is that tree diversification in cocoa may provide greater productivity by fully exploiting nutrients, water, and light resources within a stratified mixture of food crops, tree crops, and shade trees (Gillison et al. 2004). In a diversified system, mixtures of species with different growth requirements and production potentials may reduce inter-specific competition and increase yields as compared to mono-specific stands (Jose et al. 2006). For example, when faster growing over-story tree species (that may improve nutrient availability in the soil, increase soil moisture, or create shaded environments) are combined with slower growing shade tolerant species the resulting mixed stand can facilitate better survival and growth rates (Montagnini et al. 1995). Multi-strata cocoa can also help to extend forest-like environments, to conserve particular forest tree species, and to provide agroforestry habitat for key animal species that play vital roles in maintaining and conserving forest species (Schroth and Harvey 2007). Given these potential benefits, by providing solutions to some of the current limitations to tree diversification in cocoa farms, diversification will be able to help farmers stabilize and potentially increase the total productivity of their cocoa farms with income generating activities all year round, while maintaining or improving biodiversity on farm and across the landscape.

Finally, diversification can facilitate a positive policy environment, either by making farmers aware of the laws and their rights, or by ushering in new user arrangements or legislation. Across Africa, a rough policy terrain has inhibited, rather than promoted biodiversity conservation in agroforestry systems that exist within protected area landscapes (Ashley et al. 2006). In Ghana, for example, there is not a culture of tree planting on farm. Instead, farmers select and nurture trees that grow naturally in the landscape to fulfill various functions on their farm (Amanor 1996). However, in the eyes of the State as stipulated by the Government of Ghana's Concession Act, No. 124, 1962, section 16(4), farmers only own trees which they plant; they do not own trees that regenerate naturally in their farms, making farmers vulnerable to the logging of timber trees in their cocoa systems. But if farmers were encouraged to diversify their cocoa farms through active planting of timber species they would be ensuring rights of timber ownership and sale.

Current practice of diversification in Ghana

In many cases, cocoa farms are already diverse in nature. These farms contain multiple species of food crops and trees which provide shade to the cocoa and furnish subsistence and/or market products at different points in time (Amoah et al. 1995; Osei-Bonsu et al. 2003). However, given that the current practice of tree diversification relies upon the natural processes of regeneration within forest-fallow systems there are no definite patterns in the diversity, richness or arrangements of the various species in time and space.

Initially, farmers clear and/or burn the understory vegetation, and either thin or completely eliminate the over-story trees to make growing space for their cocoa and food crops (Ruf and Zadi 1998). Instead of clearing all of the vegetation, some farmers choose to preserve certain mature trees for shade, instead of removing them from the system through cutting, ring-barking, or burning. Food crops like plantain, cocoa yam, maize, and cassava are planted first, followed by the cocoa, to provide key initial shade to the cocoa seedlings, and to provide food and income to the farm family over the next growing season (Osei-Bonsu et al. 1998).

As the cocoa farm continues to mature, weeds and seedlings of non-cocoa trees establish rapidly and occupy the growing space along side the cocoa seedlings and relic trees that were retained during cultivation. While it is likely that the open conditions will favor species from highly shade intolerant to moderately shade intolerant guilds, it is difficult to entirely predict which trees will emerge as part of the initiating cohort. Just as natural disturbances occur at various scales, the scale and intensity of land clearing and/or weeding regimes (considered as anthropogenic disturbances) have a significant impact on those tree seedlings that are able to regenerate. The species of trees that emerge are also determined by the species of trees that were retained or coppiced within the farm, the species of trees growing in the surrounding landscape, differences in tree's regeneration mechanisms, and the presence of birds or other mammals that play a role in pollination and seed distribution (Finegan and Nasi 2004).

Over the next few years, as the cocoa seedlings mature, farmers select certain naturally regenerated forest tree saplings and coppice sprouts to grow in association with the cocoa and provide essential shade for the young cocoa trees. The majority of forest seedlings that sprout amidst the cocoa are eliminated during the weeding process in an effort to reduce competition and release growing space to the planted cocoa seedlings and the remaining shade trees. In this thinning process, farmers keep trees that have economic, domestic, or environmental value, and many trees are able to serve multiple functions. Many farmers also plant valuable fruit trees like *Persea americana, Elaeis guineensis, Carica papaya*, *Mangifera indica*, and *Citrus spp.*, and a few plant valuable timber species with the cocoa (Amanor 1996; Asare 2005), although timber planting is comparatively rare. As the cocoa matures into full production, farmers continue to eliminate or integrate trees according to their priorities and the changing conditions within the farm.

How many non-cocoa trees is enough on a cocoa farm?

There are two schools of thoughts on how many non-cocoa trees should be incorporated into cocoa agroforests and/or plantations. Environmentalists argue that cocoa farms with a diversity of forest tree species can help to connect fragmented forests and to form corridors for animal passage which will help conserve biodiversity and improve the environment. Through the Sustainable Agriculture Network, the Rainforest Alliance has developed criteria and indicators for cocoa production which advocate for 70 emergent non-cocoa tree species, twelve of which must be native species, per hectare of cocoa, providing a shade density of approximately 40% for cocoa trees underneath the emergent canopy (SAN 2005). This density is roughly equivalent to a shade tree spacing of 12m x 12m.

In Ghana, The Cocoa Research Institute of Ghana (CRIG), which is primarily focused on optimal cocoa production, recommends up to 18 emergent trees (≥ 12 meter height) per hectare (roughly a 24 m x 24 m spacing) providing permanent shade cover corresponding to approximately 30-40% shade (Anim-Kwapong 2006). Despite the difference in the number of recommended stems per hectare, these two perspectives are clearly compatible in terms of recommended shade density, particularly if applied over the entire life span of the cocoa tree. The variation in the recommended number of shade trees can be attributed to differences in tree canopy architecture, as well as age. In fact, Alvim (1977) found that the appropriate level of shade falls between 30%-70% over the life span of the cocoa tree. According to Ghana's COCOBOD, cocoa farms are categorized into four age classes: A Class (0-7 years); B Class (8-15 years); C Class (16-30 years) and D Class (over 30 years), which require different levels of direct light incidence. Hence, a shade regime consisting of 70% shade during the establishment phase of cocoa (A Class) can be thinned to between 30-40% during cocoa's mature phases (B, C, D Class) to give an optimum yield result and still potentially consist of the number of tree species required to make a significant impact on conserving a diversity of forest tree species in the managed cocoa landscapes.

Tree diversification in Atwima and Amansie West districts, Ashanti Region, Ghana

Site description

Atwima District and Amansie West District are located in southwestern Ashanti Region, and are part of what many consider to be Ghana's old or 'traditional' cocoa growing areas. Today, much of the districts' original forest cover has been degraded, due in part to cocoa cultivation, which was introduced in the area in the early 1900s, as well as legal and illegal logging operations. Surface mining at the Bonte Gold mines and other surface mining activities in the districts have also had a devastating effect on the natural forest vegetation and cocoa farming due to the resulting soil degradation.

Atwima District lies between latitudes 6^{0} 22' and 6^{0} 46'N and longitudes 1^{0} 52' and 2^{0} 20'W and Amansie West District is situated between latitudes 6^{0} and 6^{0} 45'N and longitudes 1^{0} 30' and 2^{0} 15'W. Atwima covers an area of about 2411 km^2, while Amansie West occupies an area of 1136 km^2. The districts are located in the Wet Semi-Equatorial Climatic Zone, marked by a bi-modal rainfall pattern with the major rainy season occurring from March to July and a minor season from September to November. Mean annual rainfall ranges between 1700 and 1850 mm. The dry period extends from December to mid-March. Temperatures are uniformly high throughout the year with monthly minimum and maximum temperatures of $27\,^{0}$C and $31\,^{0}$C occurring in August and March respectively. Relative humidity is generally high throughout the year. Floristically, the area falls under the moist semi-deciduous forest zone and common species include *Celtis mildbraedii, Nesogordonia papaverifera, Entandrophragma utile, Pericopsis elata, Khaya anthotheca, K. ivorensis,* and *Cola nitida* among others (Hall and Swaine 1981).

In 2003, Atwima and Amansie West districts were selected as pilot sites for STCP. To date there are 2,188 of farmers and 73 farmer groups who have participated in farmer field school (FFS) activities within the districts. The tree diversification exercises were conducted with farmers from six communities. All of the participants are graduates from the FFS. Graduates were selected because they are familiar with FFS methods (David 2006) and are accustomed to working together and learning from each other.

Stages of participatory tree diversification

Between April 2006 and July 2007, a tree diversification program was designed and implemented together with key informants and farmers in the two districts using a participatory action learning approach that contains six steps: 1) identifying tree diversification options; 2) developing and testing a decision support tool for desirable tree selection; 3) selecting desirable trees and cocoa farms; 4) drawing farm maps; 5) accessing improved planting materials; 6) land preparation and tree planting on cocoa farms. It was envisaged that such an approach will encourage a process of continuous learning and reflection, and allow individual farmers to gain knowledge with and from each other. In the long run, this will help to improve management of on-farm ecological processes and to support farmer decision-making strategies with regards to active integration of forest trees in cocoa establishments (Mendez and Bacon 2006). Participatory action learning is also an effective approach in ensuring ownership and adoption of suggested practices. With regard to the specific characteristics and nature of native trees vis-à-vis cocoa, it is also very useful in helping to draw out farmers' indigenous knowledge and priorities.

1. Identifying tree diversification options

The first step in the tree diversification process is to identify the various options for diversifying cocoa farms that are locally relevant. In order to capture these options in Atwima and Amansie West, workshops were organized for key informants with local knowledge on trees in cocoa. The informants consisted of 21 FFS trainers (including agricultural extension officers, village opinion leaders and farmers). During these workshops, the participants worked to define tree diversification as it pertains to cocoa farming in Ghana, and to translate terminologies and technical expressions into local dialects (e.g., Twi in this case) to ensure comprehensive understanding. Terms that required careful attention included 'tree diversification', 'tree diversity', 'shade quality', 'soil moisture', 'soil fertility', 'temporary shade', 'permanent shade', 'shade quality', 'wind break' and 'air circulation'. For example, key informants had a difficult time distinguishing between tree diversification as a process and the diversity of trees on farm. They also had difficulty differentiating between a tree's ability to serve as a wind break and/or to allow air circulation within the farm.

The key informants identified three main options for diversification, and determined that these options occur in different forms depending on the agro-ecological zone, the age and stage of the cocoa farm, the market for tree products, the availability of planting material, and cultural practices. Diversification may occur for short, medium and long term agronomic, ecologic and/or economic gains and therefore can occur with combinations of; 1) food crops, 2) other fruit trees apart from cocoa, and 3) timber trees. They indicated that diversification with these crops and trees occurs sequentially and the options are not necessarily mutually exclusive.

According to the key informants, food crop diversification takes place during the initial stages of cocoa establishment (from year 0 to 3) when farmers combine food crops like *Musa spp*., *Colocasia esculenta*, *Dioscorea spp*., *Manihot esculenta*, *Zea mays*, etc. with cocoa seedlings. This they claim may provide cocoa seedlings with the much needed temporary shade and reduce competition from weeds since food crops grow faster than trees. It also provides farmers with income and food for the household in the short term until the cocoa is ready for harvest. Food crops may also be incorporated in mature cocoa fields during enrichment planting when gaps created as a result of dead trees are filled with new cocoa seedlings and food crops are planted to provide shade for these seedlings. In planting the food crops with cocoa, farmers do not follow any planting pattern per unit area. However, these crops are planted in between the cocoa seedlings in an arrangement such that the shade effect is prominent while reducing initial competition.

Farmers also diversify by integrating fruit trees (other than cocoa) in cocoa plantations. These include, but are not limited to *Mangifera indica*, *Citrus sinenses*, *Persea americana*, *Cola nitida*, and *Elaeis guineensis*. Farmers integrate these fruits for medium and long-term subsistence and economic gains. They plant or retain them amongst the cocoa right from the first year or as a replacement for food crops after year three when the cocoa (hybrid variety) canopy has closed.

Similarly, farmers also diversify with timber trees as permanent shade in cocoa for medium to long-term economic and agronomic gains. Trees like *Milicia excelsa*, *Ceiba pentandra*, *Terminalia ivorensis*, *T. superba*, *Alstonia boonei*, *Khaya ivorensis*, *Triplochiton scleroxylon* etc, were mentioned by informants as reliable shade trees for cocoa. Key informants indicated that mature or relic timber trees may be left during initial establishment of cocoa or planted after the cocoa is established. Seedlings may also be allowed to regenerate naturally together with the cocoa.

Key informants established that diversification with timber trees in cocoa is the most attractive option. However, there are numerous challenges due to their long gestation period, as well as their long lasting impact on cocoa. The key informants agreed that developing a procedure that will address some of these challenges will go a long way to broaden farmers' knowledge on how to improve upon their current practice. Hence, a decision support tool was needed to help farmers characterize compatible trees for cocoa cultivation.

2. Developing and testing decision support tool for desirable tree selection

Using the experience and information from the key informant workshop, as well as an initial template for tree diversification (Asare 2006), a decision support tool was designed to capture the knowledge and reasoning that informs farmer perceptions of desirable and/or undesirable shade trees, and then focuses this knowledge into a matrix that evaluates specific cocoa-shade tree interactions. According to Franzel (2001), participatory methods that use such matrices to rate species are valuable because they are specifically suited to farmers' conditions.

Specifically, the decision matrix considers farmers' knowledge of trees in terms of characteristics like shade quality, soil fertility, moisture stress, weed growth, wind breaks, air circulation, branch shedding (that might damage cocoa trees), host to pests and diseases, and economic and social value. [See Table 1] However it is up to the participants to determine the final list of characteristics that they will use to rate different tree species. These biophysical and socio-economic characteristics are referred to as 'attributes'. These attributes are then numerically rated against different species of shade trees according to the group or individual farmer's judgment. It is worth noting that there is no good system available for integrating the information into an overall rating for each species as different criteria have different weights.

For shade quality, key informants considered crown size, density, compactness, and height of the tree to be critical factors. Crown size was described according to its diameter, while crown density was determined by number and size of the leaves per unit area on the branch. Relatively large extensive branches negatively affect shade quality. Size and orientation of leaves were noted to affect the compactness of the canopy. While relatively small and dispersed leaves promote an open canopy that allows adequate sunlight to penetrate to crops beneath the canopy, broad and closely spaced leaf arrangements were identified to intercept most of the sun light resulting in a closed canopy that promotes high humidity. This condition, according to key informants, creates an optimal environment for diseases like Black Pod, and other fungal diseases. Tall trees, according to key informants are good permanent shade while relatively short trees serve as appropriate temporary or intermediate shade.

Table 1: Decision tool matrix for identifying desirable trees

Attributes	*Tree species*				
	Species 1	Specie 2	Specie 3	Specie 4	Specie 5
Shade quality					
Moisture					
Soil fertility					
Weed suppression					
Mechanical damage					
Wind break					
Allows good aeration					
Good timber value					
Good NTFP value					

Source: Asare (2006). Rating as 1,3,5,7,9 from low to high. Non timber forest products (NTFP)

With regards to soil moisture, deep rooted trees were noted to compete less with cocoa for soil moisture. According to informants, they facilitate recycling of water to the surface compared to shallow rooted trees. Leaf shedding rhythm was also used to assess soil moisture and the overall desirability of a tree. According to the informants, trees that maintain most of their leaves in the dry season and shed them in the wet season control desiccation and high humidity, both of which are major problems in the area.

Soil fertility was assessed by the rate at which organic matter is added to the soil through leaf shedding. Farmers paid particular attention to the time it takes for leaves to decompose and the softness or hardness of the leaves. Thus, a tree that has a high rate of leaf shedding and has soft leaves that decompose quickly promotes soil fertility. Key informants did not assess different forest trees' impact on soil nutrient availability or leaching as these are difficult processes to observe. However Hartemink's (2005) review of the literature argues that in tree crop systems, nutrients which leach to deeper soil horizons are able to be up-taken by tree roots and thus maintained in the system. Therefore, nutrient losses in cocoa systems are less significant than under annual crops. A species ability to suppress weeds was determined by how frequently a farmer weeds around that particular tree. It was agreed that trees with higher litter fall have higher weed suppression ability since the litter serves as mulch and prevents weed germination.

Mechanical damage was judged according to the self pruning ability of the tree and how often this occurs. The key informants described them as soft or hard branch trees. Trees with a high rate of self pruning have soft branches and trees that are not prone to self pruning have hard branches. Wind break ability of trees was determined by the strength of the root system and the softness or hardness of branches, therefore deeply rooted trees with hard branches serve as a good wind break for cocoa.

Good aeration was assessed by the height of the tree; relatively tall trees allow for better aeration under the canopy than short trees. The timber and non-timber product value of a tree were determined by a tree's uses and the potential monetary benefits that can be obtained. Thus, a tree with highly valued timber or one with many local uses is favored by farmers.

In order to make the diversification decision-matrix relevant and adoptable by cocoa farmers, the key informant group was assembled a second time to test and give feedback on the decision matrix. In small groups the participants identified common trees found in cocoa farms, and then sought to rate each tree based on the list of biophysical and socio-economic 'attributes'. In testing the matrix, the key informants were also instructed on how to create and administer the decision-making matrix with farmers. In constructing the matrix, the duty of the facilitator is to help farmers list as many 'attributes' as possible. This ensures that good trees meet all requirements, while bad trees stand out. The ratings given to the various species are used to compare specific attributes across the various species, rather than attempts to rank the species. When the matrix is well developed it allows farmers to dwell on a whole range of characteristics to help pass judgment on a particular tree with regards to its compatibility with cocoa. For example, a farmer may appreciate a tree for its ability to improve soil moisture despite its low timber value. Hence, the process helps farmers to identify the trade-offs that exist in integrating different tree species in their farms. When the decision matrix is used in groups, ratings of the various attributes depend on consensus so that experience is shared from various view points.

After the creation and testing of the decision support tool, six farmer trainers were then selected to introduce the decision matrix to the original FFS groups from the villages of Gyeninso, Akataniaso, Bonteso, Aniamoa, Nerebehi, and Twenedaaso. Each trainer met with their respective FFS group and together with the participants selected five farmers to test the applicability of the decision-making tool and to initiate a tree diversification process on their cocoa farm. Each group met separately, and through a participatory process created a plan of action for initiating tree diversification. The plan involved the following steps in the diversification process.

3. Selecting desirable trees and cocoa farms

Workshops that introduced the concept of tree diversification in cocoa were organised for all six farmer groups in the various communities. One advantage of holding the workshop in the community is that the majority of tree species mentioned were local species. In these workshops, farmers identified and defined tree diversification options pertinent to their local area and conditions. The farmer facilitators, who had served as key informants, explained and translated in local dialects the various diversification terminologies and expressions to the participants. Farmers then worked together to identify commonly preferred or desirable tree species that often occur in cocoa farms. The trees include *Alstonia boonei, Funtumia elastica, Terminalia ivorensis, T. superba, Milicia excelsa, Khaya ivorensis , Triplochyton scleroxylon, Aningeria altisima/robusta, Spathodea campanulata, Ficus capensis, Ceiba pentandra,* and *Newbouldia laevis*. Tables 2a – 2f show species selected by each community and how they were rated.

Each community then listed in the matrix the trees that they had agreed upon and each species was numerically rated according to the group's collective knowledge and perceptions of the biophysical and socio-economic attributes of the tree. A key element of the process was to allow the farmers an opportunity to debate their rating for each tree so that a broad range of details and experiences were shared between everyone in the group. Eventually, the farmers must come to a consensus on an appropriate rating for each tree. Trees are rated on an odd number scale of one to nine, with one being negative or bad and nine being positive or very good. The goal of this exercise was not to select particular species for planting, *per se*, but rather to encourage farmers to start thinking about how to assess the compatibility of different tree species with cocoa.

Farmers from four communities rated *Milicia excelsa* relatively high in all the attributes. In their experience it has a relatively small, open canopy, with a good leaf arrangement that allows adequate sun light to reach cocoa – indicating good shade quality. This observation is confirmed by Isaac et al. (2007) who found that the light availability under *M. excelsa* is within the optimal range for cocoa production. Farmers judged it to be a deep rooted tree with soft leaves, and to have a high leaf decomposition rate that improves soil moisture and fertility. Isaac et al. (2007) found improved nutrient cycling capabilities among cocoa trees under shade canopies that included *M. excelsa*. The observation that *M. excelsa* retains its foliage during the dry season, giving cocoa protection against desiccation, corresponds to research findings that leaf shedding occurs at the end of the dry season (Joker 2002). Finally, farmers described *M. excelsa* as a tall tree with few, though hard branches that do not cause mechanical damage. These characteristics enable it to serve as a good wind break against torrential rainfalls, to provide good aeration, and above all to furnish valuable timber and non-timber products.

Terminalia ivorensis and *T. superba* were noted by farmers to have lateral branches with relatively small dispersed leaves giving it a small and opened canopy. However, farmers in Aniamoa observed that the two species have soft branches and as a result cause mechanical damage to cocoa. Farmers in Bonteso corroborated this assessment, particularly with regard to *T. superba*. Poorter et al. (2004) described the two species as having spreading crowns of whorled boughs with clustered leaves, and self-pruning branches in *T. ivorensis*. Norgrove and Hauser (2000) describe divergent leaf shedding patterns between the two trees with *T. ivorensis* losing its leaves during the dry season and *T. superba* losing its leaves during the rainy season. Farmers from Akataniaso made the same observations and gave *T. superba* a higher rating for retaining its leaves during the dry season, as compared to *T. ivorensis*. Farmers indicated that having both *T. ivorensis* and *T. superba* on the farm at the same time maintains certain level of shade for cocoa, especially in the dry season due to their alternating leaf shedding rhythms. Overall, the trees' tall nature, soft and high rate of leaf decomposition, and good timber value make them desirable trees with cocoa. *Ceiba pentandra* was also noted to have soft branches by Nerebehi farmers.

Newbouldia laevis has a very narrow columnar crown and as a result provides very little shade. These observations largely correspond to researcher's descriptions of its narrow, dense canopy, resulting in high canopy openness and adequate levels of light infiltration for cocoa growth and pod yield (Isaac et al. 2007). Farmers in Aniamoa gave it the lowest rating in the shade category due to the small crown size. Having little shade implies low risk of mechanical damage; hence it was rated high for no mechanical damage and good aeration. Used for medicine and as live stake for growing yams, it is highly appreciated by farmers for its NTFP value. In terms of soil fertility, farmers in Aniamoa gave it a good rating. Studies of *N. laevis* with cocoa found that exchangeable K was higher in the top soil as compared to a cocoa monoculture (Isaac et al. 2007).

Spathodea campanulata was rated to have no timber value by all the farmers in the five communities where it was selected, but its ability to improve soil moisture makes it attractive in cocoa farms. For instance its local name "Kuokuonisua", literally means "tears from the eyes". Farmers claim that droplets of water drip from the tree throughout most of the year, manifesting its ability to pump water from deep in the soil to the surface. It was rated as having soft leaves which decompose quickly and help improve soil fertility. These observations are confirmed by Anim-Kwapong (2006) who recorded high annual leaf litter production and decomposition rates relative to other common species in mixed fallows. He also found that *S. campanulata* retains over fifty percent of its leaf cover throughout the year (Anim-Kwapong 2006). Presumably, this would help to reduce cocoa tree desiccation during the dry season.

Khaya ivorensis was preferred by farmers in Akataniaso and Twenedaso but their ratings were somewhat contradictory. While farmers in Akataniaso claimed it had very good shade quality, which can be associated with its narrow crown (Poorter et al. 2004) and contribution to soil fertility. Farmers in Twenedaaso only rated it as average in shade quality and below average in soil fertility because it competes with cocoa for nutrients, especially during the dry season. Taylor (1960) found that *K. ivorensis* prefers rich alluvial soils near water ways or in damp areas, but requires good drainage. However, both communities agreed on its good timber value, which makes it worth having a *Khaya spp.* in a cocoa farm as security for the future.

Triplochiton scleroxylon was rated very poorly on soil moisture, soil fertility and weed suppression abilities by farmers in Nerebehi. According to the farmers it competes with cocoa for nutrients and water as indicated by the dryness of the soil that persists around the tree for most of the year, particularly during the dry season. These observations correspond to findings that *T. scleroxylon* seems to prefer fertile soils in areas with adequate (1100-1800 mm) bi-modal rainfall patterns (Poorter et al. 2004). However, the farmers felt that if it is growing in areas where drainage is a problem, it does not have a negative effect on the cocoa and can help reduce water logging. Therefore, the farmers agreed that if one is able to manage it properly, then it can fit well with cocoa. It was also appreciated for its high value timber.

Alstonia boonei, Ficus capensis and *Funtumia elastica* were species that were favored despite their low timber values to farmers. This corresponds with Manu and Tetteh's (1987) assertion that *A. boonei* and *F. elastica* are desirable forest trees for cocoa cultivation. Farmers in Bonteso and Gyeninso appreciated their biophysical qualities which establish favorable conditions for a healthy cocoa stands. *Aningeria robusta* was considered favorable by farmers in Nerebehi for its high value timber, as well as other positive attributes. It is also important to note that farmers did not associate any pests or diseases with any of the above trees.

Tables' 2a-2f: Application of decision tool matrix in communities

Me=Milicia excelsa, Ti=Terminalia ivorensis, Ts=Terminalia superba, Nl=Newbouldia laevis, Sc=Spathodea campanulata, Ki=Khaya ivorensis, Ab=Alstonia boonei, Fc= Ficus capensis, Fe=Funtumia elastica, Cp=Ceiba pentandra, Tsc=Triplochiton scleroxylon, Ar=Aningeria robusta

Table 2a: Aniamoa

Attributes	**Species Ratings**				
	Me	***Ti***	***Ts***	***Nl***	***Sc***
Shade Quality	7	5	5	1	5
Moisture	7	5	3	5	9
Soil Fertility	9	5	7	7	9
Weed suppression	9	7	9	5	7
Mechanical damage	9	1	1	9	7
Wind Break	9	5	7	5	9
Allows good aeration	9	7	7	7	7
Good Timber value	9	9	7	1	1
Good NTFP value	9	9	7	5	5

Table 2b: Gyeninso

Attributes	**Species Ratings**				
	Me	***Ts***	***Ab***	***Fe***	***Sc***
Shade Quality	7	7	9	5	5
Moisture	9	7	7	5	9
Soil Fertility	9	7	7	7	7
Weed suppression	7	5	9	5	3
Mechanical damage	9	5	3	3	7
Wind Break	7	3	3	5	5
Allows good aeration	9	7	5	7	7
Good Timber value	9	7	5	3	3
Good NTFP value	9	7	7	7	5

Table 2c: Akataniaso

Attributes	**Species Ratings**				
	Me	***Ti***	***Ts***	***Ki***	***Sc***
Shade Quality	9	7	9	9	7
Moisture	9	5	7	9	9
Soil Fertility	7	5	9	7	9
Weed suppression	7	5	7	7	7
Mechanical damage	9	5	5	9	5
Wind Break	7	5	5	7	5
Allows good aeration	9	5	7	9	7
Good Timber value	9	7	3	9	3
Good NTFP value	9	7	7	9	7

Table 2d: Twenedaso

Attributes	**Species Ratings**				
	Fc	***Ti***	***Cp***	***Ki***	***Sc***
Shade Quality	9	7	5	5	7
Moisture	9	5	7	5	9
Soil Fertility	7	5	7	3	9
Weed suppression	9	7	5	3	9
Mechanical damage	7	7	5	7	7
Wind Break	7	7	5	3	7
Allows good aeration	5	5	7	7	7
Good Timber value	1	7	7	9	1
Good NTFP value	5	7	5	9	5

Table 2e: Bonteso

Attributes	**Species Ratings**				
	Me	***Ti***	***Ts***	***Fc***	***Sc***
Shade Quality	9	7	7	7	7
Moisture	9	9	5	7	7
Soil Fertility	7	7	7	5	7
Weed suppression	7	7	7	5	5
Mechanical damage	7	5	3	3	3
Wind Break	7	7	7	7	7
Allows good aeration	7	9	9	5	5
Good Timber value	9	9	7	1	3
Good NTFP value	9	7	7	5	7

Table 2f: Nerebehi

Attributes	**Species Ratings**				
	Tsc	***Ti***	***Ts***	***Cp***	***Ar***
Shade Quality	5	7	7	9	9
Moisture	1	9	9	7	9
Soil Fertility	1	9	9	5	9
Weed suppression	3	7	7	9	9
Mechanical damage	5	5	5	1	5
Wind Break	5	7	9	5	7
Allows good aeration	7	7	9	3	9
Good Timber value	9	9	7	7	9
Good NTFP value	7	9	7	5	5

After the tree species selection exercise, each of the 36 farmers and facilitators were then asked to identify one acre of cocoa farm that he or she would use for the tree diversification process. Of the 31 potential diversification plots picked by farmers and facilitators, the ages of the cocoa trees ranged from 1 to 30 years, depending on each farmer's motivation for diversifying, as described in Table 3. These farms were therefore grouped into four main cocoa-age classes. Farmers who opted to diversify cocoa farms of 0-3 years explained that their ultimate goal in diversifying is to grow timber trees and cocoa. However, these farmers also chose to initially diversify with food crops so as to ensure food for the household, to provide initial income through the sale of surplus crops, and to provide much needed initial shade for the cocoa seedlings.

Farmers who selected farms from 4 to 14 years indicated that they were interested in improving the tree diversity on their farms to ensure that the shade trees that are planted or regenerated are compatible with cocoa, provide appropriate permanent shade for cocoa, and potentially bring additional income in the medium and long term through the sale of wood and other NTFPs. Finally, farmers who had plots of more than 14 years indicated that strategic planting of compatible trees in these comparatively older cocoa farms can replace incompatible trees and potentially improve farm production, provide future shade cover for new cocoa seedlings that will be planted to replace unproductive trees, and finally to provide economic benefits.

Table 3: Cocoa farm age groups and diversification goals

Farm age groups/years	*Stage of farm*	*Reason for diversification*	*Farmers (n=31)*
0 – 3	Early	Initial income, initial shade, food security, long term economic benefits, permanent shade	9
4 – 7	Young	Additional income, permanent shade	8
8 – 14	Mature	Additional income, permanent shade	9
> 14	Old	Additional income, permanent shade, shade for rehabilitation	5

4. Drawing farm maps

On each of the selected one acre cocoa farm plots, maps were developed to serve as blue prints for tree planting. In developing the farm maps the age of the cocoa trees, name of farm location, names of intended tree species to be planted, and date for planting were recorded. As a first step, farmers and facilitators walk through each farm plot to identify non-cocoa trees and their regeneration regimes. This gave an indication of tree species that already existed and helped farmers to decide on the species that they wanted to plant.

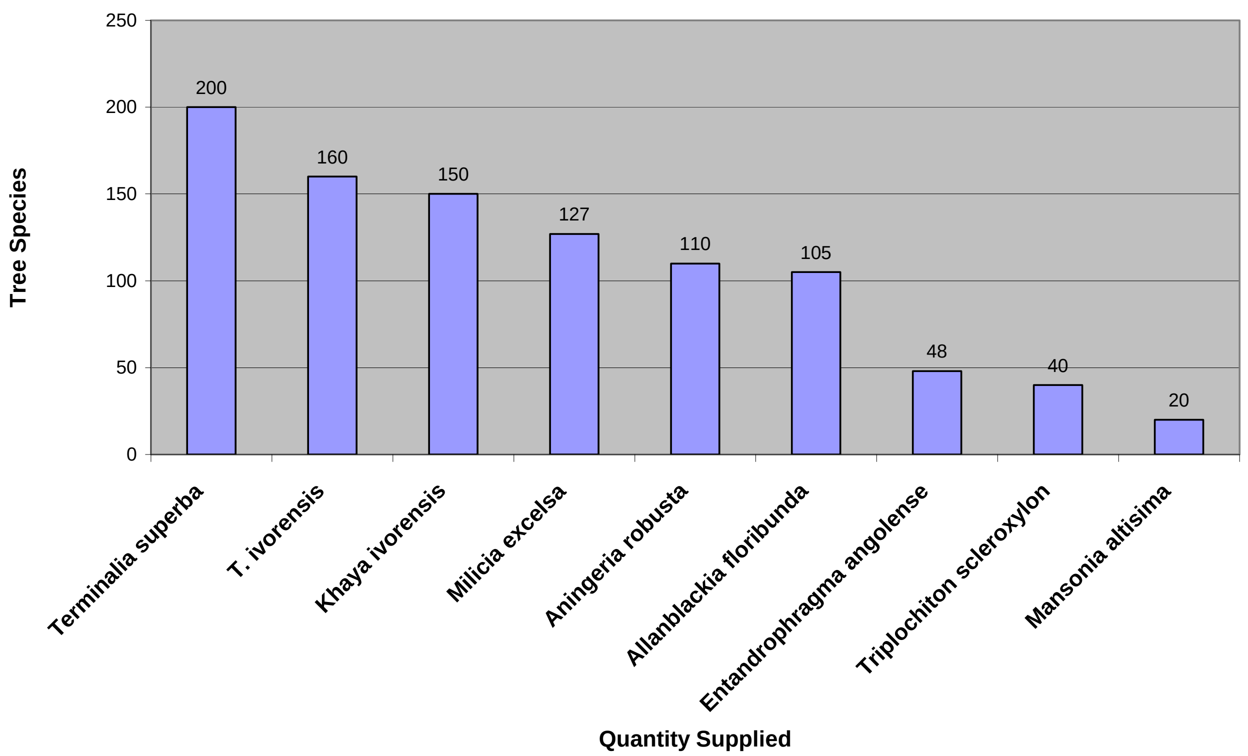
After the tree identification process, the inspection team then identified a reference point on the fringes of the farm. From this reference point the farmer is asked to indicate the direction of the morning sun (sun rise) and evening sun (sun set), and then to identify a landmark which can indicate north and south. For some farmers this landmark was the major road that runs from Kumasi in the south up to Tamale in the north. These cardinal points give a basic orientation to the farm. With the cardinal points in place and standing at the reference point, an outline of the farm is drawn showing any major landmarks that exist. These include slope direction, water bodies, foot paths, farm settlements, relic trees, etc. Still standing at the reference point an indication is made on the map showing the spot where the first non-cocoa tree will be planted and the direction and planting pattern of subsequent seedlings. This document then becomes a simple map that outlines the planting arrangement for the non-cocoa trees. The map also serves to document that the trees were in fact planted and nurtured by each farmer should disputes arise.

5. Accessing improved planting material

The next step in the process is to identify sources where farmers can access improved planting materials for the preferred species. Farmers from the six groups brainstormed potential tree seed sources, including; farmland, nearby forest patches, the nursery at the district forest offices, commercial tree seed nurseries, private tree seed nurseries, and the tree nursery at the Forestry Research Institute of Ghana (FORIG).

Despite the fact that some farmers wanted to transplant wildlings from farmlands or nearby forests patches to their designated plots, it was agreed that since it is difficult to authenticate the genetic quality of those materials, it is more appropriate to access planting materials from a reliable source so as to ensure that planted trees are of good genetic quality. Contact was made with the district forest offices, however the desirable species were not available and so planting materials were obtained from FORIG. In all, 960 tree seedlings of nine different species were requested and subsequently supplied to farmers in the six communities. Figure 1 shows the species and quantities that were distributed to the farmers.

Figure 1: Tree Seedlings Distributed



All nine of the species that farmers requested and received are economically valuable timber species. During discussions with the farmers it became clear that while they appreciate many of the less economic trees like *Alstonia boonei, Ficus capensis, Newbouldia laevis, Spathodea campanulata*, as was evident in their matrix assessments, they indicated that these trees were abundant in the landscape and therefore preferred to plant high value timber trees instead.
Interestingly, they requested two high value timber species, *Mansonia altissima* and *Allanblakia floribunda*, which they had not originally listed in the matrices. Farmers that chose these two tree species explained that the decision support tool caused them to think more critically about desirable tree species and make selections according to their priorities.

6. Land preparation and tree planting on cocoa farms

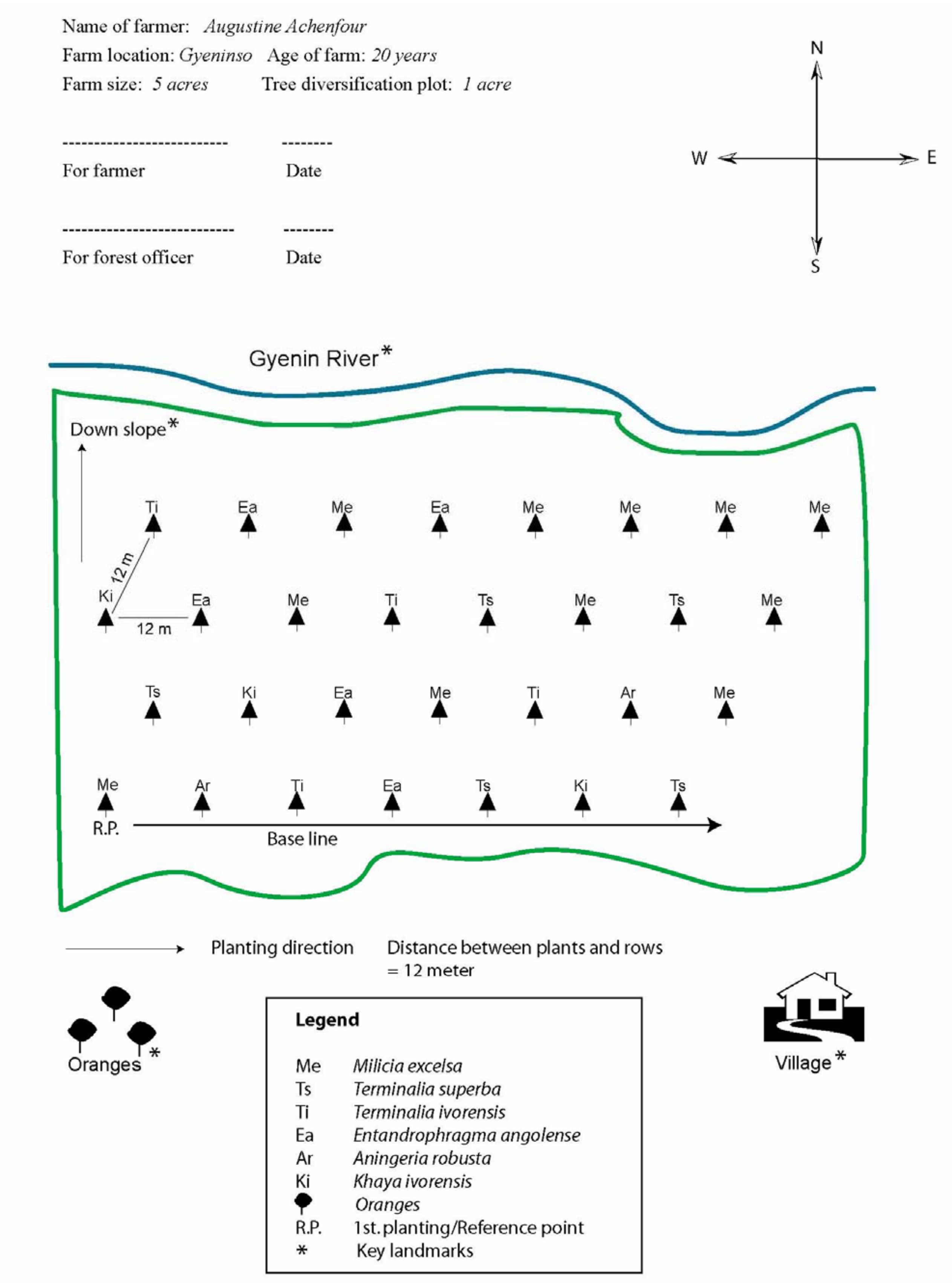
Prior to planting on their own plots, each group of farmers participated in demonstration plantings. With the aid of a forest technician and the farmers, facilitators demonstrated how to plant the selected tree seedlings in a triangular pattern at a planting distance of 12 x 12 meters (Anglaaere 2005) that would later be thinned to 24 x 24 meters in the future when shade is perceived to be too much. Thus, each farm has an initial density of 28 trees per acre and a final density of 8 trees per acre. One of the purposes of tree diversification is to enhance complimentarity between shade trees and the cocoa trees; hence farmers are encouraged to follow this planting arrangement which reduces potential competition.

At the start of the planting process, farmers eliminated weeds and other obstacles that could obstruct free movement of materials for the planting exercise. Then the group layed out the pattern for planting using a measuring tape, ropes and wooden pegs. A horizontal base line was created with the rope tied to a peg at the reference point and the rope stretched along a straight path following the direction of planting (Figure 2). Along the rope, intervals of 12 meters are marked with the measuring tape and pegs placed at these points to indicate holes for tree planting.

With the baseline in place a triangular pattern was created by tying one 12 meter rope (rope A) to the reference peg (peg 1) and a second 12 meter rope (rope B) to the next peg (peg 2) on the baseline. The ropes are held at each end by two farmers and stretched diagonally to their 12 meter limits until they meet right in the middle of pegs 1 and 2. A peg is placed at this point completing the first triangular pattern. Still moving in the direction of planting, rope A is removed from peg 1 and placed at peg 3. Here, the rope is tied to the peg and the farmer at the other end stretches it diagonally, while the farmer who is holding the other end of rope B stretches it until the two farmers meet at a point between pegs 2 and 3 to create the second triangle. Rope B is then removed and placed at peg 4 and the whole process repeated until 27-30 pegs are staked, corresponding to the different trees that the farmer has chosen to plant.

During the planting process, different tree species were planted in consecutive holes to ensure diversity and to avoid same species following each other in the line of planting. The planting process is a tedious activity, hence other farmers in the group helped in the planting and this allowed for information sharing through questions and answers. After the demonstration, each farmer group worked together to plant the selected tree seedlings on each member's farm plot following the mapping exercise. Group collaboration helps to reduce the costs and labor of planting each one acre plot, and provides each farmer the opportunity to gain experience in different farm environments.

Figure 2: Sample of a farm map showing planting arrangements of tree species



Conclusions

Across West Africa, it has been noted that farmers are generally reducing the level of shade found on cocoa farms. This trend has largely been attributed to the introduction of improved cocoa planting material, which requires lower shade densities, as well as the introduction of chainsaws which facilitate easy removal of canopy tree species. Additional issues also limit the density and diversity of shade trees on cocoa farms, including institutional, technical, marketing and legal factors. Clearly, there is ample room to increase the socio-economic value of cocoa agroforests, improve biophysical interactions within the farm, and strengthen farmers' user-rights to valuable timber species while potentially enhancing the biological diversity within the cocoa farming landscape. Through the use of a participatory action learning approach, tree diversification can help farmers to meet these objectives.

Implementing this six step approach with farmers demonstrated that tree diversification can be a useful method for combining farmer knowledge and priorities with available technical information to encourage and improve shaded cocoa systems for social, economic, agronomic, and ecological benefits. This six step approach entails:

1. Identifying tree diversification options
2. Developing and testing a decision support tool for desirable tree selection
3. Selecting desirable trees and cocoa farms
4. Drawing farm maps
5. Accessing improved planting material
6. Land preparation and tree planting on cocoa farms

The six step approach provided a framework for farmers to identify tree diversification options that are relevant to their farming practices. It gave them a decision support tool that helped farmers to select desirable shade trees that are compatible with cocoa, and then provided a structure for planning the integration of these shade trees into their farms through the use of farm maps and planting arrangements. The development, adoption and the implementation of the tree diversification approach also revealed how knowledgeable farmers are in terms of their expectations of a compatible or desirable shade tree in cocoa.

In all, farmers planted a total of 960 tree seedlings from nine different species in a triangular 12 x12 meter spacing arrangement on 31 farms (31 acres) within Atwima and Amansie West districts. The majority of these farmers opted to plant species that they had identified as being biophysically compatible with their cocoa trees and economically valuable for either their timber or non-timber products. By planting a variety of high value timber species farmers demonstrated a willingness and capacity to diversify their farms according to a structured and well planned process. While this approach was tested amongst Ghanaian cocoa farmers, it has the potential to be used in other tree crop systems or in tree domestication programs.

The Way Forward

Although the planting of tree seedlings is the end of the first phase of tree diversification, it by no means marks the end of the diversification process. The hope is that farmers will expand diversification to other parts of their cocoa farms, and that other farmers can learn from their neighbors and relatives to adopt the practice as well. However, further steps are required to create a positive environment for diversification and to ensure that diversification remains a viable option for small-holder cocoa farmers. The key areas that are critical to the long term success of diversification include:

1. Monitoring and evaluation: In subsequent phases of diversification farmers and facilitators need to actively monitor and evaluate their plantings. Where seedlings die or are stolen farmers can replant. Each group will keep records of seedling survival, height, and girth, as well as general observations on the overall conditions of the cocoa farm. Of specific interest is which species have the best survival rates and growth increments over time, as well as how the different species interact with the cocoa.
2. Accessing planting materials and nurseries: Reliable sources of tree seedlings are crucial to the continuation of the diversification process. In Ghana, FORIG can provide a wide range of seeds and seedlings; unfortunately their nurseries are not easily accessible to most farmers. Therefore, providing initial support to encourage or diversify local nursery enterprises will be necessary, as well as connecting nursery operators to viable seed sources. A second option is to link with local timber companies who are legally required to engage in replanting exercises and therefore maintain private nurseries that could potentially be accessed by farmers.
3. Accessing markets: Smallholder production of indigenous timber for legal sale on the market is relatively uncommon in Ghana. At present, no market chain exists for timber production in smallholder cocoa farms. Therefore, a major activity during the second phase of the diversification process is to work with farmers, District Assemblies, the Forest Services Division, national and international timber companies, as well as local and regional timber merchants to create avenues for the sale of timber from cocoa farms. For those farmers who opt to diversify with food crops and/or fruit trees, these markets already exist but are not well established in all areas.
4. De-mystifying timber policies and laws: Because farmers can not own trees that naturally regenerate on their land, many farmers remain skeptical as to whether they can own a planted timber tree. Some are also unconvinced that they will be given the right to cut or use the tree as they choose. The forestry laws in Ghana as stipulated by the Concession Act of 1962 and Timber Resources Management Act of 1997 indicate that a planted tree is the property of the person who plants it. Unfortunately, farmers also express reservations about forestry officials' ability or willingness to recognize a 'planted' tree (as compared to one that grew naturally in the landscape) or their rights to that tree. Therefore, not only is it necessary to build awareness amongst farmers about the current forest policies and their user-rights, but it is also important to sensitize local governments and forestry officials of the legitimacy of the diversification process. At a national level, increasing government support for smallholder production of indigenous timber will provide substantial motivation to farmers and help to allay some of their fears.
5. Shifting government priorities in cocoa: Ghana's government is focused on increasing the overall production of cocoa in the country, largely through the introduction of mass spraying activities, and intensification of farming practices using high tech methods (hybrid cocoa varieties, disease spraying, and fertilizer application). But on the ground, farmers are rather expanding their new farms into uncultivated forest and fallow areas. If the government can adopt diversification as one of its priorities, then diversification, paired with good cultural practices, can help to rejuvenate the agro-forest landscape of the old cocoa growing areas which have very good soils but have lost much of their original forest cover. One way that

the government could encourage tree diversification in cocoa farms is to make desirable forest trees seedlings available in their cocoa seed production units, which are dispersed all across the cocoa growing belt and are patronized by farmers.

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References

Abbiw DK (1990) Useful plants of Ghana. I.T.P. Royal Botanical Gardens, Kew, England

Adeyemi AA (2000) Effective management of cocoa farms in Nigeria for profitability. Cocoa Growers' Bulletin No.52: 21-32

Alvim PD (1977) Cacao. In: Alvim PD and Kozlowski TT (eds) Ecophysiology of tropical crops. Academic Press, New York

Amanor KS (1996) Managing trees in the farming system. Forestry Department Planning Branch, Kumasi, Ghana

Amoah FM, Nuertey BN, Baidoo-Addo K, Oppong FK, Osei-Bonsu K and Asamoah TEO (1995) Underplanting oil palm with cocoa in Ghana. Agroforestry Systems 30:289-299

Anglaaere LCN (2005) Improving the sustainability of cocoa farms in Ghana through utilization of native forest trees in agroforestry systems. Dissertation, University of Wales

Anim-Kwapong GJ (2003) Potential of some Albizia species as shade trees when replanting cocoa in Ghana. Agroforestry Systems 58:185-193

Anim-Kwapong GJ (2006) Potential of planted and natural tree fallows for rehabilitation of degraded cocoa farmlands in Ghana. Paper presented at conference on extending cacao for biodiversity conservation, Kumasi, Ghana, 14-18 August 2006

Asare R (1999) Managing trees on farm levels: impact on crop production, case study of the Joint Forest Management Project, Gwira-Banso, Ghana. Master's Thesis, Royal Veterinary and Agricultural University

Asare R (2005) Cocoa agroforests in West Africa: a look at activities on preferred trees in the farming systems. The Danish Centre for Forest, Landscape and Planning (KVL), Horsholm

Asare R (2006) Learning about neighbor trees in cocoa growing systems- a manual for farmer trainers. The Danish Centre for Forest, Landscape and Planning (KVL), Horsholm

ASB (2000) Alternatives to slash-and-burn: summary report and synthesis of phase II in Cameroon. ASB Coordination Office, ICRAF, Nairobi

Ashley R, Russell D and Swallow B (2006) The policy terrain in protected area landscapes: challenges for agroforestry in integrated landscape conservation. Biodiversity and Conservation 15:663-689

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

David S (2006) Learning about sustainable cocoa production: a guide for participatory farmer training. 1. Integrated crop and pest management. Sustainable Tree Crops Program, Internatinal Institute of Tropical Agriculture, Accra, Ghana

DiFalco S and Perrings C (2003) Crop genetic diversity, productivity and stability of agroecosystems. A theoretical and empirical investigation. Scottish Journal of Political Economy 50:207-216

Duguma B, Gockowski J and Bakala J (2001) Smallholder cacao (*Theobroma cacao* Linn.) cultivation in agroforestry systems of West and Central Africa: challenges and opportunities. Agroforestry Systems 51:177-188

Famaye AO, Adeyemi EA and Olaiya AO (2003) Spacing trials in cocoa/kola/citrus intercrop. Paper presented at 14th international cocoa research conference, Accra-Ghana, 13-18 October 2003

Finegan B and Nasi R (2004) The biodiversity and conservation potential of shifting cultivation landscapes. In: Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL and Izac A-MN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington D.C

Franzel S (2001) Use of an indigenous board game, 'bao', for assessing farmers' preferences among alternative agricultural technologies. In: Tomorrow's Agriculture: Incentives, Institutions, Infrastructure and Innovations Proceedings of the 24th International Conference of Agricultural Economics, Berlin, 13-18 August, 2000

Gillison AN, Liswanti N, Budidarsono S, van Noordwijk M and Tomich TP (2004) Impact of cropping methods on biodiversity in coffee agroecosystems in Sumatra, Indonesia. Ecology and Society 9:7

Gockowski J and Dury S (1999) The economics of cocoa-fruit agroforests in Southern Cameroon. In: Jimenez F and Beer J (eds) Multi-strata agroforestry systems with perennial crops. CATIE, Turrialba

Gockowski J, Tchata M, Hietet JP, Fouda G and Moneye JJ (2006) The value of biodiversity in the Beti Cocoa Agroforests of Southern Cameroon. Paper presented at International Society of Tropical Foresters conference on conservation and the agricultural frontier, Yale University School of Forestry and Environmental Studies, New Haven, CT, 7 April 2006

Gockowski J, Weise SF, Sonwa D, Tchata M and Ngobo M (2004) Conservation because it pays: shaded cocoa agroforests in West Africa. Paper presented at National Academy of Sciences conference on the science behind cocoa's benefits, Washington, D.C., February 10 2004

Greenberg R, Bichier P and Angon AC (2000) The conservation value for birds of cacao plantations with diverse planted shade in Tabasco, Mexico. Animal Conservation 3:105-112

Hall JB and Swaine MD (1981) Distribution and ecology of vascular plants in a tropical rain forest: Forest vegetation in Ghana. Dr. W. Junk Publishers, Boston

Hartemink AE (2005) Nutrient stocks, nutrient cycling, and soil changes in cocoa ecosystem: a review. Advances in Agronomy 86:227-253

Herzog F (1994) Multipurpose shade trees in coffee and cocoa plantations in Côte d'Ivoire. Agroforestry Systems 27:259-267

Isaac ME, Timmer VR and Quashie-Sam SJ (2007) Shade tree effects in an 8-year-old cocoa agroforestry system: biomass and nutrient diagnosis of *Theobroma cacao* by vector analysis. Nutrient Cycling in Agroecosystems 78:155-165

Jeffrey AM and Schroth G (2006) Agroforestry and biodiversity conservation - traditional practices, present dynamics, and lessons for the future. Biodiversity and Conservation 15:549 - 554

Joker D (2002) Milicia excelsa. Danida Forest Seed Centre, Humlebaek, Denmark

Jose S, Williams R and Zamora D (2006) Belowground ecological interactions in mixed-species forest plantations. Forest Ecology and Management 233:231-239

Kindt R, Van Damme P, Simons AJ and Beeckman H (2006) Planning tree species diversification in Kenya based on differences in tree species composition between farms. I. Analysis of tree uses. Agroforestry Systems 67:215-228

Leakey RRB (1998) Agroforestry in the humid lowlands of West Africa: some reflections on future directions for research. Agroforestry Systems 40:253-262

Manu M and Tetteh EK (eds) (1987) A guide to cocoa cultivation. Cocoa Research Institute of Ghana (CRIG), Tafo

Mendez VE and Bacon CM (2006) Ecological processes and farmer livelihoods in shaded coffee production. Magazine on low external input and sustainable agriculture (LEISA) 22 (4):22-23

Montagnini F, Gonzalez E, Porras C and Rheingans R (1995) Mixed and pure forest plantations in the humid neotropics: a comparison of early growth, pest damage and establishment costs. Commonwealth Forestry Review 74:306-314

N'Goran K (1998) Reflections on a durable cacao production system: the situation in Ivory Coast, Africa. Paper presented at conference on shade grown cacao, Panama, 30 March - 2 April 1998

Nomo B (2005) Farmers' ecological and agronomic knowledge about the management of multistrata cocoa systems in Southern Cameroon. Dissertation, University of Wales

Norgrove L and Hauser S (2000) Leaf properties, litter fall, and nutrient inputs of *Terminalia ivorensis* at different tree stand densities in a tropical timber- food crop multistrata systems. Canadian Journal of Forest Research 30:1400-1409

Obiri BD, Bright GA, McDonald MA, Anglaaere LCN and Cobbina J (2007) Financial analysis of shaded cocoa in Ghana. Agroforestry Systems 71:139-149

Oduro CA, Osei-Bonsu K and Tetteh JP (2003) Traditional cocoa agroforestry: 2. Indigenous selection criteria for shade trees on cocoa farms in a typical cocoa growing district of Ghana. Paper presented at 14th international cocoa research conference, Accra, Ghana, 13-18 October 2003

Opoku IY, Akrofi AY and Appiah AA (2002) Shade trees are alternative hosts of the cocoa pathogen *Phytophthora megakarya*. Crop Protection 21:629-634

Osei-Bonsu K, Ameyaw-Oduro C and Tetteh JP (2003) Traditional cocoa agroforestry: 1. Species encountered in the cocoa ecosystem of a typical cocoa-growing district in Ghana. Paper presented at 14th international cocoa research conference, Accra, Ghana, 13-18 October

Osei-Bonsu K, Amoah FM and Oppong FK (1998) The establishment and early yield of cocoa intercropped with food crops in Ghana. Ghana Journal of Agricultural Science 31:45-53

Osei-Bonsu K, Opoku-Ameyaw K, Amoah FM and Oppong FK (2002) Cacao-coconut intercropping in Ghana: agronomic and economic perspectives. Agroforestry Systems 55:1-8

Padi B and Owusu GK (1998) Towards an integrated pest management for sustainable cocoa production in Ghana. Paper presented at international conference on shade grown cacao, Panama, 30 March-2 April 1998

Poorter L, Bongers F, Kouame FN and Hawthorne WD (2004) Biodiversity of West African forests. CABI Publishing, Wallingford

Rice RA and Greenberg R (2000) Cacao cultivation and the conservation of biological diversity. Ambio 29:167-173

Rolim SG and Chiarello AG (2004) Slow death of Atlantic forest trees in cocoa agroforestry in southeastern Brazil. Biodiversity and Conservation 13:2679-2694

Ruf F and Konan A (2001) Les difficultes de la replantation. Quel avenir pour le cacao en Côte d'Ivoire. Oleagineux Corps Gras Lipides 8:593

Ruf F and Schroth G (2004) Chocolate forests and monocultures: A historical review of cocoa growing and its conflicting role in tropical deforestation and forest conservation. In: Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL and Izac A-MN (eds) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington

Ruf F and Zadi H (1998) Cocoa: from deforestation to reforestation. Paper presented at international conference on shade grown cacao, Panama, 30 March-2 April 1998

SAN (2005) Additional criteria and indicators for cocoa production. Sustainable Agriculture Network, Rainforest Alliance. http://www.rainforest-alliance.org/programs/agriculture/certified-crops/standards_2005.html Accessed on September 10, 2007

Schroth G, da Fonseca GAB, Harvey CA, Gascon C, Vasconcelos HL and Izac A-MN (eds) (2004) Agroforestry and biodiversity conservation in tropical landscapes. Island Press, Washington

Schroth G and Harvey CA (2007) Biodiversity conservation in cocoa production landscapes: an overview. Biodiversity and Conservation 16:2237-2244

Siebert SF (2002) From shade- to sun-grown perennial crops in Sulawesi, Indonesia: implications for biodiversity conservation and soil fertility. Biodiversity and Conservation 11:1889-1902

Simons AJ and Leakey RRB (2004) Tree domestication in tropical agroforestry Agroforestry Systems 61:167-181

Sonwa D, Weise SF, Tchatat M, Nkongmeneck B, Adesina AA, Ndoye O and Gockowski J (2001) The role of cocoa agroforestry in community and farm forestry in southern Cameroon. Rural Development Forestry Network, London

Sonwa DJ, Nkongmeneck BA, Weise SF, Tchata M, Adesina AA and Janssens MJJ (2007) Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. Biodiversity and Conservation 16:2385-2400

Taylor CJ (1960) Synecology and silviculture in Ghana. Thomas Nelson and Co., London

Wessel M and Gerritsma W (1994) Re-thinking the shade policy for cocoa growing in West Africa. In: Proceedings of the 11th international cocoa research conference, Yamoussoukro, Côte d'Ivoire, 18 - 24 July 1993

Zapfack L, Engwald S, Sonke B, Achoundong G and Madong BA (2002) The impact of land use conversion on plant biodiversity in the forest zone of Cameroon. Biodiversity and Conservation 11:2047-2061