CZECH UNIVERSITY OF LIFE SCIENCES, PRAGUE

FACULTY OF ENVIRONMENTAL SCIENCE

DEPARTMENT OF ENGINEERING ECOLOGY

TREE DIVERSITY IN COCOA AGROFORESTRY IN THE WESTERN REGION OF GHANA

DIPLOMA THESIS

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DIPLOMA THESIS ASSIGNMENT

Samuel Kudjo Ahado

Nature Conservation

Thesis title

Tree diversity in cocoa agroforestry in Ghana

Objectives of thesis

The main focus of this research is the assessment of tree species richness and diversity in the cocoa agroforestry systems at the western region of Ghana. We intend to achieve this by specifically carrying a search to:

•Assess the impacts of forest conversion on tree communities by comparing tree species richness, and composition as wellas responses at individual species level, between natural primary and secondary forest and cocoa agroforestry systems.

•Compare the average basal area between the habitat types.

•Investigate the effect of the current trend in cocoa cultivation on tree diversity in the Western Region of Ghana.

•Elicit and sample farmer's ecological knowledge on the interactions between trees and cocoa in the agroforestry systems.

•To identify tree species valued by farming community for incorporation into these System.

•To find species –specific pattern of abundance along the habitat gradient.

Methodology

A total of 20 farmers will be interviewed using a semi structured questionnaire and a total of 15 plots one square 25 x 25 m plot will be measured in the area of primary forest, secondary forest and cocoa agroforestry (five in each habitat). For each cocoa agroforest, one point will be selected based on visual observations to guarantee certain homogeneity. Within each plot in agroforestry sites all trees from 2.5 cm will be counted, identified to species, diameter-breast-height (DBH – 130 cm above ground level) measured by forestry meter. Cocoa trees were also measured. The tree species richness and diversity was will be evaluated by number of classical indices: Simpson's, Shanon and classical Jaccard indices were used to compare tree species similarity among the three land-use systems.

The proposed extent of the thesis

40-60 pages

Keywords

Cocoa agroforestry, Cocoa, Ghana, primary forest, secondary forest, species richness, species diversity, biodiversity, tropical rainforest.

Recommended information sources

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

Krebs Ch. J. 1994. Ecological metodology. University of British Colombia. 581pp

Vebrová H, Lojka B, Husband TP, Chuspe Zans ME, Van Damme P, Rollo A and Kalousova M. 2014. Tree diversity in cacao agroforests in San Alejandro, Peruvian Amazon. Agroforestry Systems 88:1101–1115.

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Prague on 19. 04. 2017

DECLARATION

STUDENT'S DECLARATION

I, SAMUEL KUDJO AHADO, hereby declare that except for reference to other people's work which have been duly cited and acknowledged, this Action research is the results of my own effort and that it has neither in whole nor in part been presented elsewhere.

SIGNATURE………………………. DATE……………………….

(SAMUEL KUDJO AHADO)

SUPERVISOR'S DECLARATION

I hereby declare that preparation and presentation of this thesis was supervised in accordance with the guidelines binding the supervision of Diploma thesis laid down by the Czech University of Life Sciences.

SIGNATURE………………………. DATE……………………….

(BOHDAN LOJKA)

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Abstract

Cocoa cultivation that maintains higher proportions of shade trees in a diverse structure (cocoa agroforestry) is gradually being considered as a sustainable land-use practice that complements the conservation of biodiversity. Our basic hypothesis was that cocoa agroforestry systems can support relatively high tree diversity compared to primary and secondary forest. The objective of this study was to assess the impacts of forest conversion on tree communities by comparing tree species richness, diversity and composition between natural primary and secondary forest and cocoa agroforestry systems. In all we collected data in 15 (25 x 25 m) plots on three land-use systems (5 in cocoa agroforestry, 5 in secondary forest and 5 in primary forest) in Bedum in the Western region of Ghana. All trees were identified to species, and their height and DBH recorded. Cocoa farmers were also interviewed to ascertain their knowledge about association of cocoa with trees. Our results support the hypothesis that cocoa agroforestry contains relatively high tree species richness and diversity comparable to secondary forest. Although we found higher tree density in primary and secondary forest compared to cocoa agroforestry. The species richness was found the highest in the primary forest. Per the species diversity indexes, the species composition of cocoa agroforestry is higher than in secondary forest. Farmers have very good and extensive knowledge about advantages that trees provide for cocoa, soil improvement and biodiversity conservation. However, we also find that tree species cultivated in cocoa agroforestry are not very different from the species found in primary forest, so that seems to partially answer the question "if the relatively high tree diversity and richness can support some of the original faunal diversity found in natural forest". In this context, our study forms a good scientific background for the further monitoring of ecological changes in human modified landscape in the Western region of Ghana.

Key words: Cocoa agroforestry, Cocoa, Ghana, primary forest, secondary forest, species richness, species diversity, biodiversity, tropical rainforest.

Abstrakt

Pěstování kakaa pod vyšším podílem stínících stromů rozmanité struktury (kakaovníkové agrolesnické systémy) je postupně vnímáno jako udržitelná praktika využívání půdy, která současně přispívá k zachování biologické diverzity. Naší základní hypotézou bylo, že kakaovníkové agrolesnické systémy mohou podporovat relativně vysokou rozmanitost druhů stromů v porovnání s primárním a sekundárním lesem. Cílem této studie bylo posoudit dopady přeměny deštného lesa porovnáním druhové bohatosti a rozmanitosti a složením druhů stromů mezi přirozeným primárním lesem, sekundárním lesem a kakaovníkovými agrolesnickými systémy. Celkem jsme shromáždili data na patnáct (25 x 25 m) parcelách ve třech odlišných systémech využití půdy (5 v kakaovníkových agrolesnických systémech, 5 v sekundárním lese a 5 v primárním lese) v oblasti San Alejandro, peruánská Amazonie. U všech stromů byl zjištěn a zaznamenán druh, výška a DBH. Farmáři pěstující kakao byli též dotazováni ohledně znalostí o propojení kakaa se stromy. Výsledky podporují naši hypotézu, že kakaovníkové agrolesnické systémy obsahují poměrně vysokou druhovou pestrost a rozmanitost stromů, srovnatelnou se sekundárním lesem, i když jsme zjistili vyšší hustotu stromů v primárním a sekundárním lese ve srovnání

s kakaovníkovmi agrolesnickými systémy. Nejvyšší druhová bohatost byla zjištěna v primárním lese. Podle indexů rozmanitosti je druhové složení kakaovníkových agrolesnických systémů vyšší, než sekundárního lesa. Zemědělci mají velmi dobré a rozsáhlé znalosti o výhodách, které stromy poskytují pro kakaovníky, obohacení půdy a zachování biologické rozmanitosti. Zjistili jsme však také, že druhové složení stromů v kakaovníkových agrolesnickch systémech je velmi odlišné od druhů v primárním lese, a proto je otázkou, zda relativně vysoká druhová bohatost je schopna podpořit některou z původní rozmanitosti zvířecích druhů nacházející se v přírodním lese. V této souvislosti naše studie tvoří dobrý vědecký základ pro další monitorování ekologických změn v lidmi pozměněné krajině Západní region Ghany.

Klíčová slova**:** Kakao Agrolesnické, kakao, Ghany, primární les, sekundární les, druhová bohatost, rozmanitost druhů, biodiverzita, tropický deštný.

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CHAPTER ONE

INTRODUCTION

There has been a wide recognition of the ecological and socio economic importance of traditional agroforestry systems in recent times. These land use systems provide various important products for household and national economies including medicinal products and food for humans, animals, cash income, wood for construction and fuel. This also contributes to biodiversity, sustainable of soil nutrients and water cycles and buffer climatic extremes. (FAO, 1999). Severe droughts and utilization pressure in the last decades have led to an increasing interest in promoting their conservation and in further improving their management to increase their benefit they provide to farmers. Cocoa agroforest can create forest-like habitats which can serve as fauna refugee (Griffith ,2000).

The term biodiversity can be explained to mean the sum of all biotic variation from the level of genes to ecosystems (Purvis, 2000). Biodiversity, the variety of life, is distributed heterogeneously across the Earth. Some areas teem with biological variation; e.g. some moist tropical forests and coral reefs (Gaston, 2000). Land use change including the expansion of intensive agriculture, is one of the most cited explanations for biodiversity loss worldwide (Sala et al., 2006). To affirm this assertion, researches in conservation biology seek to promote less intensive agriculture such as agroforestry systems whose components (shrubs, crops, trees, livestock, wildlife, etc.) occupy separate layers of the level vertical structure of the community that provide farmers with income while protecting biodiversity (Schroth et al., 2004).

From the very beginnings of agriculture, many farmers maintained or actively included trees as part of their agricultural landscapes. Trees provided shade, shelter, energy, food, fodder and many other goods and services that enabled the farmstead to prosper. Especially in the tropics, trees were essential components of the fallow vegetation on temporarily abandoned fields, and many trees were also retained without specific purpose on farm land where they did not interfere with the use of the land. In some humid tropical regions trees have such a prominent place in farming systems that the difference between forest, old fallows, and extensively managed traditional tree crop plantations is not immediately evident to the untrained eye. Despite the presence of trees in tropical farming systems since the very beginnings, knowledge about their use in farms and farmed landscapes has only relatively recently been consolidated into the science of agroforestry, and much remains to be learned about the relationships between trees, crops and their potential for biodiversity conservation. For the first roughly two decades of agroforestry research, agroforestry scientists were mostly concerned with the sustainable production of agricultural goods, especially food, and this line of research has lost none of its relevance. However, over the last decade or so, scientists have also become interested in the environmental services that agroforestry practices may provide to local and even global society by maintaining watershed functions, retaining carbon in the plant–soil system and, most recently, by supporting the conservation of biological diversity (McNeely and Schroth, 2006).

Agroforestry practices have often been shown to increase levels of wild biodiversity on farm land, and it is hypothesized that they are also able to play a supporting role in the conservation of biodiversity in remnants of natural habitat that are interspersed with farm land in tropical land use mosaics (McNeely and Schroth, 2006). Various studies from all over the tropics deal with the question; how much biodiversity can be found in agricultural landscapes (Schulze et al. 2004).

Cocoa agroforests that retain a floristically diverse and structurally complex shade canopy have the potential to harbor significant levels of biodiversity (Schroth et al., 2007). Given that cocoa plantations are potentially rich in medicinal as well as edible plants that can increase the peasant's revenues, Zapfack et al. (2002) recommended that management strategies should include selection and reintroduction of original forest species into plantations of cocoa trees. Diversity of one group of organisms can also promote diversity of associated groups, for example between mycorrhizas and plants or plants and insects (Van der Heijden, 1998).

The objective of this study was to assess the impacts of forest conversion on tree communities by comparing tree species richness, diversity and composition between natural primary, secondary forest and cocoa agroforestry systems. We will compare the tree density and basal area of trees between the different habitat types. Our basic hypothesis was that cocoa agroforestry systems can support relatively high tree diversity compared to primary and secondary forest. It is also our expectation that species composition will change along the habitat gradient with forest species being gradually replaced by species of open country, and to find species-specific patterns of abundance along the habitat gradient. Improvement of agricultural systems in the Western region of Ghana, possibly through improved agroforestry systems.

CHAPTER TWO
LITERATURE REVIEW

2.1 General overview

The practice of cultivating Cocoa in the West African sub region has heavily been reliant on cultivation on partly cleared forestland utilizing the ‘forest rent’ of newly cleared areas i.e. soil fertility built up in the forest soil and the shade provided by the remaining trees. But, in recent years the potential of this practice has reduced significantly in most areas due to great loss of forest areas (Ruf et al., 1998).

The remaining forest cover in West Africa per Nielsen et al (2004) accounts for only one-fifth of its original state. This partly indicates the beginning of the end of expansion of cocoa farms into forested areas. Hence increased access and co-ordination of information on shade trees in cocoa systems will help to improve the policies and decision-making process on cocoa farm management. This is very important in Ghana and Côte d’Ivoire since an extensive use of the forest rent to maintain and increase cocoa production has led to a considerable depletion of the forest cover (Ruf et al., 1998; Ministry of Science and Environment, 2002).

Cocoa as a cash crop contributes a greater percentage of foreign exchange earnings in these countries (Crook, 1990; ISSER, 2003). Hence, governmental decision and policies in the two countries have always benefited production increase, which has mostly depended on expansion of farmlands at the expense of forested areas. Côte d’Ivoire in the 1960s, launched a new policy with the motto 'land belongs to those who develop it' by the government, encouraged immigrant farmers to migrate to the forest zone to cultivate cocoa (Ruf, 2001). The policy initiated an interest for forest clearing to establish land ownership by both migrants and inhabitants. This policy coupled with research recommendations of the use of high yielding Upper-Amazon hybrid cultivated under direct sunlight and government’s subsidies on cocoa cultivation contributed to increased production using forested areas (N’Goran, 1998; Ruf and Schroth, 2004). Similarly, in Ghana, colonial policies that imposed taxes on males facilitated the movement of migrant labor from the north into the high forest zone to seek wage labor to meet this obligation (Konings, 1986: cf. Amanor, 1996). Further, cocoa production spread from the eastern parts of the country to the west into new forest frontiers due to deterioration of cocoa farms in the old growing areas.

Farmers neglected and abandoned farms and migrated westwards instead of re-investing in their ageing and depleted farms. The deterioration was due to diseases and pest damage, soil depletion, and loss of appropriate vegetation cover (Ministry of Finance, 1999). Furthermore, with the adoption of hybrid varieties that favor no to low shade systems (Padi and Owusu, 1998) farmers found it necessary to eliminate forest tree species to effect high performance of these new varieties and thus large areas of forested land were lost. In Ghana and Côte d'Ivoire, studies conducted on levels of permanent shade in cocoa farms indicate that about 50% of total cocoa farm area in both countries is under mild shade while an average of 10% and 35% was under no shade in Ghana and Côte d'Ivoire respectively (Freud et al., 1996: cf. Padi and Owusu, 1998).

Per Padi and Owusu there is a gradual shift towards the elimination of shade trees in the cocoa agroforests. However, giving the absence of a 'New Forest Frontier' in both countries (Amanor, 1996; Ruf and Zadi, 1998), production can only be sustained over the long term if cultivation methods that incorporate rehabilitation and recycling of land using forest tree species are adopted hence the increasing need for cocoa agroforestry. Cameroon and Nigeria's national economies never depended on cocoa production as heavily as those of Ghana and Côte d'Ivoire. Therefore, government policies did not prioritize cocoa production to the same extent leading to cocoa farmers neglecting their farms and shifting labor to other sectors of the economy (Ndoye and Kaimowitz, 2000; Ayoola et al., 2000). Consequently, cocoa farms in Cameroon and Nigeria are noted to be heavily shaded with high numbers of forest tree species. In a study by Gostkowski et al. (2004) Cameroon and Nigeria were classified as having high and medium shade levels respectively compared to Ghana and Côte d'Ivoire who were classified as both having low shade levels. None the less, the shade dominated cocoa farms in places like southern Cameroon has been described as one of the best forms of permanent agriculture that has preserved a forest environment and some of its biodiversity (Ruf and Schroth, 2004).

The challenge for policy makers in Cameroon and Nigeria now is how to reduce shade in cocoa orchards but at the same time maintain their diversity to enhance cocoa production and conserve biodiversity in central Cameroon, cocoa producers have developed a complex agroforestry system, which allows them to produce yields that are lower than in an intensive model, but can be maintained over a much longer time without fertilizer applications. CIRAD researchers have analyzed the dynamics of this cocoa production system to understand its function, evolution and the factors involved to propose a new sustainable and environmentally-friendly model for cocoa production.

Today, 75% of world cocoa production is of African origin. In Africa, cocoa production is based on shifting production zones to the detriment of forests, which have practically disappeared in the main producer countries. When farmers are faced with degraded production conditions in old cocoa plantations, they prefer abandoning them and setting up new ones on cleared forest land. In this context, the central basin in Cameroon provides a counter-example. The main part of the cocoa orchard is made up of old plots where cocoa trees are associated with a multitude of fruit and forest species. Despite its ecological interest, there has been little research on this complex agroforestry model because of its low yields in commercial cocoa.

The technical model proposed to farmers generally gives priority to the intensive management of cocoa as a single crop or with light shade. With this model, yields are high during the first years of cocoa production.

However, after 30 to 40 years, yields collapse because of the lack of mineral fertilization. On the contrary, in central Cameroon, where 80% of cocoa plantations are over 40 years old, farmers manage to obtain cocoa yields, which though lower than for an intensive model, are maintained over a much longer time with no fertilizer inputs. The main factors that explain the longevity of this cocoa production system include: continually replanting cocoa stands, coppicing senescent cocoa trees and the spatio-temporal management of the numerous fruit and forestry species, associated with cocoa trees of several different generations. The management of the system is also very flexible. In fact, when old cocoa plantations are taken over by a new generation of farmers, their trajectory often involves a phase of rupture followed by a revival after which the cocoa yields recover their former level.

Cocoa yields linked to the structure of cocoa trees. The research conducted by CIRAD on these systems proves that interactions occur between the cocoa stand and associated trees. The cocoa yield is closely linked to the density of cocoa trees and the structure of the associated stands (density, number and type of species). The average basal area per cocoa tree is a major determining factor in cocoa yield. This variable is linked to the average number of pods per cocoa tree. The positive relationship between the average number of trunks per cocoa tree and the average basal area per tree, due to the coppicing of senescent cocoa trees, appears to have an important role in the long-term maintenance of cocoa yields.

This research has identified the factors limiting cocoa yield in agroforestry systems and has helped farmers improve the systems in which cocoa remains the principal component in terms of use value. However, the overall evaluation of these systems does show the importance that farmers give to other species, which meet different household needs and fulfil ecological functions. The results confirm that the technical innovations that seek to improve cocoa agroforestry systems should take account of their multi-functionality and the complexity that is attributed to them by farmers.

Cocoa cultivation is a major economic activity and land use in Ghana. Traditionally, cocoa was planted under partially cleared forest with remaining trees providing shade to the cocoa trees (Asare 2005;) Anglaaere et al. 2011). In recent times management practices in new cocoa fields in Ghana particularly by migrant farmers have been associated with wide spread forest clearings where little or no shade is maintained (Ruf 2011). Given how fast agricultural activities diminish biodiversity, the major challenge for conservationists and agriculturists in biodiversity areas in Ghana is how to balance the economically driven agricultural expansion with strategies necessary for conserving natural resources, and maintaining ecosystem integrity and species viability (Asare ,2006).

The rain forests are unique world ecosystems that have a great ecological value. Tropical rainforests are highly destructed by human activities. The rapid destruction of tropical primary forests is one of driving factors for the global loss of biodiversity (Sala et al. 2000). The Amazonian rain forest forms one of the most precious ecosystems and provides a habitat for more than 50% of described plant and animal species (SFSU, 1996). The environment of the Eastern region of Ghana is under high population and ecological pressure. Increasing population density and human activity are destroying the forest landscape and inflicting the loss of biological diversity.

2.1.3 Environmental conditions

The region is characterized by a hot and humid climate with only slight variation throughout the year. The rainfall ranges from 1500 to 2000 mm and 900 to 1300mm in the forest and savannah zones respectively. Average rainy days' ranges between 85 and 130 days' Rainy seasons – major (March-July) and minor (September-November). And dry season – (November

– February) and is characterized by cold dry weather the mean annual temperature is 22-33^0 C with the mean annual relative humidity reaching Moderate between 65-95%80% (Ministry of Food and Agriculture 2010).

2.1.4 Farming System

Farming system represents a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints and for which related development strategies and interventions would be appropriate (FAO 2015). Shifting cultivation, sole cropping, inter-cropping, mixed cropping and mixed farming is predominant in the Western region of Ghana. one year cropping and 2 to 3 years' fallow period or crop rotation. Intensive land use with high rate of both inorganic or organic fertilizers and backyard farming is also practiced in the region. Slash-and-burn agriculture is practiced by majority of peasant farmers in the communities and extensive cattle ranching on degraded pastures by migrants' cooperatives and individual large owners. The terminology "slash-and-burn farming" is used in our study, however in other sources; it is referred to the "shifting cultivation" or "swidden-fallow agriculture" that is synonymous. The land-use system is defined as "a system in which relatively short periods of continuous cultivation are followed by relatively long periods of natural fallow" (Robinson and McKean, 1992). Both indigenes and immigrants after 2 or 3 years of producing vegetables and grains crops on the cleared land, then they abandoned it for another land or plot. Trees, bushes and forests are cleared by the method of slashing, and remaining vegetation is burnt. The ashes add so much nutrient to the soil including potash and the seed are then sown after the rains.

2.1.5 Agroforestry

The Association for Temperate Agroforestry defined agroforestry as "an intensive land management that optimizes the benefits from the biological interactions created when trees and /or shrubs are deliberately combined with crops and /or livestock". Agroforestry is a new name for a set of old practices as indicated by (Nair 1993). Agroforestry is, as defined by Lundgren and Raintree (1982), 'a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboo, etc.) are deliberately used in the same land management units as agricultural crops and/or animals, in some forms of spatial arrangement or temporal sequence. In the system of agroforestry, there exist both economic and ecological and interactions between different components'.

2.2 Cocoa (*Theobroma cacao L.*)

Cocoa (*Theobroma cacao*) is mostly regarded as the most important perennial cash crop for the economy of Ghana. Growing as an understory tree, it needs high annual rainfall and temperatures between 18◦C to 32◦C. Because of its climatic requirements, cocoa harvesting is highly vulnerable to climatic fluctuations, which may cause reduction in production.

Cocoa (*Theobroma cacao*) is a small, 4–8 m tall, evergreen tree in the family *Sterculiaceae*. Cocoa leaves are alternate and 10-40 cm long. The flowers are produced in clusters directly on the trunk and older branches. Cocoa flowers are pollinated by tiny flies. The fruit is ovoid pod 15–30 cm long and 8–10 cm wide, ripening yellow to orange, and weighs about 500 g when ripe. The pod contains 20 to 60 seeds embedded in a white pulp (Valíček et al., 2002).
Cocoa is a tropical commodity, grown on plantations but also by many smallholder farmers, and it is often grown under shade (Rice and Greenberg, 2000), that could range from scattered one species shade trees to very complex agroforests. Shade trees reduce the stress of cocoa by ameliorating adverse climatic conditions and nutritional imbalances, but they may also compete for growth resources (Beer et al., 1998). Shade for cocoa cultivation is becoming critical because of the large-scale deforestation (Salleh, 1997). The Centre of origin of the cocoa tree probably is on the eastern equatorial slope of the Andes and undoubtedly in the Amazon basin. The oldest real Centre of cultivation seems to have been Central America, where the crop has been under cultivation for more than 2000 years (Valíček et al., 2002). Within the 17th, and then during the 19th and 20th century it spread to the South-East and to the West Africa. Nowadays, the main producers of cacao are the Côte d'Ivoire, Indonesia, Ghana and Nigeria, which produce at least two thirds of the total world harvest (FAO, 2007). Optimum yield of dry beans is more than 2.0 t/ha, while average yields was in 0.52 t/ha (FAO, 2008).

2.2.1 Traditional Cocoa Agroforests

Cocoa agroforests are a widely used farming system in the humid zone of west and central Africa, in which forest trees provide shade and other environmental services as well as marketable products. Agroforests based on shade-tolerant sub canopy species such as cocoa are usually established by selectively clearing natural forest and under planting it with tree crops (Schroth et al., 2004). Traditional forms of growing cocoa in agroforestry systems differ in diverse regions in the world. The most utilized traditional systems come from Brazil (known as *cabruca* plantation), Cameroon and from Côte d'Ivoire.

Cabruca cocoa plantations of Bahia, Brazil are agroforests based on understory crops, and differ from those based on canopy trees by having a more open canopy, which is managed to allow sufficient light transmission and to grow understory and midstory tree crops (Schroth et al., 2004). In *cabruca* agroecosystem, cacao is planted under large trees retained from the original forest (Johns, 1999). Per Johns (1999), the traditional practice of establishing *cabruca* plantations was to remove about one-third of the original forest canopy trees, often some of the largest, and underplant them with cocoa trees. This resulted in a shade canopy of about 50-60%, considered necessary by most farmers for maintaining a humid microclimate, conserving soil fertility, reducing weed growth and insect attack, and conserving pollinator species (Schroth et al., 2004). Planting cocoa in the *cabruca* system took smaller investments per unit area than the clear-cuts system and was more amenable to the minimal management system practiced by absentee owners of large estates (Hill, 1999 in: Schroth et al., 2004).

2.2.2 Planting cocoa with shading trees

Agroforestry may be introduced at various stages in agricultural development. A common case is when tree crops are introduced into shifting cultivation systems, typically fruit or multipurpose trees. They tend to increase the labor inputs per hectare and are more labor intensive than shifting cultivation or pastures but not more than continuous cropping of annuals. The main driver behind the development is population growth (higher land scarcity and the need to provide more food from a limited land area), and agroforestry is a low-cost intensification in response to the need to supplement subsistence food production (e.g., fruit or protein banks as fodder supplement for cattle) and products traditionally collected from the forests. The other case is like the previous one in that land is abundant and the forest frontier is still open. The principal difference is that the driver behind the adoption of agroforestry is the desire to produce commercial tree crops for an outside market. Commercial tree crops can be introduced and consequently modify existing systems, or might become so dominant that the system cannot be classified as agroforestry anymore. The third case presents a different situation in which scarcities of land and forest products are major driving factors for implementing agroforestry on farmland to provide forest products. The demand for these forest products typically is from local or regional markets, not international ones (Angelsen and Kaimowitz, 2004).

Most agroforestry technologies appear to be more labor intensive, although some practices such as the use of tree shade to reduce weed pressure (and to replace hand weeding) in cropping systems aim to reduce the labor needs (but compared with herbicides, tree shade tends to be more labor intensive). Compared with traditional shifting cultivation, pasture, and slash-and-burn annual cropping systems, permanent agroforestry practices entail more labor per unit area. In fact, labor shortage often is a reason why agroforestry practices are not adopted. Interestingly, a technology characteristic (labor intensiveness) that makes farmers reluctant to adopt agroforestry practices is the same characteristic that makes the practice, once adopted, less likely to lead to primary forest encroachment (Angelsen and Kaimowitz, 2004).

Moreover, farmers have cut grids into existing forest to establish cacao under the remaining canopy. Establishment also involves planting hardwood shade trees such as mahogany (*Swietenia macrophylla*) and fruit trees (Rosenberg and Marcotte, 2005). Most the trees in cocoa agroforests are native tree species, and occur in surrounding forest fragments.

2.2.3 Full-sun production cocoa

The most widespread land use system in the Guinean rain forest (GRF) is cocoa farming (Gockowski and Sonwa, 2011). Most areas in this farming systems especially from Guinea to Cameroon which was identified as biodiversity hotspot (Meyers et al., 2000). Some farmers switching to full-sun production because of lower labor costs and higher short-term yields. For example, Sulawesi cocoa farmers are switching from long fallow shifting cultivation of food crops to intensive full-sun cocoa (Belsky and Siebert, 2003).

Siebert (2002) reports that between 1990 and 1999 in Moa cocoa production rose from one household to all households, replacing shifting cultivation farms with full-sun cocoa, and suggests that in the long-term this replacement may result in decreased soil fertility and require the use of chemical inputs if shifting back to the cultivation of food crops becomes necessary. Some farmers began adding shade and fruit trees to their full-sun cocoa after a drought caused widespread mortality of cocoa seedlings.

However, those farmers that have added trees oftentimes remove them when fruiting begins to maximize sun and yield (Belsky and Siebert 2003). Full-sun production is being adopted in other areas as well. Whereas previously 94% of the cocoa farms in Ecuador used traditional shade-grown cocoa, half of the trees planted in the last years are of the modern full-sun varieties (Bentley et al., 2004). collapse of the quality grading system that had been in place prior to the 1960s was mainly attributed to this change. With all varieties fetching the same price, the incentive for growing high quality cocoa has disappeared.

In other words, full-sun production results in increased yields in the short-term but demands the application of chemical fertilizers to ensure high yields (Rice and Greenberg, 2000). Full-sun conditions also encourage the growth of weeds leading to greater use of herbicides (Clay, 2004). There are an estimated thirty-two common pesticides used in cocoa production, some of which are banned in consuming countries, and nine of which are included in the ‘‘dirty dozen’’ identified by the Pesticide Action Network. Improper use of these chemicals not only causes damage to the local environment but can also be very harmful to farm workers.

As discussed by Clay (2004), high-yield varieties used in intensive production systems, and planting at high densities with or without intercrop species, may serve as a means of alleviating the pressure to clear primary forest to expand production. Yet this may only be a short-term solution. Such varieties grown intensively tend to produce for a much shorter time, often only 6–8 years, whereas shade varieties are reported to continue producing for 80–100 years (Bentley et al. 2004), though with yields declining 15 to 20 years after planting (Clay, 2004). Although some areas of intensive production may be replanted when productivity declines after six years, new plantings will not always be confined to the same areas, and the claim that such intensive production systems will reduce the clearing of new forest cannot be guaranteed. In addition, while the shade cocoa uses little to no chemical inputs, intensive production systems require these inputs and farmers using such production techniques will be dependent on chemical inputs but not always able to afford them (Leiter and Harding 2004). Furthermore, farmers may face a reduction of future food production potential on land where full-sun cocoa is grown (Belsky and Siebert, 2003).

2.2.4 Tree species used in cocoa based agroforests

Farmers generally associate cocoa with native and exotic trees in complex agroforestry systems. In all the agroforests, food producing tree species tended to be more frequent than another species. The results of study done by Sonwa et al. (2007) in Southern Cameroon shows that two thirds of the food trees were native forest species and one third was introduced. The density of food producing trees doubled and the density of exotic food-producing species increased relative to native species. Some local species producing high-value non-timber forest products were found in the agroforests, but their density was far lower than that of exotic tree species. The agroforests also provide medicine, charcoal and other products for household consumption and sale. Asase et al. (2010) have found in south-eastern Ghana that 18 native forest/non-crop trees species in the agroforestry systems were commonly recorded as being used; 100% of them being used as fuel wood with 83.3 and 77.8%, respectively, used as medicines and materials. The high percentage of useful (including exotic) tree species in cocoa agroforests and their increased abundance in the more intensely used landscape reflect the fact that farmers actively retain or introduce useful tree species into the cocoa agroforests.

This illustrates the multiple uses of native biodiversity in the cocoa agroforests. Income from trees associated with cocoa can complement that from the cocoa itself. Snowa et al. (2007) found many potentially valuable NTFP and timber species from the local forest flora that can grow well in cocoa agroforests. However, with increasing market access and land use intensity, native forest species were increasingly replaced with common and often exotic tree crops such as oil palm, banana, plantain and avocado. To counter this market pressure and maintain the potential of cocoa agroforests to conserve local forest tree species under increasing land use pressure, more efforts are needed to develop the markets for native forest species and provide rewards to farmers for their conservation efforts. Such efforts would have the benefit of helping to maintain access for poor people to forest products such as food, medicinal products and charcoal despite increasing land use pressure.

Some species are regularly retained on cocoa farms for use as timber and construction. Several timber species also provide popular seeds or fruits, consumed by people as well as wildlife. Fuelwood species (some also used for timber or construction) are used to dry cocoa or for household use. Two basic cocoa shade management models can be identified: (1) cocoa under ‘‘service’’ legume shade trees; and (2) cocoa under ‘‘productive’’ shade tree crops (timber or perennial tree crop species) (Somarriba and Beer, 2011). In model one, the legume trees are spaced, pruned and thinned per (only) the needs of the cocoa. In model two, both the companion tree crop and the cocoa provide valuable products and plot management must simultaneously satisfy the growth and yield requirements of all productive components of the system. For instance, timber species shall not be pruned or thinned considering only the light regime needed by the cocoa, but also to ensure that: (1) only the best formed and fastest growing trees are kept for future harvest; and (2) a significant number of timber or fruit trees are retained in the plot to reach the output goal for these components set by the land manager, which may result in some over shading and sub-optimal cocoa yields.

2.2.5 Fruit trees

The indigenous farming systems of many developing countries often include several fruits- and nut-producing trees. These are common components in most home gardens and other mixed agroforestry systems; they are also integrated with arable crops either in intercropping mixtures or along boundaries of agricultural fields. These fruit trees are well adapted to local conditions and are extremely important to the diet, and sometimes even the economy, of the people of the region, but they are seldom known outside their common places of cultivation (Nair, 1993). Fruit trees are predominantly planted as shade trees in association with cocoa where they are also a source of income, as their fruits are widely traded locally and regionally (Ndoye et al. 1997) and even internationally (Awono et al. 2002). As demand for fruits and other non-wood forest products are increasing, the supply of indigenous fruits from forests is threatened by increasing deforestation. This situation of increasing demand and decreasing supply of fruits from the wild provides a considerable opportunity for rural farmers willing to invest in agroforestry technologies and to participate in the selection of elite trees for multiplication as cultivars and planting in the fields (Tchoundjeu et al. 2002).

2.2.6 Timber trees

Timber production on farms can take many different forms. Trees can provide many services and even secondary non-timber products. In some cases, harvest of these products can begin after only few years, and may provide a steady income throughout the life of the trees until they are harvested for their timber. Planning for multiple uses from the timber trees requires some extra efforts in species selection, and many involve balancing the timber yields with the desire for secondary products (Elevitch and Wilkinson, 2000).

Different characteristics of trees will result in different products. Currently, eucalypts, pines, and teak are the most commonly planted timber trees, accounting for 86% of all plantation timber in the tropics (Evans, 1992). Probably, none of them have wide application in Peru. However, efforts to improve conservation and sustainable land use in the tropics are leading to the improved management and diversification of timber plantations, the planting of trees in agroforestry systems, and the promoting of sustainably grown native timber and non-timber forest products. Expanding the use and planting of lesser-known timbers is part of this trend (Sosef et al., 1998). Simultaneously, new technologies for processing, wood preservation, and treatments have extended the potential uses and marked opportunities for lesser-known species (Lemmens et al., 1995).

2.2.7 Fuelwood, firewood and charcoal trees

Many woody species have been identified as fuelwood crops. It could be argued that any woody material can be a fuelwood, and therefore any woody plant can be a fuelwood species. But the term "fuelwood (or, firewood) crops" as used in the swelling literature refers to plants suitable for deliberate cultivation to provide fuelwood for cooking, heating, and sometimes lightning (Nair, 1988). In addition to shading the cocoa plantations, one of the main uses of trees is for firewood. In the study from Brazil of Sambuichi et al. (2012) many firewood trees were climax species, but the clear majority were of early secondary species. The most-cited species were *Inga* spp. and *Senna* spp., two fast-growing trees very common in cocoa agroforestry that the farmers consider good fuel wood species.

2.2.8 Medicinal trees

Human societies throughout the world have accumulated a vast body of indigenous knowledge over centuries on medicinal uses of plants, and for related uses including as poison for fish and hunting, purifying water, and for controlling pests and diseases of crops and livestock. About 80% of the population of most developing countries still use traditional medicines derived from plants for treating human diseases (de Silva, 1997).

Several species are valued for their medicinal properties. Their products may find markets with traditional healers for treating human and livestock diseases, or in the growing herbal supplement industry. Some of these products may be marketed fresh, or can be processed into dried products, juices, extracts, concentrates, or oils for added marked value (Elevitch and Wilkinson, 2000).

Forest degradation throughout the tropical world has diminished the availability of widely used medicinal plant species. Five of the top 12 medicinal trees in the eastern Amazon region of Brazil have begun to be harvested for timber decreasing the availability of their barks and oils for medicinal purposes (Shanley and Luz, 2003).

Many plants in traditional agricultural systems in the tropics have medicinal value. These can be found (either planted or carefully tended natural regenerations) in agroforestry per Rao et al., 2004, they are an invariable component of cocoa agroforestry in the Peruvian Amazon (Lamont et al. 1999). Medicinal plants accounted for about 27% of total plant species in the cocoa agroforestry in Amazon (Padoc and de Jong, 1991). Integration of medicinal plants in agroforests and multi-strata systems provides an answer to the plantation commodity conundrum. These complex agroforestry systems can be utilized to grow medicinal plants species for home use and markets. Medicinal plants produced in agroforests may be targeted to niche markets to secure higher premium on the premise of better quality like those harvested from wild. The forest-type environment of these systems facilitates the integration of species that generally grow in the forest and thereby helps conserve the endangered species and produce them for markets (Tomich et al. 1998).

2.3. Soil improving trees

Physical and chemical constraints to plant growth severely limit the productivity of vast areas of land in the world. Waterlogging, acidity, aridity, salinity and alkalinity, and the presence of excessive amounts of clay, sand, or gravel are some of the major constraints. In addition to these naturally occurring conditions that constitute wastelands, unsustainable agricultural and other land-management practices result in the creation of more and more wasteland every year (Lal, 1989). Agroforestry techniques involving planting trees that are tolerant of these adverse soil conditions have been suggested as a management option for reclamation of such areas (King and Chandler, 1978).

2.3.1 Nitrogen fixing trees

Nitrogen fixing trees (NFTs) have ability to take nitrogen from the air and pass it on to other plants through the cycling of organic matter (Elevitch and Wilkinson, 2008). Agroforestry systems offer a unique opportunity for exploiting the nitrogen-fixing qualities of multipurpose trees and shrubs. About 650 tree species are known to be, and several thousand suspected to be, nitrogen-fixing (Brewbaker and Glover, 1988). Biological nitrogen fixation takes place through symbiotic and no symbiotic means. Symbiotic fixation occurs through the association of plant roots with nitrogen-fixing microorganisms. The major group consists of many leguminous species nodulating with *Rhizobium* or *Bradyrhizobium* bacteria; these include many of the most widely used multipurpose trees, such as *Acacia*, *Erythrina*, *Gliricidia*, *Leucaena* and *Sesbania* species. In addition, a limited number of non-leguminous genera, *Alnus* and *Causuarina* species, nodulate with *Frankia*). Nonsymbiotic fixation is effected by free-living soil organisms, and can be a significant factor in natural ecosystems, which have relatively modest nitrogen requirements from outside systems. However, Nonsymbiotic N_2 fixation is of minor importance in agricultural systems that have far greater demands of nitrogen (Nair, 1993). NFTs have great ability to improve fallows and enrich soils, therefore should be utilize as much as is possible and sustainable.

NFTs produce significant quantities of organic matter, recycle nutrients and help to maintain the natural fertility of the site (Hartemink 2005), of utmost importance since most cocoa plantations are not fertilized (Bentley et al. 2004). Most cocoa shade canopies are structurally very simple with only one shade strata, usually dominated by one ‘‘service’’ (minimal or no commercial products) tree legume species. Rice and Greenberg (2000) properly named these the ‘‘back bone’’ species of the shade canopy; most backbone species, used in cocoa worldwide, belong to the genus *Inga, Gliricidia, Erythrina, Albizzia* and *Leucaena*. Basic cocoa shade management model is cocoa under ‘‘service’’ legume shade trees. In this model, the legume trees are spaced, pruned and thinned per (only) the needs of the cocoa (Sommariba and Beer, 2011).

2.3.2 Shade trees

The upper strata of a multi-layered planting are called the canopies. The trees that make up this layer play the key role in creating the understory unique environment, involving more than just shade. The shade influences air temperature, humidity, soil temperature, soil moisture content, wind movement, and more. When planning, an understory intercropping system, the canopy is a crucial element. The most influential factors are canopy shape/tree form, canopy foliage type, and tree spacing. Some trees have very wide, spreading canopies.

In contrast, some trees have a very narrow, columnar form. There are a range of canopies shapes. The form and canopy shape of the canopy trees should be used to help determine appropriate spacing for the trees and understory crops. In some cases, the form of the trees can be altered by pruning. Although understory crops can tolerate some degree of shade, some light must be available for the crops to be productive. The type of foliage should be considered along with the canopy shape/tree form, to determine the spacing needed to create optimal understory environment for the crops. Not less important is spacing. If the standards, close spacing of single-species monocultures of forestry or orchard trees is used, usually the understory crops are phased out after few years due to competition. Compared to single-species plantings for timber or fruit trees, understory cropping systems normally involve a reduced number of trees. The number of trees is usually 25-75% less than timber or fruit trees are planted alone. This wider sparing may be in a uniform pattern, or in a more random pattern of dispersed trees (Elevitch and Wilkinson, 2000). Cocoa trees evolved a shady understory environment. Traditional varieties of cocoa are grown under the shade of other trees, usually nitrogen-fixing that also add nitrogen, control erosion, recycle nutrients, and provide habitat for wildlife. Cocoa has been grown as an understory crop for centuries (Wadsworth, 1997)

2.3.3 Cocoa based agroforestry for biodiversity conservation

Species richness is a fundamental measurement of community and regional diversity, and it underlies many ecological models and conservation strategies (Gotelli et al., 2001). Biodiversity loss from deforestation may be partly offset by the expansion of secondary forests and plantation forestry in the tropics (Barlow et al., 2007). Conversion of tropical primary forest into various land use systems has serious impacts on distribution, community structure and population characteristics of flora (van Gemerden et al., 2003). Vegetation structure in shaded cacao is forest-like, often with multiple strata and diverse tree species, and high insect, bird and mammal species diversity (Rice and Greenberg, 2000).

Regarding species richness, the cocoa fields occupy an intermediate position between the forest areas and the farms. Here, many of the ‘primary forest tree species were left standing while burning, fruit trees were planted and other species (seedlings) were protected for further multiple uses. Species richness of herbaceous plants in the cocoa farm highly depends on the period of the year. They are frequently cut to care for a good yield. Cocoa agroforests are in fact the gardens where the medicinal plants are collected in case of urgency, while primary and secondary forests are being more oriented towards hunting and gathering. The cocoa fields have a potential richness in terms of medicinal and edible plants that could increase the peasant’s revenues. A good management in this area may assure the amelioration of the standards of living of the peasants and stabilize them to protect the forest. Management strategies should include the selection and reintroduction of original forest species into plantations of cocoa trees (Zapfack et al., 2002).

2.3.4 Plant diversity in cocoa based agroforestry systems

Assase and Teeth (2010) reiterated in their work” the rich floristic diversity of native forest trees reminiscent of the natural forest” was found to have decreased in the cocoa agroforests. This observation was, however, expected as several previous studies (Bobo et al., 2006) have shown a reduction of forest trees species diversity with habitat modification and land use changes. The results of previous studies (Attua, 2003) have shown that the diversity of vascular plants in cocoa agroforest was higher than that of mixed food crops agroforests. There is direct relationship between the type of cocoa variety cultivated and tree species richness in cocoa agroforests. Differences in tree species richness in agroforestry landscapes are common due to factors such as differences in management intensity, culture and farm history (Schroth and Harvey, 2007).

Some of the native forest/non-crop species in the agroforests were useful trees providing for the sources of fruits, medicines and timber. Similarly, in a study made by Assase and Teeth (2010) of traditional cocoa-based agroforestry and forest species conservation in Ondo State, Nigeria, Oke and Odebiyi (2007) found that many of the trees retained in the cocoa agroforests were fruit and timber trees. The selection and/or active planting of useful trees species may eventually lead to significant increase in the density of certain tree species in the complex agroforests compared with the rest of the landscape. For example, in southern Cameroon the density of *Dacryodes edulis* was ten times higher and that of *Milicia excelsa* was three times higher in cocoa plantations than elsewhere in the landscape (Van Dijk, 1999). Similarly, the relative density of three species, namely, *C. odorata, E. guineensis* and *T. ivorensis* were higher in the agroforests compared to the natural forest (Assase and Teeth, 2010). These results also confirm that of previous studies in that the trees retained in agroforests are usually useful trees which also provide shade to reduce the rate of trans-evaporation, erosion and wind breaks (Duguma et al., 2001). Generally, the conversion of natural forests to agricultural farmlands involves the removal of a substantial number of forest trees (Makana and Thomas, 2006) with subsequent replacement with non-forest trees (Asase et al., 2009).

In Ghana, forest species were being replaced with non-forest species such as *C. odorata* especially in the cocoa agroforest. The replacement of native forest trees with non-forest species in cocoa agroforest is also evident from floristic inventories in Costa Rica (Guiracocha et al., 2001). The complex agroforestry systems have at least some structural characteristics of the natural forest and may help reduce edge effects between the natural forest and open agricultural fields such as unshaded cocoa farmlands (Gascon et al., 2000). Besides offering habitats for several plants and animal species including many forest dependent species, the complex agroforest systems make an important contribution to the conservation of regional biodiversity by enhancing landscape connectivity, reducing edge effect and improving local climate (Schroth et al., 2004). Farmers

2.3.5 Faunal diversity in cocoa based agroforestry systems

The high structural diversity of cocoa agroforests also positively affects the diversity of animals. Thanks to diverse canopy, more avian species are present in cocoa agroforestry systems. The lack of significant differences among the management regimes of managed cocoa habitat may indicate the influences of the surrounding landscape on bird distribution (Greenberg at al., 2000). In Talamanca, Costa Rica a total of 1,464 individual birds from 130 species were detected in forest, 1,713 individual birds from 131 species were detected in abandoned cocoa and 1,708 individual birds from 144 species were detected in managed cocoa. Abandoned and managed cocoa had significantly more individual birds per point than forest, and managed cocoa had significantly more species per point than the other habitats (Reitsma et al., 2001). Regression analysis suggested that canopy tree diversity and the number of canopy trees were the most important predictors of forest bird abundance in managed cacao. These results are simile to other bird studies in agroforestry systems which demonstrate the importance of greater structural complexity, such as shade trees with bird dispersed fruits (Greenberg et al., 1997).

Managed plantations do not offer a dry season refuge for forest birds, but they support large numbers of forest bird species throughout the annual cycle (Reitsma et al., 2001). Results of Reitsma et al. (2001) indicate that forest bird species composition in 27 managed cocoas can be augmented by increasing the number and diversity of canopy food trees. Cocoa plantations cannot substitute forest, but do provide habitat for many another bird species.

2.3.6 Research questions

This study is intended to find answers to the following questions;

What tree species richness and diversity can we find in cocoa agroforestry?

What species are used by farmers and what are the reasons for using them?

How is the tree diversity in cocoa agroforestry close to natural and secondary forest?

What is the proportion of natural and planted trees of indigenous species of timber tree species and fruit trees and how do they use them?

Where the farmers obtain a germplasm of the tree species and how do they manage them?

What are the reasons behind intercropping trees with cocoa?

What potential possess these agroforestry systems to conserve original biodiversity?

2.3.7 General objectives

The focus of this research is the assessment of tree species richness and diversity in the cocoa agroforestry systems at the western region of Ghana. We intend to achieve this by specifically carrying a search to:

Assess the impacts of forest conversion on tree communities by comparing tree species richness, and composition as well responses at individual species level, between natural primary and secondary forest and cocoa agroforestry systems.

Compare the average height and basal area between the habitat types.

Investigate the effect of the current trend in cocoa cultivation on tree diversity in the Western Region of Ghana.

Elicit and sample farmer's ecological knowledge on the interactions between trees and cocoa in the agroforestry systems.

To identify tree species valued by farming community for incorporation into these System.

To find species –specific pattern of abundance along the habitat gradient.

2.3.8 Research hypothesis

Our basic hypothesis was that cocoa agroforestry systems can support relatively high tree diversity compared to primary and secondary forest.

Species composition will change along the habitat gradient with forest species being gradually replaced by species of open country.

Agroforestry systems could conserve some of the original tree species diversity characteristics for original primary forest.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study area

The study was conducted in Bedum in six different sites namely, Anwiam, Odum Adoye, Broni Krom, Aga Obeng, and Bedum Anim in the Western Region of Ghana. The region is in southern Ghana, spreads from the Ivory Coast border in the west to the Central region in the east, includes the capital and large twin city of Sekondi-Takoradi on the coast, coastal Axim, and a hilly inland area including Elubo. It includes Ghana's southernmost location, Cape Three Points, where crude oil was discovered in commercial quantities in June 2007.

The Western Region enjoys a long coastline that stretches from South Ghana's border with Ivory Coast to the Western region's boundary with the Central Region on the east. The Western Region has the highest rainfall in Ghana, lush green hills, and fertile soils. There are numerous small and large-scale gold mines along with offshore oil platforms dominate the Western Region economy. The Region covers an area of approximately 2,3921 square kilometers, which is about 10 per cent of Ghana’s total land area. The region has about 75 per cent of its vegetation within the high forest zone of Ghana, and lies in the equatorial climatic zone that is characterized by moderate temperatures. It is also the wettest part of Ghana with an average rainfall of 1,600mm per annum. It is bordered on the east by the Central Region, to the west by the Ivory Coast (Côte d’Ivoire), to the north by Ashanti and Brong-Ahafo Regions, and to the south by the Gulf of Guinea. The southernmost part of Ghana lies in the region, at Cape Three Points near Busua, in the Ahanta West District. The region has about 75 per cent of its vegetation within the high forest zone of Ghana. The south-western areas of the region are noted for their rain forest, interspersed with patches of mangrove forest along the coast and coastal wetlands, while a large expanse of high tropical forest and semi-deciduous forest is also found in the northern part of the region.

The Western Region has 24 forest reserves, which account for about 40 per cent of the forest reserves in the country. Prominent among them are the Bia Reserve, Cape Three Points National Park, and the Ankasa/Nini Suhyien Forest and Game Reserve.

The Western Region lies in the equatorial climatic zone that is characterized by moderate temperatures, ranging from 22°C at nightfall to 34°C during the day. The Region is the wettest part of Ghana, with a double maxima rainfall pattern averaging 1,600 mm per annum. The two rainfall peaks fall between May-July and September/October. In addition to the two major rainy seasons, the region also experiences intermittent minor rains all the year around. This high rainfall regime creates much moisture culminating in high relative humidity, ranging from 70 to 90 per cent in most parts of the region.

Figure 1. Map of study area

3.1.1 Data collection Method

Data were collected from February to March 2016. Sampling was done following the methodology of Kessler et al. (2005) and Asase and Tetteh (2010). This method basically involves sampling forest trees using square quadrates. The method was adopted because it has been successfully used in Indonesia and Ghana to study three different land use systems (primary forest, secondary forests and cocoa plantations). The study was done at 15 farms with cocoa agroforest Western Region of Ghana.

Cocoa farms were selected randomly from the list of the cocoa-growing farmer's association. 6 sites were selected from Bedum, namely Anwiam, Odum Adoye, Broni Krom, Aga Obeng and Bedum Anim in the western region of Ghana. The selected were involved in the management cocoa-based agroforestry systems.

On each of 15 farms one square 25 x 25 m plot was measured in cocoa agroforestry. For each cocoa agroforest one point was selected based on visual observations to guarantee certain homogeneity. Within each plot in agroforestry sites all trees were counted, identified to species, diameter-breast-height (DBH - 130 cm above ground level) measured by forestry meter and total height of tree was measured by forestry clinometer. Cocoa trees were also measured.

For comparison five plots of the same size were randomly laid down at nearby secondary forest and other five plots in primary forest. The nearest well-preserved primary forest was find out at experimental forest. which is located at about 30 km distance from the study site (near the settlement in Bedum). In each plot in secondary and primary forest only those trees that exceed 2.5 cm at DBH were counted, identified and measured. Because of difficulty due to dense vegetation in primary forest, the forestry clinometer could not be used and the height of trees was estimated by experienced cocoa research staff. The geographical position of each plot was captured by a hand held Global Positioning System unit. All plant species were counted and identified at least to morpho species level. The most common trees and understory plants were identified to species level. Identification of the trees within the plots by their local names was done by the help of experienced cocoa research staff or owners of the farms. Scientific and vernacular names (the latter given by a traditional local practitioner) were annotated.

3.1.2 Questionnaire/ farmers survey

To ascertain farmers' knowledge about association of cocoa with trees, 46 farmers were interviewed using semi structured questionnaires. Importance and main uses of native forest trees species in the agroforestry farmlands were collected. Only uses of the trees that received unanimous acclamation among the farmers were reported. The uses of the native forest trees were classified into five groups, namely, timber, shade, materials, and medicine. Some farmers were assisted with the field inventory on uses of trees in the agroforests.

Most trees found in the cocoa agroforest as well as their respective characteristics were identified by the farmers, uses and their ecological interactions with cocoa. Trees were classified by farmers as either good or bad based on their compatibility with cocoa as neighbor trees. Thus, a good tree was described as one that is suitable as shade for cocoa, and vice versa. Farmers' knowledge on tree diversity on cocoa farms was based on their usefulness.

3.3 Methods of data processing

We obtained the diversity index by relating the total number of tree species to the total number of individuals in the sample for the combined sample, number of individuals, occurrences, density and dominance of each tree species were calculated to assess the total contribution of each habitat type to the total sample, each plot was classified per the dominating forest type using the three-category system described above, that is, primary forest. secondary forest and cocoa agroforestry system. Measures of forest structure (tree density, basal area, average DBH) were calculated for each sample plot and averaged for each land-use system (Boubli et al., 2004).

For the analysis of the floristic composition of the agroforests, species richness, diversity and equitability were calculated for cocoa and non-cocoa trees in each land-use system using information from the sample plots. Species richness was expressed as the number of non-cocoa tree species per agroforest by combining all the species recorded in all the sample plots inside the plantation. Diversity was calculated using Shannon index, Simpson index (Sonké, 1998) at the level of each cocoa agroforest using the data of the individual plots. The Shannon index tends to be weighted slightly towards less abundant or rare species, while the Simpson index favors the more abundant or dominant species (Zapfack et al., 2002). The two indices together give a good description of the alpha (within site) diversity of the agroforest (Sonwa et al., 2007).

Classical Jaccard and Sorensen indices were used to compare tree species similarity among the three land-use systems. Calculating the basic indices, we used simple excel spreadsheet. To account for differences in sample area and forest structure, we compared species richness based on the total number of species recorded per plot.

The estimation indices can be calculated per following equations (Krebs, 1994):

Jackknife estimate of species

$$\bar{S} = s + (\frac{n-1}{n})\mathcal{K}$$

richness

Where $\bar{S}$ is Jackknife estimate of species richness, s is observed total number of species present in n quadrats, n is total number of quadrat samples and $\mathcal{K}$ is number of unique species (the species that occur only in one quadrate).

Shannon–Wiener of species diversity index

$$H' = \sum_{i=1}^{s} Pi \;\; In\, Pi$$

where s is the total number of species and p is the relative abundance of the i species. In contrast to direct measures of species richness (number of species), this index considers the relative abundances of species (Legendre and Legendre, 1998).

Simpson index of species diversity

$$(\lambda = \sum_{i=1}^{s} \mathrm{P}\, i^2)$$

because it weights towards the abundance of the most common species and varies inversely with species diversity (Krebs, 1994).

Beta-diversity between the land use types was estimated using the Jaccard similarity index. The Jaccard similarity index uses species presence/absence data for two sample sets (in this case land use types) and is calculated as

$$J = S/(m + N - S)$$

where *S* is the number of species shared by any two land use types (in this case *M* and *N*), *N* is the number of species in land use type *M*, and *N* is the number of species that in land use type *N* (Chao et al., 2005).

To assess statistical difference among the above-mentioned indices of the three land-use systems we compared them by analysis of variance (ANOVA using Tukey´s SD test) for parametric data distribution, and Kruskal-Wallis test (KW-ANOVA) for non-parametric data.

CHAPTER FOUR

RESULTS

4.1 Tree species composition

In total, 1,412 individuals of trees belonging to 102 species in 34 families were identified during the study. The most species rich families included Sterculiaceae, Apocynaceae, *Moraceae Euphorbiaceae, Papilionaceae, Meliaceae* and out of the tree species identified four of them, namely *Albizia zygia, Antiaris toxicaria, Baphia nitida, Hollarrhena floribunda and Voacanga Africana* was found in all the three land use types. All the tree species encountered were native to the tropics. The number of individuals of trees decreased from the primary forest (614 trees ≥ 2.5cm per five plots) through the secondary forest (333 trees ≥ 2.5 cm per five plots) to the cocoa agroforest (464 trees of all sizes per 5 plots). The density of trees per one plot was 122.8 (392 trees per ha) in primary forest, 66.6 (213 trees per ha) in secondary forest and 92.8 (296 trees per ha) in cocoa agroforestry. Observed species richness was 65 in primary forest, 29 in secondary forest and 41 in cocoa agroforestry. Out of the total number of the trees, 26 were classified only to the genus level (four from cocoa agroforestry, four from secondary forest and 21 from primary forest) and only 1 tree species from secondary forest was unknown, because of difficulty to observe samples due to large tree height.

The main products and services of trees found in cocoa agroforestry were timber, shade, construction material - leaves (mainly for roofing), fruit and medicinal properties. The most abundant tree species (152 individuals) in cocoa agroforestry sites was *Theobroma cacao (Sterculiaceae)* „cocoa "*which* is mainly for crop and *Rauvolfia vomitoria* (*Apocynaceae*)" *Kakapenpen "with (39) individuals in mainly for shading* of cocoa trees and soil protection. The leaf litter protects the soil surface and roots of other plants, helps retain nutrients in the topsoil, and (most importantly for farmers in the humid tropics) controls weeds. It is important for their fruit, timber and the branches are a source of fuelwood (Reynel et al., 2003).

The third most abundant species (36 individuals) was Sterculia *tragacantha(Sterculiaceae)* “Sofo “. Sterculia tragacantha is sometimes a deciduous shrub growing 5 - 12 meters tall, but more often it becomes a tree up to 25 meters tall with exceptional specimens to 40 meters. The crown tends to be small and sparsely branched the bole, which sometimes has winged buttresses, can be 75cm meters. The tree is valued especially for the gum obtained from its trunk, which has a range of applications. The young leaves are sometimes an important local food production and shade tree in cocoa plantations and it is also valuable fuelwood (it has a high calorific value and burns still fresh) (Reynel et al., 2003).

Table 1. Tree species found in cocoa agroforestry and their frequency

Latin name	**Family name**	**Common name**	**Frequency**
Theobroma cacao	*Sterculiaceae*	*Cocoa*	*152*
Rauvolfia vomitoria	*Apocynaceae*	*Kakapenpen*	*36*
Sterculia tragacantha	*Sterculiaceae*	*Sofo*	*36*
Ficus exasperata	*Moraceae*	*Nyankyerene*	*25*
Funtumia elastica	*Apocynaceae*	*Fruntum*	*25*
Alchornea cordifolia	*Euphorbiaceae*	*Ogyama*	*17*
Voacanga africana	*Apocynaceae*	*Ofruma*	*16*
Morinda lucida	*Rubiacea*	*Konkroma*	*13*
Albizia zygia	*Mimosaceae*	*Okoro*	*12*
Albizia adianthifolia	*Mimosaceae*	*Pampena*	*11*
Baphia nitida	*Papilionaceae*	*Odwen*	*11*
Funtumia africana	*Apocynaceae*	*Okae*	*11*
Hollarrhena floribunda	*Apocynaceae*	*Sese*	*11*
Vitex ferruginea	*Verbenaceae*	*Otwentorowa*	*9*
Antiaris toxicaria	*Moraceae*	*Kyenkyen*	*7*
Trichilia monadelpha	*Meliaceae*	*Tanuro*	*7*
Macaranga barteri	*Euphorbiaceae*	*Opam*	*6*
Millettia zechiana	*Papilionaceae*	*Fafraha*	*6*
Pycnanthus angolensis	*Myristicaceae*	*Otie*	*6*
Ficus vogeliana	*Moraceae*	*Opanto*	*5*
Tetrorchidium didymostemon	*Euphorbiaceae*	*Anenedua*	*5*
Ceiba pentandra	*Bombacaceae*	*Onyina*	*4*
Mareya micrantha	*Euphorbiaceae*	*Dubrafo*	*4*
Trichilia tessmannii	*Meliaceae*	*Tanuronini*	*4*
Amphima pterocarpoides	*Caesalpiniaceae*	*Yaya*	*3*
Spondias mombin	*Anarcadiaceae*	*Atoa*	*3*
Carica papaya	*Caricaceae*	*Pawpaw*	*2*
Discoglypremna caloneura	*Euphorbiaceae*	*Fetefre*	*2*
Ficus sur	*Moraceae*	*Nwadua*	*2*

Spathodea campanulata	*Bignoniaceae*	*Akuakuo-ninsuo*	*2*
Anthocleista nobilis	*Loganiaceae*	*Bontode*	*1*
Blighia sapida	*Sapindaceae*	*Akye*	*1*
Cola gigantea	*Sterculiaceae*	*Watapuo*	*1*
Entandrophragma angolense	*Meliaceae*	*Edinam*	*1*
Erthrina vogelii	*Papilionaceae*	*Osore*	*1*
Lannea welwitschii	*Anarcadiaceae*	*Kumanini*	*1*
Mangnifera indica	*Anarcadiaceae*	*Mango*	*1*
Milicia excelsa	*Moraceae*	*Odum*	*1*
Psydrax subcordata	*Rubiacea*	*Ntatea-dupon*	*1*
Ricinodendron heudelotii	*Euphorbiaceae*	*Wama*	*1*
Vitex grandifolia	*Verbenaceae*	*Supowa*	*1*

Sterculia tragacantha (Sterculiaceae) „ *Sofo* "was very often represented species which farmers left on their site for many years, because Sterculia tragacantha is sometimes a deciduous shrub growing 5 - 12 meter's tall, but more often it becomes a tree up to 25 meters tall with exceptional specimens to 40 meters. The crown tends to be small and sparsely branched. The bole, which sometimes has winged buttresses, can be 75cm in diameter and unbranched for up to 18 meters. The tree is valued especially for the gum obtained from its trunk, which has a range of applications. The young leaves are sometimes an important local food.

Rauvolfia vomitoria (Apocynaceae)" Kakapenpen" is mostly kept due to its medicinal value has the functions of lowering Blood pressure, sedation, blood circulation, pain relief, and detoxification. It is also used for curing high blood pressure, dizziness, insomnia, epilepsy, snake bites, bruises. Reserpine was the first drug found to interfere with the human sympathetic nervous system, and it initiated the effective pharmacotherapeutic control of hypertension. Reserpine is a naturally occurring drug that has been used for centuries in ancient India.

Rauwolfia vomitoria extract is a white to yellowish powder, extracted from the root of Rauwolfia serpentine or Rauwolfia vomitoria, plants found in India and Africa. In traditional herbal medicine, the root was brewed as a tea and used in humans to treat hypertension, insanity, snakebite, and cholera. (Reynel et al., 2003).

Albizia zygia (*Mimosaceae) "Okoro"* is a deciduous tree 9-30 m tall with a spreading crown and a graceful architectural form. Bole tall and clear, 240 cm in diameter. Bark grey and smooth. Young branchlets densely to very sparsely clothed with minute crisped puberulence, usually soon disappearing but sometimes persistent. Leaves pinnate, pinnae in 2-3 pairs and broadening towards the apex, obliquely rhombic or obovate with the distal pair largest, apex obtuse, 29-72 by 16-43 mm, leaves are glabrous or nearly so.

Flowers subsessile pedicels and calyx puberulous, white or pink; staminal tube exserted for 10-18 mm beyond corolla. Fruit pod oblong, flat or somewhat transversely plicate, reddish-brown in color, 10-18 cm by 2-4 cm glabrous or nearly so. The seeds of A. zygia are smaller (7.5-10 mm long and 6.5 to 8.5 mm wide) and flatter than either of the other Albizia, but have the characteristic round shape, with a slightly swollen center.

The genus was named after Filippo del Albizzi, a Florentine nobleman who in 1749 introduced A. julibrissin into cultivation.

Table 2. Tree species found in secondary forest and their frequency

Latin name	Family	Common name	Frequency
Baphia nitida	*Papilionaceae*	*Odwen*	*72*
Albizia zygia	*Mimosaceae*	*Okoro*	*49*
Sterculia tragacantha	*Sterculiaceae*	*Sofo*	*38*
Alchornea cordifolia	*Euphorbiaceae*	*Odwen/Ogyama*	*33*
Ficus exasperate	*Moraceae*	*Nyankyerene*	*25*
Millettia zechiana	*Papilionaceae*	*Fafraha*	*24*
Hollarrhena floribunda	*Apocynaceae*	*Sese*	*21*
Voacanga Africana	*Apocynaceae*	*Ofruma*	*14*
Albizia adianthifolia	*Mimosaceae*	*Pampena*	*6*
Ficus sur	*Moraceae*	*Nwadua*	*6*
Morinda lucida	*Rubiaceae*	*Konkroma*	*6*
Ficus vogeliana	*Moraceae*	*Opanto*	*5*
Rauvolfia vomitoria	*Apocynaceae*	*Kakapenpen*	*5*
Antiaris toxicaria	*Moraceae*	*Kyenkyen*	*3*
Solanum erianthum	*Solanaceae*	*Pepediawuo*	*3*
Adenia cissampeloides	*Passifloraceae*	*Unknown*	*2*
Albizia ferruginea	*Mimosaceae*	*Awiemfosamina*	*2*
Bombax buonopozense	*Bombacaceae*	*Akata*	*2*
Deinbollia grandifolia	*Sapindaceae*	*Mmata*	*2*
Lecaniodiscus cupanioides	*Sapindaceae*	*Anenedua*	*2*
Newbouldia laevis	*Bignoniaceae*	*Sesemasa*	*2*
Psidium guajava	*Myrtaceae*	*Guava*	*2*
Pycnanthus angolensis	*Myristicaceae*	*Otie*	*2*
Tabernaemontana Africana	*Apocynaceae*	*Obonawa*	*2*
Albizia glaberrima	*Mimosaceae*	*Okora-akoa*	*1*
Harungana madagascariensis	*Guttiferae*	*Kosowa*	*1*
Millettia rodent	*Papilionaceae*	*Tetetoa*	*1*
Spathodea campanulate	*Bignoniaceae*	*Akuakuo-ninsuo*	*1*

Vernonia amygdalina	*Compositae*	*Awonwene*	1

Wood of *Albizia zygia (Mimosaceae)* Produces a class three timber with the trade name "Okuro", this is a quality timber with a pale brown heartwood easy to work, durable but not termite proof. Used in construction, making handles of farm implements, household utensils and furniture. A. zygia is a preferred species for wood carving in the Democratic Republic of Congo.

It has medium density, straight grain and medium texture, color from pink to reddish. It has very high durability and is used in carpentry and joinery (Reynel et al., 2003).

Tree species in secondary forest were used mainly for timber. The most abundant tree species (72 individuals) found in secondary forest was *Baphia nitida (Papilionaceae)* "Odwen" The second one most abundant species (49 individuals) was *Albizia zygia (Mimosaceae)*„Okoro ". Then *Sterculia tragacantha (Sterculiaceae*) "Sofo" and Alchornea *cordifolia (Euphorbiaceae)* „ *Odwen/Ogyama* ". This pioneer fast growing tree species grow frequently in secondary forests (Table 3.). In natural forest the trees were used for timber, fruit, bark, medicinal properties and construction material (mainly for roofing). All tree species were abundant in small densities, we did not found any dominant tree species

Table 3**.** Tree species found in Primary forest and their frequency

Latin name	**Family name**	**Common name**	**Frequency**
Albizia zygia	*Mimosaceae*	*Okoro*	84
Baphia nitida	*Papilionaceae*	*Odwen*	69
Trichilia prieuriana	*Meliaceae*	*Kakadikuro*	50
Cola caricifolia	*Sterculiaceae*	*Ananseaya*	28
Microdesmis puberula	*Pandaceae*	*Ofema*	18
Sterculia tragacantha	*Sterculiaceae*	*Sofo*	17
Pterygota macrocarpa	*Sterculiaceae*	*Koto*	16
Solanum erianthum	*Solanaceae*	*Pepediawuo*	16
Morinda lucida	*Rubiaceae*	*Konkroma*	15
Voacanga africana	*Apocynaceae*	*Ofruma*	14
Blighia sapida	*Sapindaceae*	*Akye/Akyebiri*	13
Bombax buonopozense	*Bombacaceae*	*Akata*	13
Hollarrhena floribunda	*Apocynaceae*	*Sese*	13
Trichilia monadelpha	*Meliaceae*	*Tanuro*	13
Anthocleista nobilis	*Loganiaceae*	*Bontode*	12
Funtumia elastica	*Apocynaceae*	*Fruntum*	12
Sterculia rhinopetala	*Sterculiaceae*	*Wawabima*	12
Triplochiton scleroxylon	*Sterculiaceae*	*Wawa*	11
Celtis zenkeri	*Ulmaceae*	*Esakoko/Esa-koko*	10

Deinbollia grandifolia	*Sapindaceae*	*Mmata*	10
Pycnanthus angolensis	*Myristicaceae*	*Otie*	9
Tabernaemontana africana	*Apocynaceae*	*Obonawa*	9
Nesogordonia papaverifera	*Sterculiaceae*	*Danta*	8
Phyllocosmus africanus	*Ixonanthaceae*	*Akokorabeditoa*	8
Antiaris toxicaria	*Moraceae*	*Kyenkyen*	7
Celtis mildbraedii	*Ulmaceae*	*Esa*	7
Blighia unijugata	*Sapindaceae*	*Akyebiri*	6
Ficus vogeliana	*Moraceae*	*Opanto*	6
Lecaniodiscus cupanioides	*Sapindaceae*	*Dwindwera*	6
Myrianthus arboreus	*Cecropiaceae*	*Nyankum*	6
Newbouldia laevis	*Bignoniaceae*	*Sesemasa*	6
Rauvolfia vomitoria	*Apocynaceae*	*Kakapenpen*	6
Scottellia klaineana	*Flacourtiaceae*	*Tiabutuo*	6
Strombosia postulata	*Olacaceae*	*Afena*	6
Tetrorchidium didymostemon	*Euphorbiaceae*	*Anenedua*	6
Funtumia africana	*Apocynaceae*	*Okae*	5
Ficus exasperata	*Moraceae*	*Nyankyerene*	4
Millettia zechiana	*Papilionaceae*	*Fafraha*	4
Blighia welwitschii	*Sapindaceae*	*Akyebiri/Akyekobiri*	3
Entandrophragma angolense	*Meliaceae*	*Edinam*	3
Griffonia simplicifolia	*Caesalpiniaceae*	*Kegya*	3
Mallotus oppositifolius	*Euphorbiaceae*	*Anyanyanforowa*	3
Myrianthus libericus	*Moraceae*	*Nyankumanini*	3
Psydrax subcordata	*Rubiaceae*	*Ntatea-dupon*	3
Alstonia boonei	*Apocynaceae*	*Sinuro*	2
Antidesma laciniatum	*Euphorbiaceae*	*Fotonini*	2
Bridelia atroviridis	*Euphorbiaceae*	*Opamkotokrodu*	2
Carica papaya	*Caricacea*	*Pawpaw*	2
Ceiba pentandra	*Bombacaceae*	*Onyina*	2
Cola gigantea	*Sterculiaceae*	*Watapuo*	2
Diospyros piscatoria	*Ebenaceae*	*Otwe-kese*	2
Glyphaea africana	*Tiliaceae*	*Foto*	2
Leptalaus dephanoides	*Icacinaceae*	*Afena-akoa*	2
Leucaena leucocephala	*Mimosaceae*	*Leucaena*	2
Mansonia altissima	*Sterculiaceae*	*Oprono*	2
Oxyanthus speciosus	*Rubiaceae*	*Korantema*	2
Parkia bicolor	*Mimosaceae*	*Asoma*	2
Sterculia oblonga	*Sterculiaceae*	*Ohaa*	2
Trilepisium madagascariense	*Moraceae*	*Okure*	2
Dialium dinklagei	*Caesalpiniaceae*	*Dwedweedwe*	1
Grewia mollis	*Tiliaceae*	*Kyapotoro*	1
Khaya anthoteca	*Meliaceae*	*Krumben*	1
Lannea welwitschii	*Anacardiaceae*	*Kumanini*	1
Monodora tenuifolia	*Annonaceae*	*Motokorodua*	1

Trichilia tessmannii	*Meliaceae*	*Tanuronini*	1

4.1.2 Tree species responses to land use changes and similarity

Of abundant tree species recorded in cocoa agroforestry, 12 were recorded in the Primary forest and seven in secondary forest. Only three same tree species were found in secondary and primary forest. The tree species show significant responses to land use change. The relative density of three species, namely, *Albizia zygia, Baphia nitida, and Bombax buonopozense were* higher in the primary forest compared to the Cocoa agroforest and secondary forest. Relative density of *Baphia nitida, Albizia zygia, Alchornea cordifolia and Sterculia tragacantha* were highest in secondary forest and that of Theobroma *cacao, Rauvolfia vomitoria, Sterculia tragacantha and Ficus exasperata were highest in Cocoa agroforestry.* The abundance of *Albizia zygia* was similar for primary and secondary forest and the abundance of *Sterculia tragacantha* was similar for secondary and cocoa agroforestry

Table 4: Shared tree species in agroforestry, secondary forest and primary forest

Species	AF	SF	PF
Albizia zygia	X	X	X
Albizia adianthifolia	X	X	
Anthocleista nobilis	X		X
Antiaris toxicaria	X	X	X
Baphia nitida	X	X	X
Blighia sapida	X		X
Bombax buonopozense		X	X
Ceiba pentandra	X		X
Cola gigantean	X		X
Ficus sur	X	X	
Hollarrhena floribunda	X	X	X
Voacanga Africana	X	X	X
Ficus exasperata	X		X

Sterculia tragacantha	X	X

At the family level, the taxonomic composition of the habitat types showed major differences (Table 5). Cocoa agroforestry was dominated by *Sterculiaceae*, *Apocynaceae* and *Moraceae*, while Papilionaceae were also the most common family in primary forest and third common family in secondary forest. Primary forests were dominated by *Mimosaceae*, *Meliaceae* and Papilionaceae, secondary forest by *Sterculiaceae*, *Mimosaceae* and Papilionaceae.

Table 5. The three most important tree families in cocoa agroforestry, secondary forest and primary forest

AF	SF	PF
1 *Sterculiaceae*	*Papilionaceae*	*Mimosaceae*
2 *Apocynaceae*	*Mimosaceae*	*Papilionaceae*
3 *Moraceae*	*Sterculiaceae*	*Meliaceae*

The tree species composition similarity was highest between cocoa agroforestry and secondary forest. The *β*-diversity statistics showed that tree species community in the cocoa agroforests and secondary forest are most similar (Jaccard index = 0.77) followed by that between primary forest and Agroforestry (Jaccard index = 0.39). The least tree species composition similarity was found between the primary forest and Secondary forest (Jaccard index = 0.15).

Table 6. Classic Jaccard (upper right corner) and Classic Sørensen incidence-based (lower left corner) sample similarity indices

	AF	SF	PF
AF	1	0.769	0.230
SF	0.076	1	0.076
PF	0.384	0.153	1

4.2 Species richness and diversity

To compare the species richness and diversity among the land-use systems we have excluded all threes that were below 2.5 cm DBH found in cocoa agroforestry. The number of individuals of trees observed in cocoa agroforestry were 464 per 5 plots, 333 in secondary forest and 615 in primary forest per five plots. Observed species richness was 41 in cocoa agroforestry, 29 in secondary forest and 65 in primary forest. We estimated the total species richness using Jackknife estimate. The highest species richness was found in primary forest (238.9), then in cocoa agroforestry (183.4) and the lowest in secondary forest (131.4) (Table 7). Shannon-Weiner index of species diversity was also the highest for primary forest (24.7), intermediate for cocoa agroforestry (2.32) and the lowest secondary forest (2.22). The same order was for Simpson index of species diversity where (0.49) was recorded for primary forest and (0.17) cocoa agroforest and (0.16) was recorded for secondary forest.

To overcome biases, we have also tried to estimate the mean species richness and diversity per one plot (Table 7 – averages).

Then we calculate family richness, species richness and species diversity in these three land-use systems per one plot. On the results below we can observe, that these indicators were the highest in primary forest, but similar in cocoa agroforestry and secondary forest. Thus, species richness, family richness, basal area, Shannon-Weiner index of species diversity and Simpson index of species diversity per one plot were similar in cocoa agroforestry and secondary forest although the tree density per one plot was highest for cocoa agroforest.

Table 7. Species richness and density in observed land-use systems in total and means per sampled plot (mean value ± standard deviation); values in rows followed by same letter are not significantly different at p <0.05

	Unit	**Cocoa Agroforestry**				**Secondary Forest**		**Primary Forest**	
				stand.dev. (s)			stand.dev. (s)		stand.dev. (s)
No. of sampled plots		5				5		5	
In total									
Tree abundance	No. of trees in sample	464				333		615	
Species Richness observed	No. of species in sample	41				29		65	
Jackknife estimate of sp. richness	S^								
Variance of Jackknife estimate	var (S)								
Confidence limits for Jackknife estimate		183.4				131.4		238.9	
Shannon-Weiner index of sp. diversity	H'	2.74				2.493		2.120	
Simpson indes of sp. diversity	D	0.133				0.118		0.037	
	1/D	7.519				8.475		26.80	
	1-D	0.867				0.882		0.963	
Averages									
Altitude									
Age	estimated age of trees in years								
Tree density	No. of trees per plot	92.8	±	35.31	a	66.60	14.89	122.8	24
	No. of trees per ha	296.96	±		a	213.12		392.96	
Species Richness	No. of species per plot	20.2	±	4.82	a	15.40	1.14	34.2	6
Family Richness	No. of families per plot	10.2	±	2.17	a	9.60	1.67	17.2	5
Basal Area	m^2 per plot (625 m^2)	0.839	±	0.55	a	0.76	0.30	4.2564	3
	m^2 per ha	13.424	±	8.86	a	12.08	4.78	68.1024	46
Shannon-Weiner indes of sp. diversity	H'	2.329	±	0.357	a	2.22	0.19	24.78	49
Simpson indes of sp. diversity	D	0.178	±	0.077	b	0.16	0.06	0.496	1
	1/D	5.618	±	3.62	a	6.410	1.71	2.016	6
	1-D	0.822	±	0.077	a	0.84	0.059	0.504	1

4.3 Farmers survey results

The main products and services of cultivate tree species in cocoa agroforestry sites were: timber (40%), shade (20%), construction material - leaves (mainly for roofing) (10%), fruit (18%) and medicinal properties (12%). Figure 2 shows the number of species reported being used in five use categories.

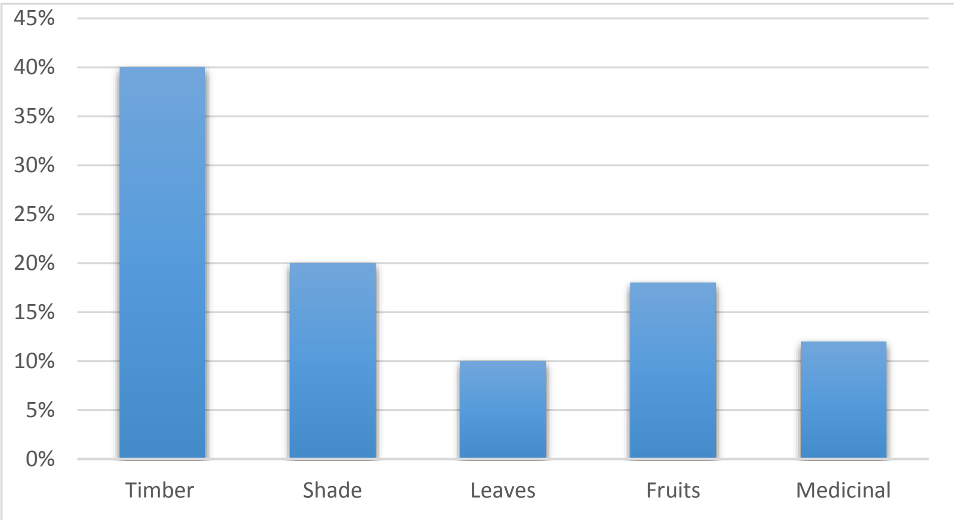

Fig. 2 the proportion of timber, shade, fruit and medicinal trees and trees used for their leaves

It was found, that 68% of trees which were observed in cocoa agroforestry were planted by farmers, 32% of the trees were from natural regrowth or left when cleared for planting (Fig. 3). From trees planted by farmers 64% were from seeds and 36% from seedlings (Fig.4).

Fig. 3. The proportion of natural and planted trees

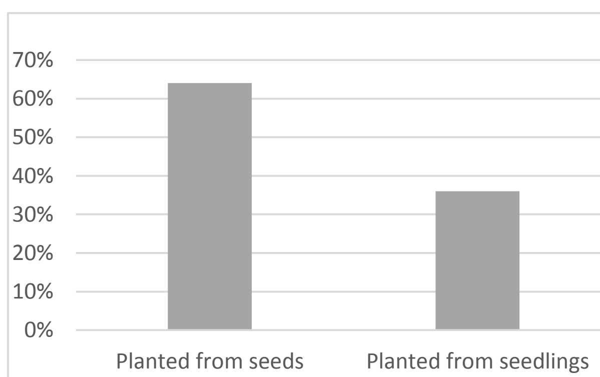

Fig. 4. The proportion of trees -seedlings

The most frequent source of planting material for farmers is from the cocoa research institute and Government (50%), seeds from own farm (20%) and market. Some farmers are also used to collect seeds in natural forest (11%). From organizations, Cocoa growers and producer's association of Ghana and NGO's (12%). Natural forest also remains an important source for most farmers recording (11%) A few sects of farmers also rely on the open market for activities concerning germplasm (7%) see figure (Fig.5).

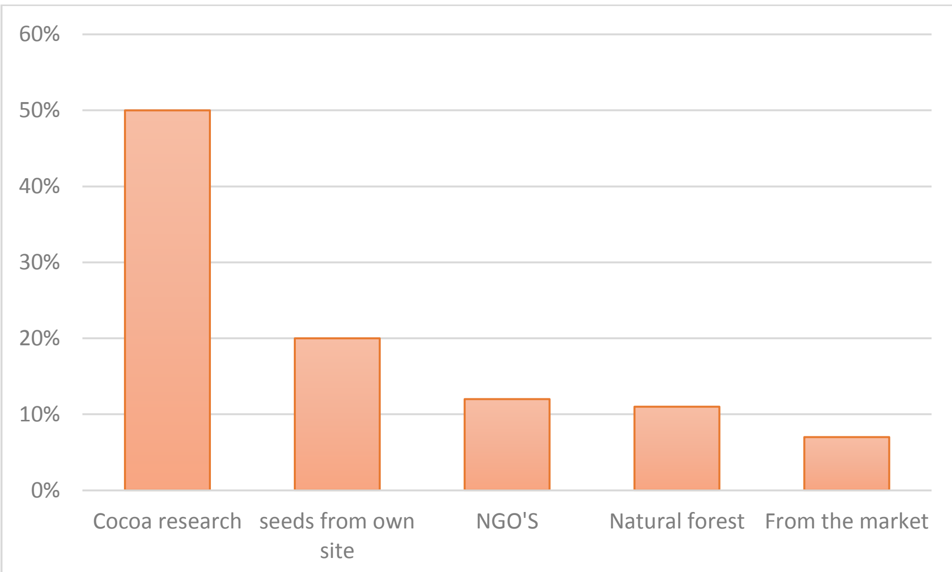

Fig. 5 the proportion of farmer's source of germplasm

CHAPTER 5

DISCUSSION

Almost all the tree species in the cocoa agroforestry were useful trees providing for the sources of timber, shade, leaves, fruit and medicines. Similarly, in a study of traditional cocoa-based agroforestry and forest species conservation in Ondo State, Nigeria, Oke and Odebiyi (2007) found that many of the trees retained in the cocoa agroforests were fruit and timber trees. The selection and/or active planting of useful trees species may eventually lead to significant increase in the density of certain tree species in the cocoa agroforests compared with the rest of the landscape. For example, in southern Cameroon the density of *Dacryodes edulis* was ten times higher and that of *Milicia excelsa* was three times higher in cocoa plantations than elsewhere in the landscape (Van DijK, 1999). Similar phenomenon we found in Bedum in the Western region of Ghana, where we observed very high density of, for example, *Albizia zygia, Baphia nitida Rauvolfia vomitoria, Sterculia tragacantha and Baphia nitida.* Our results as well as results of Duguma et al. (2001) confirm that that the trees grown in agroforests are usually useful trees which also provide shade to reduce the rate of trans-evaporation, erosion and wind breaks.

In this study, the rich floristic diversity of native forest trees reminiscent of the natural forest was found to have decreased in the cocoa agroforestry and then in the secondary forest. This result is different from several previous studies. For example, in study of Bobo et al. (2006) diversity of the natural forest was found to have decreased in the secondary forest and in the cocoa agroforestry. Many other studies found out that comparison of the tree richness in the different habitat types shows that overall primary forests are the richest, followed by secondary forests, and cocoa agroforestry, for example Parthasarathy (1999).

Differences in tree species richness in agroforestry landscapes are common due to factors such as differences in management intensity, culture and farm history (Schroth and Harvey, 2007). The primary forest data can be compared with the large number of similar forest plots inventoried elsewhere in the Amazon. Our results show that the tree species richness is comparable between cocoa agroforestry and secondary forest. In the study of Kessler et al. (2005) cocoa agroforestry had by far the lowest tree species richness. High levels of biodiversity in cocoa agroforestry in Bedum could be due to high farmer’s knowledge of biodiversity conservation. It could show that land use systems of the same crop species different in management may hold different levels of biodiversity. The recorded species number of 157 tree species of ≥2.5 cm DBH is within the range of 100–160 species typically recorded in rain forests (Whitmore, 1995).

Secondary forests are developed on previously totally clear-felled, cultivated areas that could regrow. Thus, larger trees were almost completely missing. The high richness of trees ≥2.5 cm in secondary forests, however, shows that this forest type has the potential to recover a considerable richness, if allowed to mature. compared on an individual basis, secondary forests are clearly less species-rich than primary forests. Families in secondary forests are typical fast-growing pioneer taxa of early successional stages throughout the tropics (Turner, 2001) that are of little economic interest. Field observations show that, in common with other tropical forests (Turner et al., 1997), even 50-year-old secondary forests, despite attaining a height comparable to primary forests, have a conspicuously different taxonomic composition. As regenerating forests not only have fewer trees of commercial value, but also have fewer species with large, animal-dispersed fruits than primary forests (Brown and Lugo, 1990), the economic and ecological value of the old secondary forests must be considered limited as compared with the primary forest.

Compared to results of Asase and Teeth (2005), we also found significant differences in tree basal area between the primary forest and cocoa agroforestry. Results of our study also shows, that the primary forest recording the highest value of basal area of trees per unit area compared to the secondary forest and cocoa agroforestry. The analysis of forest structure revealed considerable differences in canopy height. The greater tree heights in secondary forest than in primary forest are probably the result of different tree species of the secondary forest and different tree density to the primary forest plots. When stem diameters and basal area are compared, primary forest having many more larger size trees and higher basal area than secondary forest.

As well as Anglaaere (2010) we found that the trees were shown to be of enormous importance in the farming systems. The farmers had a strong belief that the presence of trees on their farms greatly enhances soil fertility. Several tree species were identified as indicators of soil fertility. Shade trees were also described per their socio-economic values. Most of them however, were valued for their timber quality, fruit and medicinal value. Others were desirable either for their soil nutrient and moisture enhancing qualities or purely for the quality of shade they provide. The decision to classify a tree as a good shade tree appeared however, to be greatly influenced by the socio-economic value of the tree, such as its value as a timber species, fruit tree, medicinal properties as well as some other value. Timber trees appeared to be valued the most because of their socioeconomic value.

The cocoa agroforestry systems can be subjected to differing management strategies (Sambuichi, 2012), preventing the comparison between central America, Africa and Brazil. There are data from other cocoa agroforests, however, that do not indicate such a bad ecological scenario. Results from Parrish et al. (1998), for example, from a study in Talamanca, Costa Rica, show that cocoa forests can have a high diversity of birds, equivalent to that of nearby undisturbed forests. Power and Flecker (1998) presented a case from the Dominican Republic in which bird and lizard diversities were as high in the cocoa plantations as in primary forests. Other studies also stressed the important conservation role of cocoa in the Brazilian Atlantic forest (Sambuichi, 2012), and in central America and Africa (Duguma et al., 1998). Also, agroforestry systems have served, in general, as faunal refuges (Griffith, 2000) and the cocoa agroforestry is, without doubt, a better alternative for conservation of biodiversity than traditional intensive agriculture. We believe that the cocoa agroforestry does have great potential for biodiversity conservation, since its structure provides resources and niches for a variety of native species of fauna and flora.

Besides offering habitats for several plants and animal species including many forest dependent species, the complex agroforest system can make an important contribution to the conservation of regional biodiversity by enhancing landscape connectivity, reducing edge effect and improving local climate (Schroth et al. 2004). Farmers must therefore be encouraged to retain trees in farmlands or replant native trees in cocoa agroforests to replace cut trees or old trees when they die.

Some practices for improvement of cocoa might be advanced, such as, for example, the eradication of non-native species and permanence of saplings of native species. A mosaic of cocoa agroforestry and natural forest is probably also more viable for conservation of biodiversity than a homogeneous landscape composed solely of cocoa agroforestry (Myers, 1986). The cocoa agroforestry systems have at least some structural characteristics of the natural forest and may help reduce edge effects between the natural forest and open agricultural fields such as unshaded cocoa farmlands whereby decreasing mortality of forest trees that are not well adapted to drier microclimate. This could prevent the final collapse of isolated forest fragments and forest reserves in agricultural landscapes (Gascon et al., 2000).

The fact that tree diversity show species loss and turnover as baseline forest is being converted to agricultural farmlands means that protection of natural forest should be part of any biodiversity conservation strategy in the study area. Forest protection alone is, however, unlikely to succeed because of the increasing pressure for more land for farming and other socioeconomic factors. From the data presented the cocoa agroforestry is a poor substitute for the natural forest both in terms of native forest tree species richness and vegetation structure.

Despite the loss in forest trees and simplification of forest structure, cocoa agroforestry systems have been found to support relatively higher species richness compared to other land use types such as unshaded farming systems (Bisseleua et al., 2007). Also, the study of Asase et al. (2009) showed that cocoa agroforest supported higher species richness compared to unshaded cocoa farms. There is also the possibility of additional trees being recruited from the soil seed bank. The extent to which the cocoa agroforestry is therefore needed as partial substitute for natural forest in landscape conservation strategies will obviously depend on the availability of natural forests (Schroth et al. 2004). So, appropriate recommendation for cocoa agroforestry farmers could be planting the tree species that are commonly found in primary forests. Since there is increasing demand for land and food production leading to agricultural intensification the heterogeneous mosaic landscape in which the cocoa agroforestry systems forms part could, however, be strategically managed to maximize the benefits of both sustainable agriculture production and conservation of plant diversity.

CHAPTER 6

CONCLUSION

It is evidently clear from the results that the tree species richness and species diversity is significantly higher in the natural forest compared to the secondary forest and cocoa agroforestry, but comparable between cocoa agroforestry and secondary forest. The tree species composition similarity was highest between cocoa agroforestry and secondary forest, followed by that between primary and secondary forest. The least tree species composition similarity was found between primary forest and cocoa agroforestry. Tree species cultivated in cocoa agroforestry are not totally very different from the species found in primary forest, so there is a question, if the relatively high tree diversity and richness can support some of the original faunal diversity found in natural forest.

Almost all cocoa farmers in Bedum district included in this study were members of Cocoa growers' association of Ghana, which support cocoa production in agroforestry systems. Farmers have very good and extensive knowledge about advantages that trees provide for cocoa plantation, soil improvement and biodiversity conservation.

Results mentioned in this thesis are very important for the biodiversity investigations in the Western region of Ghana and following use of the Department of Applied ecology (Nature Conservation) (CULS). The thesis forms a good scientific background for the further research of cocoa agroforestry, which seems to be tool both for sustainable agriculture production and conservation of biodiversity. We showed, that cocoa agroforestry systems in the Western region of Ghana, are supportive of tree species diversity, even though they are no substitutes for natural habitat.

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Appendix A. Questionnaire

	Simple questionnaire about agroforestry state in Western Region - Ghana
1	Name of village/name of district:
2	Name:
3	Date:
4	Sex:
5	Age:
6	How long do you cultivate your site?
7	How many ha have your land?
8	How many ha of cocoa do you grow?
9	How many ha of cocoa agroforestry you have?
10	How many ha of timber trees do you have?
11	Why do you keep trees on your farm?
12	Which benefits do you have from growing cocoa with trees together?
13	Which benefits do you have from growing cocoa without trees?
14	Which product generate your income (cocoa, fruit, timber, annual plants...)?
15	Which tree species are the most abundant?
16	Do you have natural trees or you planted them?
17	Where did you get the planting material?
18	What's yours plans with your land to the future?
19	Do you want to plant more trees in the future?
20	Did someone skilled help you with planting your trees?
21	Are you a member of some agroforestry organization?
22	Are you going to cultivate larger area with cocoa agroforestry?
23	How did you find out about agroforestry projects?

A