Voacanga africana FARMING SYSTEM IN THE ASSIN SOUTH DISTRICT: SOCIO – ECONOMIC AND SOIL NUTRIENT IMPLICATIONS

A Thesis submitted to the Department of Agroforestry, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

IN

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BY

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DECLARATION

I hereby declare that except for references made to the work of other researchers which have been duly cited, this thesis submitted to the School of Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana for the degree of Master of Science in Agroforestry is my own investigation.

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ABSTRACT

Assessing the impact of conversion of forest to agricultural land use and its induced changes on soil fertility properties is essential in addressing problems of ecosystem transformation and sustainable land-use. Adopting a case study approach, this study was conducted to assess *Voacanga africana* farming system in the Assin South District: socio-economic and soil nutrient implications in the Central region of Ghana. The specific objectives of the study were to identify management practices of farmers in *Voacanga* production systems and any potential for improvement, identify socio-economic importance of *Voacanga* in sustaining livelihoods of rural households and challenges along the production–marketing chain. The study also assessed the impact of *Voacanga africana* cultivation on soil physico-chemical properties and its potential for soil carbon sequestration along a chronosequence of secondary forest, 5, 10 and 15-year-old *Voacanga* farms. Data for the study was obtained through the administration of structured questionnaires involving 60 farmers, key informants interviews and field observations. Changes in soil physical (particle size distribution or texture and soil bulk density) and chemical (pH, soil organic carbon, total nitrogen, phosphorus, exchangeable cations and ECEC) properties were assessed through the collection of replicated soil samples at 0-10 cm, 10-30 cm and 30-50 cm soil depths and subsequent laboratory analysis of the samples. The study identified farmers to be using spacing of 4.2 m x 4.2 m, 6 m x 6 m and 8.4 m x 8.4 m in *Voacanga* system. Weeds were controlled by manual and chemical methods with pruning been the main tree management practice. Increasing demand for *Voacanga* seeds and expected income from the sale of seeds is the most important economic factor motivating farmers to go into *Voacanga* cultivation. The main constraints facing farmers were poor marketing, farm theft, lack of technical information, lack of access to credit, problems of land acquisition and inadequate labour. The constraints facing local buyers on the other hand were lack of direct marketing links with companies, absence of standardised marketing board, insufficient labour for seed processing, transportation difficulty and lack of trust worthiness of some farmers. With respect to impact on soil properties, particle size distribution differed significantly along the chronosequence with clay percentage increasing with depth. Soil bulk density (kg m^{-3}) similarly differed significantly among land-uses with *Voacanga* plots generally having higher bulk densities compared to secondary forest. Significantly, low soil pH was observed among land-uses with pH ranging from 5.1 to 6.6 in 10-year-old at 30-50 cm and 0-10 cm soil depths respectively. While mean soil organic carbon (SOC) concentration was not significantly affected at the studied depth (0-50 cm), total SOC stocks increased significantly at 5 and 15 year-old plots along the chronosequence. Total nitrogen increased with increasing age of *Voacanga* plantation at 0-10 cm soil depth but decreased with soil depth. Soil exchangeable Mg and K were low compared to Ca. Effective cation exchange capacity increased along different ages of *Voacanga* plantations. Overall, soil quality did not deteriorate over the studied duration. Under a changing climate, *Voacanga* system has the capability to sequester carbon. The study recommends that in future studies carbon stable isotopes technique can be included as a tracer of soil organic carbon, long term research has to be conducted into the economic analysis of yield and agronomic practices to generate information on management practice for *Voacanga* system.

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DEDICATION

I dedicate this thesis to my late father, Mr. J.B. Danquah, the former District Director of Non-Formal Education Division for Abura Aseibu-Kwamankese District; my mother, Adwoa Maanu and to everyone who contributed directly or indirectly in writing this thesis. God blesses you all.

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CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background introduction to the study

Voacanga africana is a small tropical African tree that grows to a height of about 6 metres. It is commonly called *Voacanga* and belongs to the order *gentianale* and family *apocynaceae*. It is known as small–fruit wild frangipani in English, *Voacanga de'African* in French and *Catagrande* in Portuguese. It is widespread in mainland tropical Africa from Senegal to Kenya in the east and south to Angola, Zimbabwe and Mozambique. It is an old genus, comprising 12 species; 7 in Africa and 5 in Asia. It is closely related to *Tabernaemontana* and has leaves which are up to 30 cm in length and the tree produces yellow seeds (Burkill, 1985; Maurice, 1993). Seeds are numerous, dark brown and ellipsoid in shape and embedded in pulp. It is propagated by seeds and vegetatively by cuttings.

Voacanga has several uses. The West African shamans (spiritual leaders) are said to have used *Voacanga* root bark as a cerebral stimulant and the seeds for visionary purposes. The seeds of *Voacanga africana* contain up to 10% indole alkaloids, including voacamine, voacangine and many related compounds. This group of indole alkaloids when ingested causes a mild to strong stimulation lasting several hours. Higher doses have a strong hallucinogenic effect (Maroyi, 2006). *Voacanga africana* is used by the 'Diola' (tribe) of Africa against infectious diseases. Reportedly, it is also used as an analgesic and to treat mental disorder (Maroyi, 2006).

Voacanga is one of the potential resourceful plant species that needs to be adapted for income generation. There has been a steadily growing market for *Voacanga*. Several hundred tonnes of seeds of *Voacanga africana* and some other *Voacanga* species are exported from Cote d'Ivoire, Ghana, Cameroon and Democratic Republic of Congo to France and Germany (Maroyi, 2006). The importance of *Voacanga* has led to an increase demand especially for the seeds. Export prices from Cameroon in 2004 were (per kg): stem bark US$ 14, stem bark powder and root powder US$ 18 each, root US$ 14, root bark US$ 47, root bark powder US$ 51 and seeds US$ 6. In the United States of America (U.S.A), the prices of seeds or root bark in 2005 were: 30 g seed US$ 20, 30 g root bark US$ 24, 115 g root bark US$ 80, 450 g root bark US$ 280, 1 kg root bark US$ 400 (Maroyi, 2006; Bisset, 1985; Tona *et al.*, 1999). In Ghana demand has been increasing and prices for seeds ranges from GH¢ 1.50 to GH¢ 4.00 per kg. With such high anticipated economic benefits, it is not surprising that interest in the cultivation of *Voacanga* by farmers is growing. In the Assin South District, plantations are springing up and farms range from as low as ½ hectare to plantations as large as 19 hectares.

Besides, the socio-economic impacts of the plant on the livelihoods of rural people, it has also been realised that plantation of *Voacanga* have the potential of contributing to carbon sequestration. According to the findings reported by Bos *et al.*, (2007) trees, agroforestry systems and tree crop plantations can sequester carbon in the soil.

1.2 The problem statement

The inhabitants of Assin South District are predominantly small-scale subsistence farmers cultivating mainly annuals (maize, plantain, cowpea, cassava) and perennial cash crops such as cocoa, oil palm and citrus etc. There has been an increased interest in the cultivation of *Voacanga* due to increasing demand for the seed as well as cash income associated with its production and marketing (Bisset, 1985; Maurice, 1993; Cunningham, 1997). Despite this growing interest in its cultivation, there is little information available on *Voacanga* farming and management practices adopted by farmers. Again, there is no available data on the impacts of conversion of secondary forest into *Voacanga* and it potential to sequester carbon.

1.3 Justification

Voacanga africana is associated with high returns from the sale of seeds as well as the various parts of the plant. The plant can serve as alternative source of income for farmers. The study seeks to find out the tree management techniques, the impact of the plant on soil fertility parameters as well as challenges which confront farmers in order to advance knowledge on the cultivation of the plant. The outcomes of this study will provide the general public and farmers, with missing information necessary to justify many of their field activities, and also provide technical information for sustainable management of the species.

There is a growing concern that the conversion of forest to agricultural land-use causes Green House Gas emissions and climate change, making earth warmer and increasing the frequency of extreme weather events. There is evidence to suggest that tree crop plantations and agroforestry systems have the potential to regain carbon lost through forest conversion to agriculture systems (Meyers, 2007). According to Bos *et al.,* (2007); Gockowski *et al.,*(2004); Smiley and Kroschel (2008) and Bos (2009), shaded-cocoa systems for example are reported to sequester up to 228 metric tonnes of carbon per hectare which is almost as much as that of natural rainforest (300 metric tonnes of carbon per hectare). In Indonesia, shaded cocoa agroforestry systems sequestered about 1.5 metric tonnes of soil carbon per hectare per year during the first 15 years. During the first five years of its cycle, the system total above and below-ground storage of carbon was reported to reach over 11 metric tonnes per hectare per year according to Bos (2009). *Voacanga*, a tree crop has the potential to do same. However, there is no documented information on its contribution to carbon sequestration in the soil.

1.4 General objective

The general objective of the study was to assess the *Voacanga africana* farming system in the Assin South District: socio-economic and nutrient implications.

1.5 Specific objectives

The specific objectives of the study were to:

1. Identify management practices of farmers in *Voacanga* production systems and any potential for improvement.
2. Identify socio-economic importance of *Voacanga* in sustaining livelihoods of rural households and challenges along the production – marketing chain.
3. Assess the impact of *Voacanga* cultivation on soil physico-chemical properties and its potential for soil carbon sequestration.

1.6 Research questions

The research questions which guided the study were:

1. Can *Voacanga* plantations contribute to climate change mitigation?
2. What current management techniques exist and do these need improvement?
3. What are the fertility management practices of *Voacanga* farmers?
4. How does *Voacanga* cultivation impact on soil physico-chemical properties?

1.7 Justification for selection of study district

Assin South District was selected for the study because according to Inkoom (1999), issues of resource of this nature require micro-level study in order to capture all the necessary factors which account for the phenomenon undergoing investigation. These will therefore, permit an in depth approach to finding the needed or appropriate strategies on the issue so that it can be scale-up to other places.

1.8 Outline of the thesis

The research work reported in this thesis is presented in six chapters. **Chapter 1** introduces the study and gives a background to the research and attempts to justify the need for the study. It presents the general objective and lists the specific objectives, research questions for the study and justification for selection of study district. In **chapter 2**, pertinent literature related to the study is reviewed. The review covers areas such as the origin and distribution of *Voacanga africana*, climatic and ecological requirements and botanical description. It also looks at tree plantation establishment and management in general. This is subdivided into land preparation and field establishment, planting, control of weeds and tree management techniques with emphasis on pruning; socio-economic importance of *Voacanga*, diseases and pests as well as *Voacanga* cultivation in Ghana and its potential as an important economic crop. Since the study assesses different aged *Voacanga* systems to achieve its set objectives, the assumptions behind the chronosequence approach to studying land-use and ecosystem dynamics is also reviewed as well as the impacts of forest clearing on soil fertility, the climate change, green house gas (GHG) emissions and the role of trees as mitigation as well as the role of other tree crops and agroforestry systems. **Chapter 3** describes the materials and methods adopted for the study. It also outlines the research approach and data collection which is subsectioned into selection of study communities, sampling method and sampling size determination, questionnaire presentation and administration. This chapter encompasses soil sampling from *Voacanga* fields, analysis of soil samples, carbon stock, degradation index and data analysis. In **chapter 4**, the results are presented as demographic characteristics of respondents, landholdings and tree tenure in *Voacanga* production, farmers enterprise characteristics, management practices, seed yield, socio-economic importance of *Voacanga* in the Assin South District as well as challenges confronting both local farmers and local buyers. It also presents soil physical and chemical parameters, total soil organic carbon stocks, basic nutrients stocks as well as soil degradation following the conversion of forest to cultivated fields. **Chapter 5** discusses the outcome of the study. They are presented as tenure and husbandry practices of *Voacanga* production, landholdings and tree tenure in *Voacanga* system, land preparation and plantation establishment, farmers enterprise characteristics, management practices, seed yield, socio-economic importance of *Voacanga*, challenges facing *Voacanga* industry in Assin South District, soil physical and chemical parameters, total soil organic carbon and total nitrogen stocks, basic nutrients stocks and land-use change on soil degradation along the chronosequence. **Chapter 6** offers research conclusions and recommendations drawn from the findings of the study and gives recommendations for future studies as well as the limitations of the study.

CHAPTER TWO

2.0 Literature review

2.1 Origin and distribution of *Voacanga africana*

According to Hendrian (2001), Schmelzer and Guri-Fakim (2008), Acquaye (1997), Burkill (1985) and Mshana *et al*., (2000) *Voacanga africana* is an evergreen shrub native to Western Africa, specifically Ghana and Côte d'Ivoire from where it has spread to many parts of Africa as well as the South-east Asia. *Voacanga* is an old genus which consists of 12 species. Out of these species, there are 7 species in Africa alone and 5 species in Asia.

Schmelzer and Guri-Fakim (2008) as well as Hendrian (2001) reported that *Voacanga africana* is widespread in the mainland of tropical Africa. It starts from the Atlantic coast to the West and the Indian Ocean to the East. It covers vast land tract; from Senegal, The Gambia, Guinea Bissau, Mali, Sierra-Leone, Liberia, Côte d'Ivoire, Ghana, Burkina-Faso, Togo, Benin, Nigeria, Cameron, Equatorial Guinea, Gabon, Congo, Central African Republic, Sudan, Democratic Republic of Congo, Uganda, Rwanda, Burundi, Kenya, Tanzania, Zambia, Malawi, Mozambique, Angola, Zimbabwe, Comoros Islands, Seychelles, Mauritius, Sao Tome and Principe to Cape Verde Islands. It can also be found in South-east Asia.

In Ghana, according to Acquaye (1997) and Mshana *et al*., (2000) the plant is distributed over the southern and middle belts of the country. Very high concentrations exist in Assin North Municipal, Agona East, Agona West, Asikuma Odoben Brakwa, Assin South, Ejumako Enyan Esiam and Abura-Asebu Kwamankese Districts of the

Central Region; Birim South and Fanteakwa Districts of the Eastern Region; Amansie East and Effiduasi Districts of Ashanti Region; Sunyani and Dormaa Districts of the Brong Ahafo Region; and Wassa Amanfi, Awowin/Suaman, Ahanta West, Wassa West, as well as Mpohor –Wassa Districts of the Western Region.

2.1.1 Climatic and Ecological Requirements

According to Maroyi (2006), Leeuwenberg (1985) and Kontoh (2008) *Voacanga africana* is a tropical plant. It occurs in the understory of open forest, often secondary forest, and in gallery forest in savanna areas. It is often gregarious in coastal forest. Though it is a tropical plant, it exhibits both deciduous and evergreen characteristics. During the hot seasons of the year especially harmattan periods, it tends to shed its leaves. However, in places where the humidity is high, *Voacanga* maintains the foliage all year round. It occurs from sea-level to 1,100 m altitude.

Kwarteng and Towler (1994) indicated that *Voacanga* grows in wide variety of soils such as stony soils, silt-loam, gravelly soils and loamy soils but it thrives best in sandy topsoil. It flowers mainly in February and the fruits mature in July. *Voacanga* requires a modest level of humidity and generally grows best in the tropic and subtropic regions where there are well defined wet and dry seasons. It thrives well in areas with annual rainfall range of 1,500 mm – 2,000 mm. It requires temperature range of 20^{o}C – 30^{o}C and a pH of 5.0 – 6.5.

2.1.2 Botanical description

Lovett *et al*., (2003), Maroyi (2006) and Bisset (1985) reported that *Voacanga* is a small tree which grows up to 25 m in height and 30-40 cm in diameter. The bark of the plant is either pale or grey-brown with smooth bark and white latex. The leaves are simple and opposite with absent stipules; petiole is up to 2 cm long with short ocreaat base. The leave blade is elliptical and pinnately veined with 8-22 pairs of lateral veins. The penducle is 6-25 cm long and consists of slender bracts which is as long as the calyx. It always leaves a conspicuous scar. The flowers are bisexual with bad smell while pedicle is 3-20 mm long. The lobes are broadly ovate to oblong with rounded to truncated apex. The stamens are slightly inserted 2-3 mm below the mouth of the corolla (Maroyi, 2006).

Anthers are narrowly triangular and are 4-5 mm long. The ovary is superior which consists of two carpals surrounded by a ring-shaped disk. *Voacanga* style is narrowly obconical, split, twisted and curled at the base while the pistil is short with a thin ring at the base as well as with five short lobes, coherent with the anthers (Maroyi, 2006).

The fruit consists of two separate globose follicles, but often only one develops and grows up to 3–8 cm in diameter. The fruit is green with numerous whitish spots. Seeds are obliquely ellipsoid, 7–10 mm long, dark brown, yellow or orange as well as pulpy.

Voacanga africana plants develop according to the architectural growth model of Leeuwenberg (1985) determined by a monopodial orthotropic trunk, which ends in a terminal inflorescence. After flowering the two uppermost axillary buds develop into branches, so that the growth is sympodial. The infructescence seems to be axillary (Lovett *et al*., 2003). According to Acquaye (1997) *Voacanga africana* flowers mainly at the end of the dry season.

2.2 Propagation Methods

2.2.1 Germinative propagation

Germinative propagation of *Voacanga* involves two main methods namely propagation by seeds and propagation by cuttings. *Voacanga* is grown from seed which is sown in nursery containers for transplanting. Kontoh (2008) and Harrington (1970) reported that *Voacanga* seeds are recalcitrant; hence do not tolerate drying and cold storage. According to Gyesi (Personal communication, 2010) seed propagation can be achieved by soaking the seeds with white vinegar for five minutes to reduce the outer coat so as to speed up germination while hydrogen peroxide is added to prevent seeds from mold. Vegetative propagation using cuttings is also possible. Cuttings are prepared from matured stems and planted direct on the field (Kontoh, 2008).

According to Evans (1951) several major industrial plantation projects in the tropics now use vegetative propagation with cuttings to develop clonal plantations. This is because, rooted cuttings for vegetative propagation take a relatively shorter time to flower and fruit, and they also preserve the genetic integrity of the parent ensuring true-to-type reproduction (Evans, 1953). Hartmann *et al.*, (1997) stated that, this makes it important for clonal testing, fertility studies, testing for diseases and drought resistance and study of incompatibility problems between stock and scion where identical genotypes are desired.

2.3 Plantation establishment and management

2.3.1 Land preparation and field establishment

Two main operations are involved in establishing plantations in general. They are clearing and preparing the site as well as planting. According to deTaffin (1998), land preparation work in general can be done manually or by machines, depending on cost consideration and local topography constraints. Manual labour has advantage of supporting local employment as well as being less damaging to the soil fertility and structure. *Voacanga* production requires good soil preparation. The reports of Collins (1960) revealed that land preparation practices vary considerably depending mainly on climate, soil type, vegetation and topography etc. Where no mechanisation is available and *Voacanga* is grown as a first crop by farmers after clearing, no land preparation is required other than the removal of the forest growth by cutting down trees, shrubs and vines to admit sunlight. *Voacanga* is planted on the flat land by inserting seedlings directly into the individual holes.

2.3.2 Planting

Studies by Kwarteng and Towler (1994) as well as deTaffin (1998) on tree crops in general indicated that planting should be undertaken during favourable climatic conditions, generally at the onset of the rain. During the month before planting, seedlings health is checked and selection is carried out. The day before seedlings are moved to the field, they should be checked and thoroughly watered if necessary, so as to maintain the soil around the roots in a firm and cohesive condition and to ensure that plant has adequate water supply for several days.

However, according to Rehm and Espig (1991) the seedlings are mostly started off in polythene bags and planted out after 4 – 6 months. Ford-Robertson (1971) and deTaffin (1998) indicated that seedlings should be lifted by polythene bags and not the collar. Before seedlings are placed in the hole, the bottom of the polythene bag should be cut with knife. All that is required to remove the polythene bag is to slit the sides and pull the pieces up. The planting distance depends on soil fertility. The spacing between the trees, according to Gyesi (personal communication, 2010) are 4.2 m x 4.2 m and 6 m x 6 m.

Rehm and Espig (1991), and deTaffin (1998) highlighted that intercrop is established to improve productivity of the land and labour and provide the grower with an income until plantation becomes complete. A wide range of crops can be grown as intercrops, including cocoyam, plantain, cassava and maize etc. Provided that the crops are well maintained, intercrops can be beneficial to the plant development.

2.3.3 Control of weeds

Tomkins (1994, 1996) reported that control of weeds is a general problem in most agricultural systems which can be related to *Voacanga* system. It involves the removal of annual plants and shrubs mainly between the 1–2 years after establishing *Voacanga* on the field when the canopy has not yet closed. It must be done regularly. The undergrowth weeds are brushed for about 3 times per annum. Care must be taken to avoid excessive disturbance of the soil at the base of the plant. Where applicable, ring weeding can be done around mature stands. According to Borger (1998; 1999) control of weeds in plantations is crucial during the first two growing seasons. Without adequate weeds control, competition for water, nutrients and light can lead to high early mortality of trees. Slow growth of surviving trees is inevitable if weeds are not controlled. Good weed control leads to fast early growth, and trees more rapidly dominate the site, providing their own measure of weed control by shading out weeds, particularly along the cultivated rows. Good weed control also ensures that nutrients and water are available to the trees. Grasses in particular are very competitive along with some of the deeper rooted broadleaved weeds. Weeds control should be continued until the trees dominate the site.

Earlier work by Borger (1998) affirmed the use of recommended herbicides as a standard practice of controlling weeds in plantations. However, chemical weed control should be carried out such that the chemicals do not touch the foliage and the stem during the young stages of plant growth since this might kill the plant especially when the chemical is not selective.

Both Tomkins (1994) and Borger (1999) asserted that herbicides used in plantation establishment are usually systemic, that is, the chemical is translocated throughout the weed. These herbicides can be described in terms of other properties; as foliar knock-down herbicides (F.K.H) or as soil residual herbicides (S.R.H). Application of soil residual herbicides provides on-going weed control for several months, particularly during the high growth seasons. These herbicides require adequate soil moisture for activation. F.K.H may be either broad spectrum i.e. controls a wide range of weeds, or specific to particular weed types e.g. grasses or classes of broadleaved weeds.

These herbicides act only through foliar uptake by existing weeds. Similarly, S.R.H may be either broad spectrum or selective and act through root uptake by existing weeds, contact by the emerging weed with chemical on the soil surface or close to the surface, uptake by the developing roots and uptake by both foliage and roots.

2.3.4 Tree management technique

Voacanga cropping systems involve close interaction with crops especially during the early plantation stages. In such situation careful tree management is important. Many and different techniques are employed to manage multipurpose trees including *Voacanga africana*. Coppicing of trees, for instance may be done to produce fuel wood. In intercropping systems, lopping of trees is done to produce fodder and where necessary, to reduce shade on adjacent crops. In homestead, trees are pruned to reduce shading, to increase flowering and fruiting and to provide fuel wood. In *Voacanga africana* farming pruning is the most important management technique (Ford-Robertson, 1971).

Pruning

Report by ISA (2011) indicated that pruning is the cutting or removal of branches or parts of trees or for improving the shape or growth of trees. This is the most common tree maintenance procedure. Usually, trees are pruned preventative or as a corrective measure to remove dead branches, diseased, weak, crowded or, eliminate hazards, and increase light and air penetration. Since each cut to a tree has the potential to change the growth, it is important to consider that no branch is removed without any reason. There are three types of pruning; architectural pruning, shape pruning and maintenance pruning (ISA, 2011):

- Architectural pruning is done when trees are young (up to 4 years of age).

The purpose of this type of pruning is to make sure the trees do not grow too tall, and have the right shape. If trees are not properly pruned at this age, they will become too tall to manage.

- Shape pruning is best done at the beginning of the rainy season, after most leaves have dropped and trees have no pods yet. The purpose of shape pruning in tree crops is to give trees a shape that allows them to capture the most sunlight with the fewer branches, without leaving holes in the canopy.
- Removing new shoots and new branches that are not needed for the health and strength of the tree throughout the year is called maintenance pruning. This type of pruning can be done at any time of the year.

Many industrial tree crops in different agroforestry systems are maintained by pruning. Notable among them are cocoa, coffee, citrus and mango etc. which can be related to *Voacanga* due to its plant architecture. According to Ford-Robertson (1971) many industrial plantation projects in the tropics have employed pruning as an important tree management practice. *Voacanga* like cocoa trees produce more branches and leaves than they need in order to be strong enough to compete. The more branches a tree grows the more energy and “food” it must provide to these branches which reduces the size and number of pods that reach maturity.

Assessment by Balasimha (2006) in India on the performance of cocoa in relation to spacing and pruning emphasised that, it is necessary to regulate the canopy size and shape of plants so that the main crop is not affected. Proper, systematic pruning is essential. Structural pruning is done to shape the canopy to desired size and architecture. For optimum productivity proper canopy management to maintain shape and size is required. Maximum leaf area should be maintained with pruning practices to avoid self-shading of leaves. In the studies on canopy architecture in tree crops, it was found that big canopy with spreading nature seems to be ideal. Pruning of canopy is necessary for maintenance of optimum leaf area index.

ISA (2011) outlined that some common reasons for pruning are to remove dead branches and to improve form. Trees may also be pruned to increase light and air penetration to reach the inside of the tree's crown or to the landscape below. Removal of foliage through pruning can reduce growth and stored energy reserves. Heavy pruning can be a significant health stress for the tree. There are many considerations, however, that make it necessary to prune trees. Safety, clearance and compatibility with other components of a landscape are all major concerns. Proper pruning, with an understanding of tree biology, can maintain good tree health and structure while enhancing the economic value.

2.4 Socio-economic importance and uses *of Voacanga africana*

Investigations by Acquaye (1997) showed that *Voacanga africana* has many uses. The indole alkaloids which are of medicinal importance are by far the most important chemical compounds of *Voacanga* spp. The total amount of alkaloids in root bark is 5–10%, in trunk bark is 4–5%, in leaves is 0.3–0.45% and in seeds is about 1.5–3.5%. According to Acquaye (1997), *Voacanga* is known to contain ten alkaloids. These important alkaloids are grouped into three categories:

(a) Vincamine and vinburnine: – they are alkaloids used in the cerebral stimulant and in the cerebro vascular and geriatric markets (mainly in Japan). In the U.S.A, they are known as memory enhancers and considerable research is being done with these alkaloids in the treatment of Alzheimers diseases and Parkinson diseases (Acquaye, 1997).

(b) Voacamine, voacangine, voacangerine and vobstusine: – these are alkaloids in the pharmaceutical industry. They are hypertensive and as such have ventricular cardio-stimulant action and a slight action on the sympathetic and parasympathetic nervous system (Acquaye, 1997).

(c) Ibrogramine, ibogaine, ibolutine and iboxygaine: – these alkaloids are certified compounds which are used to treat drug addicts.

Several authors have indicated that the seeds are the most important product from *Voacanga*. Report by Maroyi, (2006) stated that several tonnes of seeds of *Voacanga africana* and some other *Voacanga* species are exported from Cote d'Ivoire, Ghana, Cameroon and Democratic Republic of Congo to pharmaceutical companies in France and Germany. Export prices from Cameroon in 2004 were (per kg): stem bark US $14, stem bark powder and root powder US$ 18 each, root US$ 14, root bark US$ 47, root bark powder US$ 51 and seeds US$ 6. In the United States of America (U.S.A), the prices of seeds or root bark obtained in 2005 were: 30 g seed US$ 20, 30 g root bark US$ 24, 115 g root bark US$ 80, 450 g root bark US$ 280, 1 kg root bark US$ 400.

According to Tan and Nyasse (2002), Cunningham (1997), Leeuwenberg (1985) and Hedberg *et al*., (1982) different plant parts of *Voacanga africana* are used medicinally throughout its distribution areas. The latex or decoctions or infusions of the stem bark, leaves or roots are put on wounds, boils and sores, and used to treat gonorrhoea, eczema, fungal infections and scabies. They are also taken to treat heart problems, hypertension and rheumatic afflictions. The latex is used to treat dental caries or drop in the eye to cure ophthalmic. In Senegal and Côte d'Ivoire according to Bisset (1985) a leaf decoction is drunk as tonic and against fatigue. A root decoction is drunk three times daily to treat post–partum pains and hernia while a decoction of the leaves is applied as a wash against diarrhoea, put into a bath against oedema, and is used as a friction and in a drink in the treatment of leprosy. Pulp from the leaves or stem bark is applied to soothe convulsions in children and the juice is put in the nostrils as a tranquilizer. The fruit is used in infusion to treat peptic ulcers.

Investigations by Latham (2004) and Tona *et al.*, (1999) showed that in Democratic Republic of Congo the bark decoction is taken against internal worms, but this is considered a dangerous remedy. An infusion of the twigs is applied in bronchitis. A paste of the roots is applied to the head to kill lice. The dried and powdered roots without the outer bark are mixed with porridge and taken against kidney troubles and menstruation problems in women. The wood is used to make musical instruments. In Tanzania, Hedberg *et al*., (1982) and Lovett *et al*., (2003) indicated that the fruit and seeds are extracted with cold water and the extract taken against internal sores. The seeds are also used to treat high blood pressure. *Voacanga africana* possesses anti-ulcer compound with histamine H_{12} receptor blocking activity. The pharmaceutical companies extract tabersonine from the seeds, which is readily converted into vincamine, a compound widely used in medicines for geriatric patients. Seed extracts are also used in medicines to treat heart diseases, to lower blood pressure and to treat cancer.

Study by Burkill (1985) in West Africa revealed that in Senegal the fruits are considered edible while the latex has been used for adulterating *Hevea rubber* and children also use it to make balls to play. Because of its sticky nature, it is used to trap birds. In Zambia and Ghana wood is burnt to obtain charcoal. *Voacanga africana* supplies poles for building purposes but the wood is considered inferior. Arrows and knife handles/sheaths are made from the branches. Good fibre can be obtained from the bark and is made into rope. In Nigeria, a yarn is made, which is mixed with cotton or other fibres to make mats. In Tanzania *Voacanga africana* is planted for ornamental purposes because of its sweet-scented white flowers. Similar is replicated in Ghana. It is also considered to have an ornamental value and is allowed to grow in some traditional homes to provide shade. This characteristic adds extra value; beauty and shade to homes where it is planted (Bisset, 1985).

Report by von Carlowitz (1989) hinted that the provision of fuel wood by trees which *Voacanga* is one provides domestic and other wood product of industrial purposes which significantly eases pressure on forests and thus contributing to their conservation and preservation. *Voacanga africana* contributes to the reduction of wind speed and excessive evapotranspiration as well as soil and water conservation. These are important considering the current spate of forest destruction and the threat of desertification. According to CTA (2008) the growing of trees in general indirectly curtails for some of the losses of biodiversity and plant genetic resources as agricultural activities expand uncontrolled into forest areas.

The *Voacanga* tree provides vegetative matter which plays an important role in carbon sequestration. Rural communities can benefit from and derive important livelihood products from non-timber forest and on-farm tree resources through conservation and agroforestry. *Voacanga*, considered as one of the ‘trees outside forest’

(TOF), improves air quality and the micro-climate. It is a valuable carbon 'sink' and also helps to reduce soil erosion by checking wind velocity and water runoff. It is highly valued by many communities living in hot climates as providers of shade and has significant symbolic, social, religious and cultural status. Assessment by Levetin and MacMahon (1999); Leeuwenberg (1985) and Acquaye (1997) revealed that the seeds of *Voacanga africana* contain 10% indole alkaloids, including voacamine, voacangine and many related compounds. The same alkaloids are found in the bark, but in much lower levels. This group of indole alkaloids when ingested causes a mild strong stimulation lasting several hours. High doses have a strong hallucinogen effect. As a close relative of tabernanthe iboga and many other psychoactive members of the *apocynaceae*, *Voacanga* species are generally ingested to increase endurance and stamina and also for magic as well as religious purposes. West African shamans (traditional healers) are said to ingest the *Voacanga* root bark as a cerebral stimulant and seeds for visionary purposes. *Voacanga africana* is used by the "Diola" (tribe) of Africa against infectious diseases (Neuwinger, 2000).

2.5 Diseases and pests of *Voacanga africana*

Voacanga as one of the tree crops cannot be exempted from diseases and pests. However, there are few reported cases of serious pests and diseases in *Voacanga* cultivation systems. Report by Pyle (2008) revealed that caterpillars are the most noted insect–pests which attack the plant. According to the author their occurrences start from November to January when humidity is moderately low. They feed and remove the chlorophyll from the leaves. This gives the leaves the skeletonised appearance. The leaves become completely pale to whitish. The caterpillars may be fixed or free, suspended by one thread or more to a leaf or branch with blackish fecal droppings on the ground. The destruction of leaves is coupled with defoliation. Using recommended chemical control measure at the younger stages of the plant is ideal unlike mature stage where the canopy is densely closed. However some are destroyed by birds etc.

2.6 Voacanga africana cultivation/farming in Ghana and its potential as an important economic crop

Ghana abounds with enormous agricultural potential. Most of these potential ranges from annual food crops, vegetables, non-traditional crops, forestry and to its popular cash crop notably cocoa. There are huge sums of monetary value obtain from these crops. The incomes generated are both felt at the local and at the international levels. But as much as the expectations and the returns from other agriculture crops such as cashew, cocoa and oil palm etc are over stretched, there are other lesser-known crops such as *Voacanga* which is gaining attention. The cultivation of *Voacanga* will offer alternative source of income and employment for farmers from the sale of the seeds and the other parts of the plant which can improve the livelihood of farmers. Indications are that, there is a steady market for the seeds. According to Kontoh (2008) many tonnes of seeds of *Voacanga africana* are exported from Ghana to pharmaceutical companies in Europe such as France and Germany as well Asia as a non-traditional export commodity. Currently, 13 kg of dry *Voacanga* seeds is sold for US$ 20 on the international market. Investigation by Kontoh (2008) indicated that, it also generates substantial income for the rural poor who are engaged in the *Voacanga* business. The *Voacanga africana* tree architecture also has great potential to protect river bodies. Its broad leaves, dense canopy and well spread out crown as well as its ability to survive in a wide range of soil types makes it very ideal for plantation along river bodies. The plant has ability to grow on fragile soils and therefore can rejuvenate depleted vegetation and provides biomass which plays important role in carbon sequestration. The seed has a latent possibility or potential of providing oil in large quantities from the commercial extraction of tabersonine. The oil has promising cosmetic and nutritional value. It contains main fatty acids such as palmitic (15 – 20%), stearic (7 – 16%), oleic (49 – 60%) and linoleic (15 – 20%) acids (Maroyi, 2006).

2.7 Chronosequence approach to studying ecosystem dynamics

There are two main approaches in studying ecosystem dynamics. These are the temporal monitoring, where dynamics of ecosystem components such as soil and plants are studied over time on a single site where long term data are present and changes in the ecosystem components over time can be measured directly as well as the chronosequence method. According to Young (1991) and Hartemink (1998), the chronosequence method is a synchronised spatial sampling from neighbouring sites of different ages which are managed on similar soil, climatic conditions and management practices.

According to Johnson and Miyanishi (2008; 2007) because of length of time required to actually observe land-use vegetation changes in a single site, studies of land-use have employed the method of substituting space–for–time generally referred to in ecology as a chronosequence. The reason is that critical comparison can be made across space by sampling many locations to reduce the longer time one has to wait or use in recording changes in designated sites. According to Encarta dictionary (2009) the word 'chrono' is Greek for time (hence chronology) while sequence is derived from Latin word 'sequi' meaning to follow. A chronosequence in land-use is a set of land-use sites that share similar attributes but are of different ages. Since many processes can take a long time to develop, chronosequence methods are used to represent and study the time–dependent of land-use. This method infers a time sequence of development from a series of plots differing in age, that is time since the site became available for occupation. One would prefer to document changes in selected sites over time, but cannot wait that long, so instead comparison of patterns across space is done by sampling many sites at one point in time.

Geddes *et al.*, (2011), Walker *et al.,* (2010), Knops and Tilman (2000) stated that the assumption that underlies the chronosequence approach is that the only thing that differs between sample sites is their age and that each site has traced the same history both in its biotic and abiotic components. All sites are assumed to have been the same initially, and to have experience the same conditions thereafter. If these assumptions are correct, then each site will have repeated the sequence of every other older site up to its present age.

Investigations by Collins and Adams (1983) as well as Pickett (1988) revealed that, there have been previous critiques of the chronosequence method in ecology that pointed out its inherent problems and limitations. They suggested the need to validate or justify the critical assumptions that abiotic and biotic conditions have remained constant over the time span of the study and that all sites have tracked the same history.

2.8 The impact of forest clearing on soil fertility

Soils, as complex ecosystems in themselves, are essential to any future use of land. According to Lal (1996) however, clearing of forests of the humid tropics for agricultural fields is expected to produce, in the long-term, a decline in soil organic matter content and soil fertility. The principal impact of forest clearing on chemical and nutritional properties is related to a decrease in the organic matter content of the soil and to disruption in nutrient-recycling mechanisms owing to the removal of deep-rooted trees. The decrease in soil organic matter content is mostly due to the high rate of mineralisation caused by high temperatures. Changes associated with vegetation removal can provide an early indication for slower, less easily detectable soil organic matter changes. Microbial biomass can also provide an index of soil fertility because it represents an important labile pool of soil nutrients and plays an active role in preventing nutrient loss. Conversion of forest to arable land use has drastic impacts on soil properties.

Reports by Pritchett and Fisher (1987) as well as Nye and Greenland (1964) revealed that the principal soil degradation effects include adverse effects on soil structure leading to crusting, compaction and hard setting. Reduction in infiltration, increase in surface runoff, and soil exposure to raindrop impact and to the shearing effect of overland flow accentuate soil erosion risks. Alterations in pore size distribution and reduction in the colloid content of the surface soil, owing to eluviation, and preferential removal of clay and organic carbon by erosion drastically reduce plant-available water reserves. High soil temperatures, often reaching $40^{o}C$ – $45^{o}C$ at 0 – 5 cm soil depth for 4 to 6 hours a day, further aggravate the frequency and intensity of drought stress experienced by shallow-rooted crops. The absence of actively growing roots in the subsoil horizon leads to leaching of bases such as Ca, Mg, K and Na and increase in soil acidity. In addition to leaching, loss of nitrogen and sulphur also occurs owing to volatilisation. Vegetation removal couples with burning remove soil-stabilising elements- the roots of trees and soil micro-organisms. Heavy tropical rains then turn to wash away topsoil and litter as well as removing nutrients. When forests are cut and burned, the ash and decomposed vegetation release nutrients into the soil. The soil, thus enriched, can support two to three years of growth of shrubby and herbaceous plants, after which nutrient levels fall below that necessary for agriculture. Because of this, cropping in tropical areas is transient, necessitating the abandonment of fields within few years.

2.8.1 Alterations in soil nutrients

Investigation by Pritchett and Fisher (1987) stated that forest soils are often not excellently fertile. There is generally very little external input of nutrients, so soil fertility depends on an extremely complex system of nutrient cycling based on the decomposition of leaves, dead plants and animals due to the activities of soil flora and fauna. This provides most of the nutrients in the soil, but they are rapidly taken up again by the plants, leaving little organic material in the soil. This elegant and fragile system, which permits some forests to exist on poor soils, is seriously disturbed sometimes. When the vegetation cover is removed, nutrients are leached out by rainfall, which also washes away the delicate layer of topsoil because of high water flow rates. The worst offenders are the areas where the vegetation and litter have been scraped away. The remaining soil is left with high levels of insoluble compounds of iron and aluminum oxides, but little organic matter. Since most organic matter is in the vegetation, removing trees reduces many nutrients (and potential organic matter), while burning volatilises carbon and nitrogen which forest soil scientists have long considered as master variables determining soil fertility. Soil fertility does not return for decades, so many nutrients are lost which the forest may not be able to recover. Tropical forests contain twenty to fifty times more carbon in their vegetation than do agricultural lands which replace them. Houghton (1995) reported that closed forest is estimated to contain at least 116 metric tonnes of carbon per hectare in the soil and vegetation. On the other hand, assessment by Matson (1997) and Lodge *et al.*, (1996) indicated that carbon levels in the soil are reduced by 50% after cultivation within five years of forest cutting. In areas of the Amazon rainforest for instance, which were converted to sugar cane plantations, soil carbon levels fell to 83–93% within 12 years (Lodge, *et al.*, 1996). Other estimates indicate that the conversion of forests to agricultural land can cause 40% reduction in soil carbon levels and conversion to pastureland, can also cause 20% reduction. Shifting cultivation causes declines in soil carbon by 18–27%, and fallow periods of at least 35 years are required for soils to regain their original carbon content (Dwetwiler and Hall, 1988). Erosion, topsoil removal and soil oxidation further reduce carbon content and soil fertility. Loss of forest area also generates ancillary damage.

In Malaysia, Brown *et al*., (1991) found that 18% reduction in forested land was able to reduce biomass by 28%. Every tonne of carbon released by clearing of forest, 0.6 tonnes more of carbon was released by the reduction in biomass of the forest surrounding the cleared area due to degradation. According to Houghton (1995) the 38% of forest area lost in Southeast Asia between 1880 and 1980 has led to a 50% loss in biomass.

2.8.2 Irreversible changes in soil structure

According to Koetke (1993) the clearing of forests exposes the soil to sun and oxygen. In some soils, chemical changes occur in the soil under these conditions, resulting in the formation of a rocklike material, laterite. This has occurred in many places, and is not only a modern phenomenon. The same has happened in many places in the Amazon, producing "pavements of rock." Only certain tropical soils are suitable for agriculture. In addition, the use of heavy machinery compacts tropic soils, diminishes soil aeration and water absorption.

2.8.3 Loss of microbial flora and invertebrates in soils

Sutherland and Spreat (1993) asserted that microbial decomposition of organic matter is the major source of soil carbon. Many fungi and bacteria which are vital in decomposition and nutrient cycling are vulnerable to disruption by the removal of forest vegetation and its trees because they are sensitive to moisture fluctuations and increase temperatures caused by the opening of the canopy. Among these organisms are nitrogen-fixing bacteria without which plants cannot survive, as soil nitrogen stores need to be replenished. Mycorrhizal associations with tree roots are also disrupted.

2.9 Climate change, greenhouse gas emission and the role of trees as mitigation

Studies conducted by IPCC (2000; 2001) showed that over the last hundred years, the average air temperature near the earth's surface has risen by little less than $1^{o}C$ or 1.3^{o} F. The rise has succeeded in significant changes in the world climate. The causes include both natural and human-induced gas emissions, contributing to the green house effects that warn the earth's surface. Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (such as hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride) are synthetic, powerful greenhouse gases which are emitted from a variety of industrial processes. The current rise of greenhouse gas emissions coupled with deforestation has increased CO_2 in the atmosphere. In 2005, global atmospheric concentration of CO_2 was 35% higher than they were before the industrial revolution. Carbon losses also occur through decreased vegetation productivity, deforestation and other poor land management practices. Land use changes account for 1.6 ± 1.0 Gt. of CO_2 to be released to the atmosphere annually with deforestation of tropical forest emitting most of the greenhouse gases (IPCC, 2000; Meyers, 2007).

Study by Heimann and Reichstein (2008) indicated that the increasing release of greenhouse gases into the atmosphere contribute substantially to climate change which in turn limits the ability of terrestrial ecosystems plants to sequester carbon. Besides that human–induced activities enhance greenhouse gas release into the atmosphere; prospects for the use of carbon dioxide by plants as a strategy for mitigating climate change are increasing according to Meyers (2007). This is considered to be a relatively cost effective emission strategy for the environment. Therefore, the United Nations, World Bank and other non-governmental organisations are encouraging reforestation; avoided deforestation and other projects that encourage tree planting to mitigate the effects of climate change. Trees in the world over provide many important benefits to mitigate climate change. Trees in general help to slow down global warming by sequestering carbon. The carbon is stored as plant biomass in the trunks, branches, leaves and roots of the plants and organic matter in the soil. They help regulate local and regional rainfall. As globally important storehouses of carbon, trees play a critical role in influencing earth's climate change. Trees and soils drive the global carbon cycle by sequestrating carbon dioxide through photosynthesis and releasing it through respiration. Although carbon uptake by photosynthesis eventually declines as trees age, many mature trees continue their carbon sequestration in the soils. The sequestration activities help prevent global climate change by enhancing carbon storage in trees and soils, preventing nutrients loss and runoff as well as reducing emission of carbon dioxide (CO_2) and nitrous oxide (N_2O) (Noss, 2001; Schulze *et al*., 2000).

2.10 The role of other tree crops and agroforestry systems

The role of other tree crops and agroforestry systems cannot be over emphasised as they have become critical component in the economies of many nations especially the developing countries. According to World Bank (2002) many hectares of land are cultivated to cocoa, coffee, rubber, coconut, oil palm, cashew and citrus etc. Tree crops and agroforestry systems account for significant percentages of total agricultural export in many countries: in Cote d'lvoire they comprise 35%, in Ghana 25%; in Ethiopia 26% while in Uganda they account for a massive 53%. This has contributed to drop in percentage threshold of poverty from 54% in 1992 to 35% in 2000 in Uganda.

Many smallholder farmers through the practice of agroforestry and tree crops cultivation obtain their source of employment and income for the rural farming families. They bring cash for agricultural environment that often have few alternatives. Wealth created in this way generally has a multiplier effect that improves the entire local economy and can also benefit the national community. While most of them generate substantial income and foreign exchange at household and national levels, some of the tree crops and agroforestry systems contribute to food security both at home and regional levels. In societies whose land ownership is communal or customary, the perennial nature of the crops tend to be owned by individuals or families rather than collectively. Tree crops establish clear defined tenure in areas with little formal land registration. In some cases tree crops and agroforestry systems play an important role in the encouragement and preservation of species and ecosystem diversity (Ruf and Zadi, 1998; Gockowski, 2001; Schroth *et al*., 2004).

Since the Rio Summit in 1992, environmental concerns are acknowledged as integral component of sustainable development. Faced with the threat of depletion of primary forests, land that has already been cultivated needs to be replanted. Tree crops are forest-type of cultivated ecosystems which can constitute systems. They help to protect existing forest by supplying wood for industry and energy. According to Pushpakumara (2001) for example, in Sri Lanka tree crops based farming systems supply over 50% natural timber and 80% fuel wood needs. Agroforestry systems and tree crops make substantial contribution towards carbon sequestration. Rubber trees for example can sequester more than 100 tonnes of carbon per hectare over 33 years (Hamel and Eschbach, 2001). Tree crops offer permanent cover, and fairly systematic use of the cover effectively protects soil from erosion. The soil cover provided by tree crops in turn reduces the risk of leaching, and legumes often associated with tree crops help to improve the nutrient balance. They also provide fodder to curtail for the welfare of the animals. Most tree crops and agroforestry systems are sensitive to fertility levels than food crops. Some of them can help stabilise the marginal or degraded lands. In Central America, according to Garrity *et al*., (2006) arabica coffee trees helped to fix many fragile mountain soils. Willey (1975) highlighted that in agroforestry systems, microclimate ameliorations involving soil moisture and soil temperature relations occur from the use of trees since in general shading causes reduction in temperature and temperature fluctuations as well as suppression of weeds

CHAPTER THREE

3.0 Materials and methods

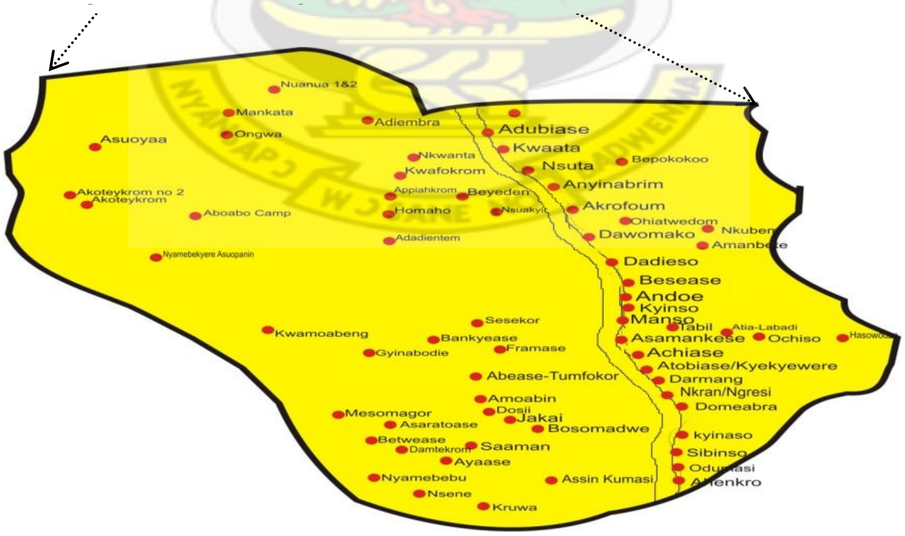
3.1 Description of the study area

The study was conducted in the Assin South District in the Central Region of Ghana (Figure 3.1). The district is bounded on the north by Assin North Municipal, south by Abura–Aseibu Kwamankese District, on the east by Asikuma–Odoben–Brakwa District, and on the west by Twifo-Hemang–Lower–Denkyira and Twifo Ati-Mokwa Districts. The district occupies an area of 1,187 sq km with Nsuaem–Kyekyewere as its capital. Assin South District has 400 settlements with a population of 116,897 based on the 2000 housing and population census with annual growth rate of 2.9%. The area has available arable land, labour and enjoys ready market for the *Voacanga* seeds (Assin South District Profile, 2006).

3.2. Climate and Vegetation

Assin South District falls within the Evergreen and Moist Semi-deciduous Forest Zones. Most of the trees shed their leaves in the dry seasons, but not at the same time for all the trees of the same species. The rainfall pattern is bi-modal with the major rainy season starting from April to July while the minor rainy season starts from September and ends on November. The District also experiences dry harmatan or North – East Trade winds which blow from the Sahara Region. The annual rainfall is between 1,250 mm to 2,000 mm. Annual mean temperature is 26^{o}C. Humidity is fairly moderate but quite high during rainy seasons and early mornings. Average relative humidity range from 60% to 70%. The fair distribution of rainfall and temperature enhances the cultivation of many food crops and cash crops throughout the District (www. Assinsouth ghanadistrict.gov.gh).

Figure 3.1: Location of the study area in Ghana



Assin South District

3.3 Relief and Drainage

The topography of the district is undulating, with an average altitude of about 200 metres above sea level with highest rising to 611 metres around Bosomadwe and lowest around the river plains and streams. The main rivers are Kakum, Ochi, Dwayere, Kyina and Wanko. The district is endowed with numerous streams, ephemeral pools and wetlands (www.Assinsouth ghanadistrict.gov.gh).

3.4 Soil types

Geological strata of Cape Coast granite complex belonging to the pre–cambrian platform underlie the district. It consists of granite, grandiosities and adamellites. Broadly soils of the district fall between Asuansi–Kumasi/Nta–Ofin Compound and exhibit specifically the characteristics of Asuansi series as well as Nsaba-Swedru/Nta – Ofin Compound and also exhibit characteristics of Swedru series under this compound. The Asuansi series have deep, yellowish red, gravelly and concretionary clay loams and clays on middle to upper slopes. The Swedru series have deep, well drained gravelly and concretionary clay loam on summits and upper slopes (Assin South District Profile, 2006).

3.5 Research approach and data collection

Data for the study was collected from both primary and secondary sources. A combination of methods namely interviews (through the administration of structured questionnaires to farmers and key informants), field observation and laboratory analysis of soil samples were used.

3.5.1 Selection of study communities

An initial reconnaissance survey was conducted across the district to identify communities where *Voacanga* cultivation is undertaken, the farmers involved and the key actors. A total of 25 farming communities were visited out of which 10 were purposively selected based on the presence of *Voacanga* farms with sizes ranging from < 1 to 15 hectares and within the age brackets of 1 to 19 years.

3.5.2 Sampling method and sampling size determination

The study was based on both primary and secondary data. The primary data were collected through survey. In order to establish a sampling frame for the study, a population of 105 farmers was selected from ten (10) communities in consultation with some local buyers. These communities were Nyankomasi Ahenkro, Anyinabrim, Bosomadwe, Achiase, Asamankese, Atobiase, Darmang, Nsuaem, Kyekyewere as well as Ngresi. The sample size was calculated from percentage determinant criteria and sample population using the sampling frame summary equation from Jankowicz (2000):

Sample size = percentage determinant (%) x sampled population.

Six (6) farmers were interviewed from each community to represent a sample size of 60. Fifty eight percent criterion was used to ensure that the sample was enough to justify the results being generalised for the district. Simple random sampling was used in selecting respondents for the interview. The key informants were purposively selected by taking into account the guidance and recommendations of early respondents in choosing the subsequent interviewees. The key informant technique (Tremblay, 1982) targeted principally the middlemen engaged in the purchase of *Voacanga* seeds from local farmers. Five key informants were interviewed based on their specialised knowledge.

3.5.3 Questionnaire preparation and administration

A structured questionnaire was designed to collect information from farmers involved in growing *Voacanga africana*. The questionnaire covered demographic characteristics, farm size, seed yield, tree management techniques, farm resources and challenges as well as the socio-economic importance of *Voacanga*. Questionnaires were pre-tested with six farmers resulting in some modification to make data collection easier. Subsequently questionnaires were administered to a total of 60 farmers, with 6 farmers selected from each community. In the case of the key informants a separate unstructured checklist was prepared as a guide for five key informants.

3.5.4 Soil sampling from *Voacanga* fields

Four treatments of 1 – 5-year-old with spacing of 4.2 m x 4.2 m, 6 – 10-year-old with spacing of 6 m x 6 m as well as 11–15-year-old with spacing of 4.2 m x 4.2 m of *Voacanga* land-use were used as well as secondary forest was also used as control. Each land-use treatment was represented by three plots and each plot was replicated three times. Soil samples were taken from six spots along z-shaped transect on each of the 5 m x 20 m subplot by auguring at three depths namely 0-10 cm, 10-30 cm and 30-50 cm. The Sampling design followed was complete randomised design. Soil samples collected from subplots were bulked and sub-sampled taken for laboratory analysis.

3.5.5 Analysis of soil samples

Soil samples were air dried in the laboratory and passed through a 2 - mm sieve prior to analysis. Soil pH was determined by using pH meter in 1:1 soil/water ratio while organic carbon was determined by chromic acid digestion. The Total nitrogen was determined by the kjeldahl digestion, distillation and titration method. The available phosphorus contents of the extract were determined by the Olsen extraction method (Olsen *et al.*, 1954), available potassium was extracted with a solution of ammonium acetate (1 mol/L) adjusted to pH 7 and measured by flame emission (Chapman, 1965) while Ca and Mg were determined with an atomic absorption spectrophotometer (Motsara and Roy, 2008). Exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ were extracted by the Mehlich-3 procedure (Mehlich, 1984). The ECEC for the soils was calculated as the sum of the exchangeable base cations. Particle size distributions were analysed using field moist samples, which were stored at temperatures around 4°C. Sand-size particles were removed by sieving, while silt and clay contents were determined using the pipette method (Gee and Bauder, 1986). For the determination of the bulk density, three undisturbed soil cores with a volume of 100 cm^3 each were taken from all the three depths (0-10 cm, 10-30 cm and 30-50 cm) designated in the study.

3.5.6 Data analysis

The analysis of the socio-economic data involved coding of the numerical and non-numerical responses, and drawing verifying conclusions on the data from the survey research; using Statistical Package for Social Science (SPSS) software version 16.0. Pearson chi–square **(χ^2)** analysis was used to test for association of variables. Data was summarised and the results presented in tables (frequencies/percentages) and graphs such as pie charts and bar graphs. Data analysis of soil samples was conducted using analysis of variance (ANOVA) using completely randomised design. Means were separated using the Least Significant Difference (LSD) comparison test. All the tests of statistical significance were based on a 5% level of probability. The analyses were done using software package Genstat 9.2 (Analytical software, 2011).

3.5.7 Carbon stock

The total soil carbon stocks (kg ha^{-1}) in the soils of each treatment of *Voacanga* field selected were calculated from percentage (%) SOC contents of samples, soil layer thickness (z metres) and bulk density (P_b kg m^{-3}) of the samples using equation from Solomon *et al*., (2002) and Veldkamp, (1994):

SOC STOCK (kg ha^{-1}) = SOC % x (P_b kg m^{-3} x Z metres x 10,000 m^2).

Clearing of forest and its cultivation can lead to compaction and also increases the bulk density of the cultivated soils with time. Significantly, because soil bulk density has important effect on carbon balance calculation, such difference in soil bulk density between secondary forest and *Voacanga* plantations has to be accounted for.

Therefore, the thickness (z metres) of the individual soil depth of the *Voacanga* was corrected (z corrected) based on the method described by Solomon *et al*., (2002) and Veldkamp (1994) assuming that the bulk density and depth of the cultivated soils were originally the same as those of the corresponding secondary forest soils:

Z corrected = (P_b forest / P_b *voacanga* field) x Z

Where; P_b = bulk density (kg m^{-3}), Z = thickness of soil depth (m).

The stocks of carbon and basic nutrients N, P and K in 0 – 10 cm, 10 – 30 cm and 30 – 50 cm soil depths were summed up to give an overall soil stock in the 0 – 50 cm soil layer.

3.5.8 Soil degradation index

The soil degradation indices (DIs) were calculated as the difference between mean values of individual soil properties from *Voacanga* land-use chronosequences and the baseline values of similar soil properties under the forest land-use expressed as a percentage of the values under the forest (Islam and Weil, 2000; Lemenih, 2004). These percentages were summed up across all soil properties to compute an index of soil degradation or improvement. Values of pH was not included in this calculation because the criterion of 'more is better' (i.e. higher value means higher fertility level) is uncertain over the range of values in this study for soil properties (Islam and Weil, 2000).

CHAPTER FOUR

4.0 RESULTS

4.1 Personal and demographic characteristics of respondents

The demographic features of the respondents interviewed are represented in Table 4.1. Majority of the respondents (50%) were within the age group of 47-60 years followed by 36-46 years (23.3%). A few of the respondents (8.3%) were within the active age group of 25-35 years. An assessment of their educational background showed that, about 61% of the respondents have had formal education. The majority of the respondents (46.7%) had secondary education, 5% tertiary education, 10% basic education while 38.3% had no formal education. Overall, 51.7% of the respondents were males while females constituted 48.3%. Out of the 60 respondents interviewed, 75% were married, 6.7% were single while 18.3% had been divorced.

4.2 Landholdings and tree tenure in *Voacanga* production system

The landholdings and tree tenure in *Voacanga* production system is presented in Figure 4.1. The results indicated that 43 respondents representing 71.7% owned the land themselves through inheritance and 17 representing 28.3% also acquired land in the study area through lease. However, all the respondents in the study area including the 28% who acquired land through leasing indicated that they are permitted to plant tree crops on the land.

Table 4.1: Demographic characteristics of the respondents in the Assin South District

Demographic Features	Frequency	Percentage (%)
Age Class		
25—35	5	8.3
36—46	14	23.3
47—60	30	50
Above 60	11	18.3
Education		
Basic	6	10
S.H.S	28	46.7
Tertiary	3	5
None	23	38.3
Gender		
Males	31	51.7
Females	29	5.3
Marital status		
Single	4	6.7
Married	45	75
Divorced	11	18.3

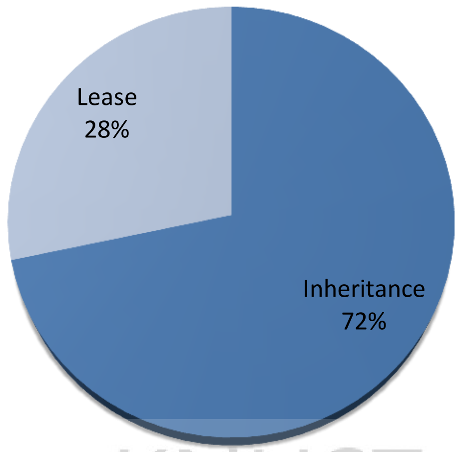


Figure 4.1: Landholdings of respondents in the Assin South District

4.3 Farmers enterprise characteristics

The characteristics of respondents' farm enterprises such as farm size, years of farming experience as well as sources of finance are presented in Table 4.2. The results indicated that the majority of the respondents (45.8%) owned farms with sizes of between 2 – 4 hectares, while 3.4% also owned large farms of between 8 – 11 hectares. With respect to sources of funding, majority of respondents (88.3%) financed their farming enterprise through personal savings while only 3.3% relied on family assistance. The remaining 8.3% relied on loans from financial institutions to fund their farming activities.

Table 4.2: Farmers enterprise characteristics of respondents in the Assin South District

Characteristics	Frequency	Percentage (%)
Farm-size owned/hectare		
< 1 hectare	20	33.9
2 - 4 hectares	27	45.8
5 - 7 hectares	10	16.9
8-11 hectares	3	3.4
Years of farming experience		
1 – 5 years	11	18.3
6 – 10 years	36	60
11 – 15 years	13	21.7
Source of financing		
Personal savings	53	88.3
Family support	2	3.3
Loans from financial institutions	5	8.3

4.4 Management practices

4.4.1 Spacing and control of weeds.

Majority of the respondents (70%) did not employ any standardised spacing. Ten percent used planting distance of 6 m x 6 m, 3.3% have adopted 4.2 m x 4.2 m while 8.4 m x 8.4 m planting distance was adopted by 16.7% of the respondents. The planting distance is based on the experience and recommendations by other farmers. In the initial growth stages crop combination such as cassava, maize and plantain etc. are intercropped depending on the planting distance up to the fifth year when the canopy has closed. At this stage the farm is managed solely with *Voacanga* products in mind. The respondents indicated that weeds are either controlled manually (hoe, cutlass) or through chemical means two times in a growing season. The table 4.3 shows spacing used by respondents.

Table 4.3: Spacing used by respondents in the Assin South District

Spacing	Trees per hectare	Frequency	Percentage (%)
4.2 m x 4.2 m	120	2	3.3
6 m x 6 m	80	6	10
8.4 m x 8.4 m	60	10	16.7
Irregular	_	42	70
Total		60	100

Plate 4.1: *Voacanga* plantation with irregular planting distance

4.4.2 Tree management techniques

A large percentage of the respondents (81.7%) in the study district usually pruned the dead and weak branches while 18.3% of the respondent farmers did not prune the trees as indicated in Table 4.4. There was a significant difference in relation to communities and tree management techniques (Table 4.5).

Table 4.4: Tree management techniques used by respondents in the Assin South District

Technique	Frequency	Percentage (%)
Pruning	49	81.7
None	11	18.3
Total	60	100

Table 4.5: Chi-square (χ^2) analysis of difference between communities on tree management technique

Tree Management Technique	Communities 1	2	3	4	5	6	7	8	9	10	χ^2 Value	Significance
Pruning	1 (16.67)	4 (66.67)	6 (100.00)	6 (100.00)	6 (100.00)	2 (33.33)	6 (100.00)	6 (100.00)	6 (100.00)	6 (100.00)	χ^2 =15.1239	
None	5 (83.33)	2 (33.3)	0 (0.00)	0 (0.00)	0 (0.00)	4 (66.67)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	P-value= < 0.001	S

*(1=Achiase, 2=Ahenkro, 3=Anyinabrim, 4=Asamankese, 5=Atobiase, 6=Bosomadwe, 7=Darmang, 8=Kyekyewere, 9=Ngresi, 10=Nsuaem),
*S= Significant, *Numbers in the parenthesis are percentage (%)

4.5 Seed yield

Results indicated that majority of the respondents (51.7%) obtained an average seed yield of 90 kg per hectare (lowest range 60-180 kg), whilst 23.3% (high range 350-550 kg) obtained on the average 480 kg per hectare (Table 4.6). The majority of the respondents were within the lowest range while few were within high range. The seed yield was obtained from the questionnaire and not actual yield from careful yield study.

Table 4.6: Seed yield of respondents in the Assin South District

Yield/hectare (kg)		Frequency	Percentage (%)
Lowest range	60 - 180	31	51.7
Medium range	180 - 300	15	25
High range	350 - 550	14	23.3
Total		60	100

*****Sixty (60) kg weight is equivalent to 1 bag.

4.6 Socio-economic importance of *Voacanga* in the Assin South District

Most of the respondents cultivate *Voacanga* principally for fruit or seeds. The sale of high quality seeds is among the most important goal of *Voacanga* by farmers. Prunings from mature stands on rare occasion provide fuelwood. The 71.7% of the respondents admitted that the *Voacanga* has provided them economic benefit (income) which has come a long way to improve their livelihoods. Also 21.7% indicated that fuelwood and seeds could be obtained from *Voacanga* as well as medicinal/

fuelwood/seeds (15%). Figure 4.2 shows the socio-economic importance of *Voacanga* to households and individuals in the study area.

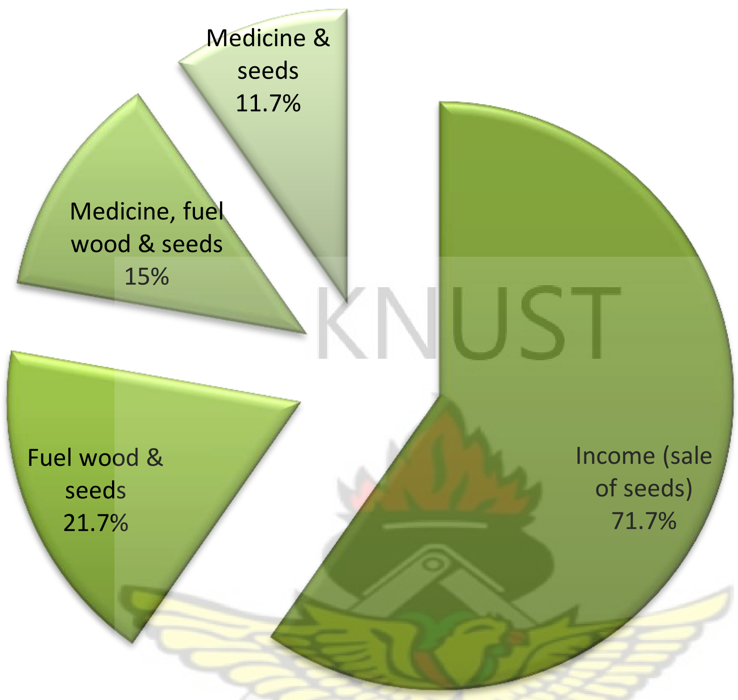


Figure 4.2: Socio – economic importance of *Voacanga* in Assin South District

4.7 Challenges facing *Voacanga* industry in Assin South District

4.7.1 Challenges facing farmers

The study revealed that, the respondents had challenges with poor marketing, farm theft, lack of technical information or poor agricultural extension services, inadequate labour and land acquisition challenges. Figure 4.3 summarises the main challenges facing *Voacanga* farmers in the Assin South District.

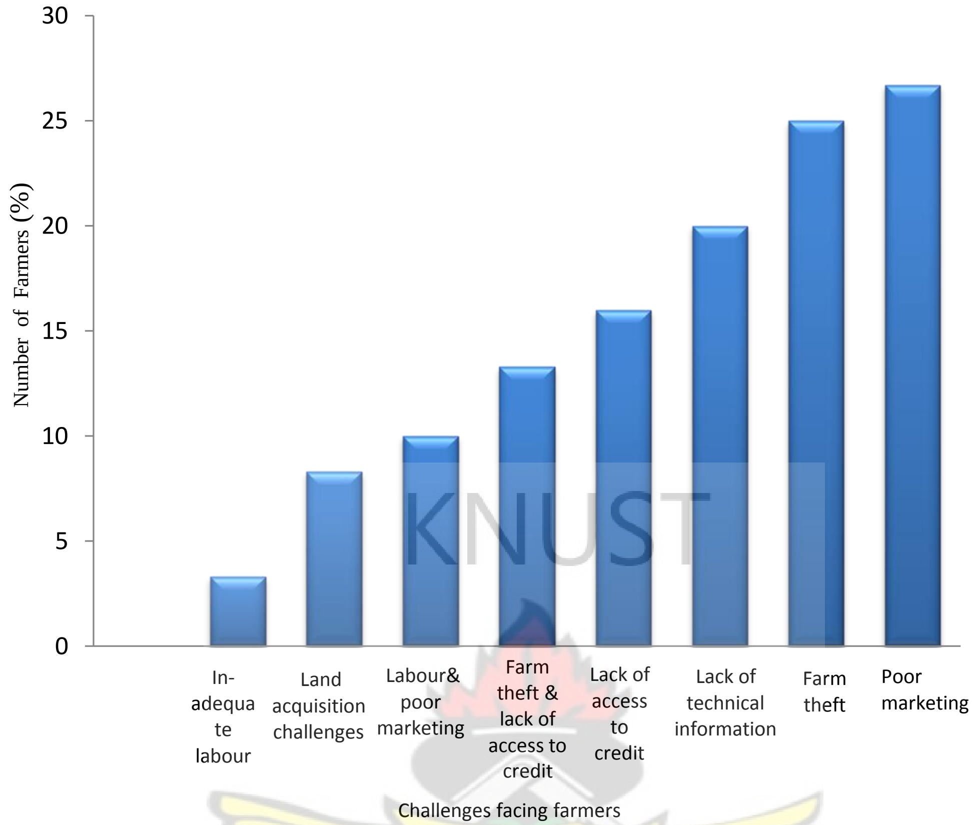


Figure 4.3: Challenges facing *Voacanga* farmers in the Assin South District

4.7.2 Challenges facing local buyers

The study revealed that those who are engaged in the buying of *Voacanga* encounter some challenges. The key informants interviewed made some comments to these effects and have been summarised as;

“insufficient labour, transportation difficulties, lack of trust worthiness on the part of farmers coupled with diversion of produce to different buyers during production seasons and lack of direct links with marketing companies have been some of the challenges we usually encounter".

4.8 Soil physical parameters

The particle size and bulk densities in the forest and different aged *Voacanga* plots for the studied depths (0 – 10 cm, 10 – 30 cm and 30 – 50 cm) are shown in Table 4.7. Between the forest and different aged *Voacanga* land-uses, mean particle size distribution for the 0 – 50 cm soil depth did not differ in percentage silt (F=1.38; P=0.2442), percentage sand (F=2.07; P=0.0654) and in percentage clay (F=1.38; P=0.2442). For the 0 – 10 cm soil depth, percentage sand (F=2.07; P=0.0654), percentage silt (F=1.38; P=0.2442) and percentage clay (F=1.38; P=0.2442) were similar. Overall soil texture (0 – 50 cm) for the study sites can be described as sandy loam (10 and 15-year-old plots), and loamy sand for the forest and 5-year-old plots (Table 4.8). The bulk density (0 – 50 cm) differed (F=10; P=0.0000) between the forest and different aged *Voacanga* plots. Bulk densities were lower in the top 0 – 10 cm soil depths than in the deeper profile across all the land-uses. The mean values for the different depths ranged from 1.220 kg m^{-3} for the 0 – 10 cm soil depth in the forest to 1.910 kg m^{-3} for the 30–50 cm soil depth in 5-year-old plots. The higher bulk densities occurred generally in the subsoil depths of 30–50 cm.

Table 4.7: Mean values for particle size distribution (%), bulk density (kg m^{-3}) and texture for the respective soil depths: 0-10 cm, 10-30 cm, 30-50 cm and 0-50 cm under the different land-uses in the Assin South District

Soil Physical Parameters	Depth (cm)	Land-uses Secondary Forest	*Voacanga* 5 years	*Voacanga* 10 years	*Voacanga* 15 years
Sand (%)	0 – 10	78.1^{a}	74.7^{ab}	66.7^{b}	71.7^{ab}
	10 – 30	68.2^{a}	70.2^{a}	59.5^{b}	68.9^{ab}
	30 – 50	69.2^{a}	62.6^{a}	62.8^{b}	65.2^{b}
Mean	**0 – 50**	**71.8^{ab}**	**69.2^{ab}**	**63.0^{b}**	**68.6^{ab}**
Silt (%)	0 – 10	17.9^{b}	21.3^{ab}	25.9^{a}	20.9^{ab}
	10 – 30	23.7^{ab}	21.8^{ab}	22.5^{ab}	19.1^{b}
	30 – 50	22.8^{ab}	19.4^{b}	17.9^{b}	18.8^{b}
Mean	**0 – 50**	**21.3^{ab}**	**20.8^{ab}**	**22.1^{ab}**	**19.6^{b}**
Clay (%)	0 – 10	4.0^{b}	4.0^{b}	7.4^{ab}	7.4^{ab}
	10 – 30	8.7^{b}	8.0^{b}	18.0^{a}	12.0^{ab}
	30 – 50	8.0^{b}	18.0^{a}	19.3^{a}	16.0^{a}
Mean	**0 – 50**	**6.9^{b}**	**10.0^{ab}**	**14.9^{a}**	**11.8^{ab}**
Bulk density (kg m^{-3})	0 – 10	1.220^{b}	1.443^{a}	1.376^{ab}	1.400^{a}
	10 – 30	1.730^{a}	1.603^{ab}	1.490^{b}	1.663^{ab}
	30 – 50	1.750^{ab}	1.910^{a}	1.623^{b}	1.767^{ab}
Mean	**0 – 50**	**1.566^{b}**	**1.652^{b}**	**1.496^{a}**	**1.610^{b}**
Texture	0– 50	Loamy sand	Loamy sand	Sandy loam	Sandy loam

Figures followed by different superscripts for different land-uses are significantly different at the same depth at $P< 0.05$ based on least significant difference test

Table 4.8: Mean values for particle size distribution (%) for 0-10 cm soil depth and texture for 0-50 cm soil depth under the different land-uses in the Assin South District

	Land-uses			
Soil Physical Parameters	Secondary Forest	*Voacanga* 5 years	*Voacanga* 10 years	*Voacanga* 15 years
Sand (%)	78.1^{a}	74.7^{ab}	66.7^{b}	71.7^{ab}
Silt (%)	17.9^{b}	21.3^{ab}	25.9^{a}	20.9^{ab}
Clay (%)	4.0^{b}	4.0^{b}	7.4^{ab}	7.4^{ab}
Texture	Loamy sand	Loamy sand	Sandy loam	Sandy loam

Figures followed by different superscripts for different land-uses are significantly different at the same depth at P< 0.05 based on least significant difference test

4.9 Soil chemical parameters

4.9.1 Soil pH

The mean pH values for the respective soil depths (0 – 10 cm, 10 – 30 cm and 30 – 50 cm) for the different land-uses are shown in Table 4.9, while the overall mean values for 0 – 50 cm soil depth are given in Table 4.10. The pH values for the various depths across the different land-uses ranged from 5.1 to 6.6 at 30 – 50 cm soil depth and 0 – 10 cm soil depth respectively. The mean pH distribution (0 – 50 cm) differed (F=3.01; P=0.0116) between forest and different aged *Voacanga* plots. Differences were significant for 0 – 10 cm and 30 – 50 cm soil depths and plots under *Voacanga* had significantly higher pH values than forest.

4.9.2 Soil organic carbon and Total nitrogen concentrations

Soil organic carbon (SOC) and total nitrogen (TN) concentrations in the forest and different aged *Voacanga* plots for the studied depths (0 – 10 cm, 10 – 30 cm and 30 – 50 cm) are presented in Table 4.9, while the overall mean values for 0 – 50 cm soil depth are given in Table 4.10. Between the forest and different aged *Voacanga* land-uses, the mean concentration for 0 – 50 cm soil depth differed significantly for percentage soil organic carbon (F=9.99; P=0.0000) and percentage total nitrogen (F=9.90; P=0.0000). Generally, both SOC and TN concentrations decreased with increasing soil depth. For the 0 – 10 cm soil depth for instance, differences were significant for both soil organic carbon and total nitrogen concentrations.

4.9.3 Basic cation concentrations

Basic cation concentrations in the forest and different aged *Voacanga* plots for the respective depths namely, 0 – 10 cm, 10 – 30 cm and 30 – 50 cm are presented in Table 4.9, while the mean values for 0 – 50 cm soil depth are presented in Table 4.10. Between the forest and the different-aged plots, mean cation concentrations for 0 – 50 cm soil depth did not differ for exchangeable Ca^{2+} (F=1.35; P=0.2591) and exchangeable K^{+} (F=3.68; P=0.2591) though there was significant difference among the different land-uses for exchangeable Mg^{2+} (F=3.49; P=0.0051). For 0 – 10 cm, 10 – 30 cm and 30 – 50 cm soil depths, differences were not significant for exchangeable Ca^{2+}. However, there were differences in the 0 – 10 cm soil depth for exchangeable Mg^{2+} as well as for 10 – 30 cm soil depth for exchangeable K^{+}.

The mean ECEC values for the various depths ranged from 3.25 cmol (+) kg^{-1} at 30 – 50 cm soil depth in the forest to 8.44 cmol (+) kg^{-1} at 0 – 10 cm soil depth in 15-year-old plot. The ECEC (0 – 50 cm) was significantly different (F=2.35; P=0.0391) between the forest and different-aged *Voacanga* plots. Between the different depths, differences were significant only at the 0 – 10 cm soil depth.

Table 4.9: Mean values for pH, Organic carbon (%), Total nitrogen (%), Available phosphorus (mg kg^{-1}), Exchangeable cations (cmol (+) kg^{-1}) and ECEC for the 0-10 cm, 10-30 cm and 30-50 cm soil depths under the forest and *Voacanga* land-uses in the Assin South District

		Land-use			
Soil Chemical Parameters	Depth (cm)	Secondary Forest	*Voacanga* 5 years	*Voacanga* 10 years	*Voacanga* 15 years
pH – H_2O (1:1)	0 – 10	5.6^{b}	5.6^{b}	6.6^{a}	6.3^{ab}
	10 – 30	5.5^{b}	5.6^{b}	5.9^{ab}	6.4^{ab}
	30 – 50	5.5^{b}	5.3^{b}	5.1^{a}	6.3^{ab}
Org. Carbon (%)	0 – 10	1.38^{a}	0.87^{b}	0.87^{b}	1.14^{ab}
	10 – 30	0.31^{b}	0.55^{ab}	0.51^{ab}	0.54^{ab}
	30 – 50	0.28^{a}	0.34^{a}	0.37^{a}	0.45^{a}
Total Nitrogen (%)	0 – 10	0.08^{b}	0.09^{ab}	0.10^{ab}	0.11^{a}
	10 – 30	0.03^{b}	0.05^{b}	0.04^{b}	0.05^{b}
	30 – 50	0.02^{b}	0.03^{b}	0.03^{b}	0.04^{b}
Available Phosphorus (mg kg^{-1})	0 – 10	5.98^{b}	5.74^{b}	11.00^{b}	24.40^{a}
	10 – 30	1.91^{b}	4.17^{ab}	4.84^{ab}	7.92^{a}
	30 – 50	2.31^{b}	2.15^{b}	5.05^{ab}	8.56^{a}
Exchangeable Ca (cmol (+) kg^{-1})	0 – 10	2.40^{ab}	2.31^{ab}	4.98^{a}	4.45^{ab}
	10 – 30	1.87^{b}	1.96^{b}	3.83^{ab}	2.76^{ab}
	30 – 50	1.87^{b}	2.14^{ab}	2.14^{ab}	4.27^{ab}
Exchangeable Mg (cmol (+) kg^{-1})	0 – 10	1.34^{b}	1.07^{b}	0.89^{b}	2.76^{a}
	10 – 30	0.80^{b}	1.16^{b}	0.85^{b}	0.89^{b}
	30 – 50	0.53^{b}	0.80^{b}	0.84^{b}	1.33^{b}
Exchangeable K (cmol (+) kg^{-1})	0 – 10	0.21^{b}	0.23^{b}	0.75^{a}	0.60^{ab}
	10 – 30	0.20^{ab}	0.15^{ab}	0.63^{a}	0.48^{b}
	30 – 50	0.12^{b}	0.15^{b}	0.28^{ab}	0.50^{a}
ECEC	0 – 10	8.87^{a}	4.24^{b}	7.25^{ab}	8.44^{a}
	10 – 30	3.76^{ab}	3.85^{ab}	6.10^{a}	4.79^{b}
	30 – 50	3.25^{b}	3.89^{b}	4.19^{ab}	6.67^{a}

Mean figures followed by different superscripts for different land-uses are significantly different at the same depth at $P < 0.05$ based on least significant difference test

Table 4.10: Mean pH, Organic carbon (%), Total nitrogen (%), Available phosphorus ($mg\ kg^{-1}$), Exchangeable cations ($cmol\ (+)\ kg^{-1}$) and ECEC for 0-50 cm soil depth under forest and the *Voacanga* land-uses in the Assin South District

	Land-use			
Soil Chemical Parameters	Secondary Forest	*Voacanga* 5 years	*Voacanga* 10 years	*Voacanga* 15 years
pH – H_2O (1:1)	5.5^{b}	5.5^{b}	5.9^{ab}	6.3^{ab}
Org. Carbon (%)	0.7^{b}	0.6^{b}	0.6^{b}	0.7^{b}
Total Nitrogen (%)	0.04^{b}	0.06^{b}	0.06^{b}	0.07^{b}
Available Phosphorus ($mg\ kg^{-1}$)	3.4^{ab}	4.02^{ab}	6.96^{b}	13.6^{a}
Exchangeable Ca ($cmol\ (+)\ kg^{-1}$)	2.0^{b}	2.1^{ab}	3.7^{ab}	3.8^{ab}
Exchangeable Mg ($cmol\ (+)\ kg^{-1}$)	0.9^{b}	1.0^{b}	0.9^{b}	1.7^{b}
Exchangeable K ($cmol\ (+)\ kg^{-1}$)	0.2^{b}	0.2^{b}	0.6^{a}	0.5^{ab}
ECEC	4.0^{a}	4.0^{a}	5.8^{ab}	6.6^{b}

Figures in the same column followed by different superscripts for different land-uses are significantly different at the same depth at $P < 0.05$ based on least significant difference test

4.9.4 Total soil organic carbon stock and total nitrogen stock

The total soil organic carbon and nitrogen stocks for the forest and the different-aged *Voacanga* plots for 0 – 50 cm soil depth are shown in Table 4.11. Total carbon stock in the 0 – 50 cm soil depth ranged from 37.3 $mg\ ha^{-1}$ in the forest to 48.3 $mg\ ha^{-1}$ in the 15-year-old land-use. The total SOC stock differed (F=8516.68; P=0.0000) between the forest and the different-aged *Voacanga* land-use plots.

Total nitrogen stock (0 – 50 cm) differed significantly (F=120,000; P=0.0000) between forest and different-aged *Voacanga* plots. The TN stock was highest under 15-year-old plots (4.4 mg ha^{-1}) while the forest stored the lowest TN stock (2.6 mg ha^{-1}).

4.9.5 Total basic nutrients stocks

The mean values for total phosphorus and total potassium stocks of forest and different *Voacanga* land-uses for 0 – 50 cm soil depth are presented in Table 4.11. Between the forest and different aged *Voacanga* land-uses, the mean phosphorus stock for 0 – 50 cm soil depth differed (F=205.17; P=0.0000) significantly. The mean value ranged from 21.24 kg ha^{-1} in the forest to 88.42 kg ha^{-1} in 15-year-old-*Voacanga* plot. The phosphorus stock decreased in the order *Voacanga* 15 years > *Voacanga* 10 years > *Voacanga* 5 years > secondary forest.

The potassium stocks in the 0 – 50 cm soil depth differed (F=12000; P=0.0000) between forest and different *Voacanga* plots. The mean values ranged from 211.12 kg ha^{-1} in forest to 742.42 kg ha^{-1} in 10-year-old plot. The potassium storage is in the order of 10-years > 15-year > 5-years > forest.

Table 4.11: Mean values for Carbon, Nitrogen (mg ha^{-1}), Phosphorus and Potassium (kg ha^{-1}) stocks for 0-50 cm soil depth under the forest and different aged *Voacanga* land-uses in the Assin South District

Land-use	Parameters (mg ha^{-1})		(kg ha^{-1})	
	Carbon	Nitrogen	Phosphorus	Potassium
Secondary Forest	37.3d	2.6d	21.24d	211.12d
Voacanga 5 years	44.6b	3.8b	28.13c	318.73c
Voacanga 10 years	41.1c	3.6c	48.19b	742.46a
Voacanga 15 years	48.3a	4.4a	88.42a	489.37b

Figures in the same column followed by different letters for different land-uses are significantly different at the same depth at $P < 0.05$ based on least significant difference test

4.9.6 Soil degradation following the conversion of forest to cultivated field.

The impact of land-use change on total soil quality (measured in terms of degradation indices) along the chronosequence is presented in Table 4.12. Each degradation index (DI) was calculated as the sum of the percentage organic C, total N, available P, Ca, Mg, K and ECEC. The indices of degradation were +69.4, +471.7 and +769 respectively for the 5, 10 and 15-year-old cultivated plots which were measured against forest as the standard reference with an index of zero (Figure 4.4). DIs of most of the soil properties in the 0 – 50 cm soil depth for different *Voacanga* land-uses were positive for TN, P, Ca, Mg, K and ECEC except for OC which was negative for 5 and 10-year-old *Voacanga* land-uses. The degradation of OC of the study soils under the *Voacanga* land-uses was the most noticeable among all of them. The DIs of each of the soil properties generally showed progressive build up of nutrients with cultivation time. Despite the apparent decrease, conversion from forest to *Voacanga* land-use indicated by the cumulative DIs of *Voacanga* field shows continues increase with increasing period under cultivation.

Table 4.12: Degradation indices (%) for some soil properties in the 0 – 50 cm soil depth under *Voacanga* land-use chronosequence at 5, 10 and 15 years of cultivation following conversion of secondary forest

Soil Property	Land – use		
	5	10	15
Organic Carbon	-14. 3	-14. 3	0
Total Nitrogen	+50	+50	+75
Available Phosphorus	+17.6	+106	+300
Exchangeable Ca	+5	+85	+90
Exchangeable Mg	+11.1	0	+89
Exchangeable K	0	+200	+150
ECEC	0	+45	+65
Cumulative DI	+69.4	+471.7	+769

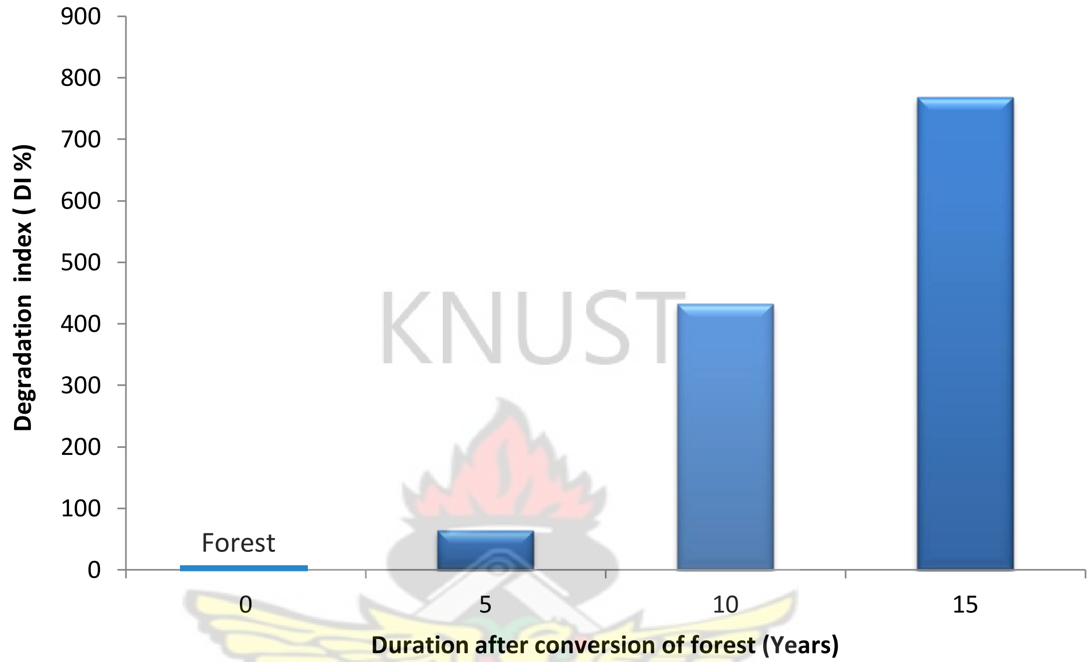


Figure 4.4: Degradation indices of forest soils along chronosequence of *Voacanga* fields at 5, 10 and 15 years of cultivation following forest conversion

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Tenure and husbandry practices of *Voacanga* production

5.1.1 Landholdings and tree tenure in *Voacanga* production system

The holding or the possessing of the land usage rights associated with a piece of land and its resources by individuals and groups under the rules of the society are strictly adhered to in the study area. Bruce (1986) stated that, tree tenure simply refers to the terms and conditions on which trees are held and used. It includes questions of both ownership and access or use rights. The set off rights that a person or some private entity holds to trees may include the right to own, to inherit, to plant, to dispose of and to prevent others from using trees and tree products (Fortmann, 1985). Tenure is not a matter of man's relationship to natural resources such as trees. It is a matter of relationships between individuals and groups of individuals in which rights and obligations with respect to control and use of natural resources are defined. It is thus a social institution according to Birgegard (1993).

Rights to trees vary between timber and non-timber species. In the case of non-timber trees such as *Voacanga,* kola, oil palm, raphia palm and bamboo etc. the rights also depend on whether the tree has some commercial value or it is for subsistence use only (Acheampong, 2003; Asare, 1986). The results revealed that majority of the farmers acquired their plots through inheritance (72%) and ownership by lease (28%). However, the 28% which acquired land through leasing gave an indication that, farmers are permitted to plant tree crops on the acquired land based on conditions under the consent of the landlord. The results conformed with Asare (1986) who in a study of indigenous tenures relating to trees and forests, observed that, in most parts of the high forest zone, any individual who has the right to use a piece of land in perpetuity also has the right to plant any species of trees, and such trees are vested in the planter/cultivator. The results revealed further that leasehold is held for a length of time on agreed conditions which include division of the proceeds either through the "*abunu"* or *"abusa"* systems after each season's harvest. The results are in agreement with Kwarteng and Towler (1994) who observed that any form of claim of ownership of land has several inherent defects which can create land improvement problems and may restrict the activities of progressive farmers. The acquisition of land by lease in the area can be attributed to the fact that some of the farmers are settlers and do not own the land themselves. They have acquired long term right to the use of land. This is in agreement with Asare (1986); Acheampong and Marfo (2011) who observed that settlers who have acquired long-term title or right to the use of land through some form of agreement (such as granting on leasehold basis) also have the right to plant and use any species of tree.

5.1.2 Land preparation and plantation establishment

Observations showed that on new forest lands the cleared vegetation is burnt after land clearing to admit sunlight while on older lands which have been cropped the previous year, there is no need to burn the vegetation prior to planting. All the respondents in the study area indicated that land clearing, site preparations as well as planting are the main operations in the *Voacanga* plantation establishment. They indicated that land preparation is done manually using cutlass, axe and hoe depending on the vegetation. The results are in agreement with deTaffin (1998) at Technical Centre for

Agriculture and Rural Co-operation (CTA; ACP – EU) on coconut plantation and Collins (1960) who reported that land preparation and plantation establishment begin with land clearing, site preparation and planting by manual (cutlass, axe and hoe) or by machines depending on cost, vegetation and topography. Besides, the respondents showed that *Voacanga* seedlings are planted directly on the flat land by inserting the seedlings into the holes at the onset of the rain.

5.1.3 Farmers enterprise characteristics

Majority of the farmers are small holders. Farms which are less than 1 hectare in size can be attributed to the fact that farmers are new in the farming or have not been in the *Voacanga* cultivation for longer years or are challenged with land acquisition. According to Rahji (2000) agricultural business is vested mainly with small scale farmers who are found mostly in rural areas and are responsible for both food consumed at domestic level as well as raw materials needed by the industrial sector of the economy. The results agree with Kotchi (1989) and Brafo – Insaidoo *et al.*, (2008) in Ghana. The authors reported that, acquisition of land is a problem for ecofarming practices for tropical smallholdings since this has encouraged small scale farmers to simply cultivate the land without investing in long term improvement of its quality.

There is the need to mention that *Voacanga* is a high income crop which explains why farmers are going into its cultivation on plantation scale. The results are in agreement with Leakey *et al.*, (2005), Ndoye *et al.*, (1997), Gockowski *et al.*, (1997), and Schreckenberg *et al.*, (2002) who observed that, in West and Central Africa, a number of indigenous fruits and nuts mostly, from farm trees contribute to regional trade.

In Cameroon, for instance the annual trade of agroforestry tree products has been valued at US$ 7.5 million, of which exports generate US$ 2.5 million (Awono *et al.*, 2002). The authors' assessment emphasised that perhaps because of this, evidence is accumulating that agroforestry tree products contribute significantly to household income and to household welfare. For example, according to Ayuk *et al.,* (1999a, 1999b, and 1999c) and Gockowski *et al.*, (1998) farm level production of three indigenous fruit and nut species (*Daccryodis edulis*, *Garcinia kola* and *Rocinodendron heudelotii*) in Southern Cameroon has been reported to worth US$ 355 from average farm size of 1.7 hectare and against an average annual expenditure of US$ 244.

5.2 Management practices

5.2.1 Spacing and control of weeds

The study revealed that, there is no standard planting distances employed in the study area. The choice of spacing depends on farmers' experience since farmers do not receive any extension information on *Voacanga* from district extension service department of Ministry of Food and Agriculture. Spacing has impact on total number of plant per hectare. Apart from plant population per hectare, another important implication of spacing is that it influences rate of litterfall, shade regime, canopy formation as well as carbon and or nitrogen decomposition. This therefore turns to affect the levels of nutrients in the soil. It is deemed better to space *Voacanga* relatively dense as this permits or leads to early canopy closure. The dense canopy formation does not only capture more light and control weeds but also offer both cover and barrier approaches for soil conservation (Young, 1997). Weed control is another operation that takes most of farmer's time and cost. All the respondents stated that it is necessary to control weeds for about two times per annum. The control of weeds in such plantations can have significant impact on plant performance which in turn can reflect on the productivity. The results agree with Tomkins (1994, 1996) and Borger (1998, 1999) on control of weeds in plantations. The authors observed that control of weeds eliminate mortality of trees, competition for water, nutrients and light.

5.2.2 Tree management techniques

Tree management interventions necessary in *Voacanga* plantation depends on the main production objective for instance (seed production). Many techniques are used to manage multipurpose trees. Where seed production is the main objective, tree management practice is probably justified. The results showed that 81.7% of the farmers carry out routine pruning while 18.3% did not prune the trees. There is significant relationship between communities and tree management. Most of the farmers in the communities prune the trees as a management practice. The prime reasons for pruning are to enhance flowering and fruiting, improve access to the tree stands during harvesting as well as removal of dead and unproductive parts. According to farmers pruning is done yearly after harvesting if judged necessary. Many studies have shown that, pruning is positively linked to good plant health in different plantations (Ford-Robertson, 1971). The 18.3% farmers who did not prune the trees can be attributed to immature nature of their farms as well as lack of technical-know-how on tree management.

5.3 Seed yield

Yields reported by farmers were variable. Generally, the weight per bag of *Voacanga* seeds is 60 kg. The results indicated that majority (51.7%) of the respondents obtained low seed yield of 90 kg per hectare, 25% of the farmers had 240 kg per hectare while only 23.3% respondents also obtained high seed yield of 480 kg per hectare. Field observation revealed that, spacing influences yield. The low seed yield can be attributed among others possibly to plant density per hectare since wider spacing is characterised by low plant density. It may also be that seed yields are compensated for by yields from other intercrops which are integrated in the fields as well as inadequate management practices such as pruning and control of weeds to enhance good seed yield. It is therefore recommended that regular weed control and pruning should be done to ensure good productivity.

5.4 Socio-economic importance of *Voacanga* in Assin South District

Many parts of *Voacanga* are exploited for different purposes. Results suggest that socio-economic considerations such as income from the sale of seeds are the reasons for *Voacanga* cultivation especially in communities with high poverty levels. The sale of seeds or pods is the most cherished outcome by the farmers. The indications are that cost of production on a hectare basis is GH¢ 30.00 (Gyesi, personal communication, 2010). One hectare is estimated to yield about 4 – 8 bags (1bag is equivalent to 60 kg) while 1 kg of seeds is reported to cost US$ 4.50. The farmers stated that income from the sale of seeds constitutes major source of income. Income earned has been very crucial in supporting their children school fees, medical bills, clothing and other household expenditure. The literature on this subject has highlighted the fact that *Voacanga* cultivation can go a long way to provide livelihood for the farmers because of the enormous economic benefits associated with the plant. This agrees with the assessment by Singh and Balooni (1995) that agroforestry undertakings on individual private holdings can be beneficial when economic benefits are given long term consideration. This also confirms that improvements in livelihoods and other benefits from *Voacanga* cultivation remains the main purpose for it cultivation (Regmi, 2003). Studies in other parts of Ghana according to Wood and Yapi (2004) as well as Adaba (2005) confirmed this view, where a tree-based crop agroforestry related undertakings in Brong Ahafo Region and the Kassena Nankana district of the Upper East Region have improved the socio-economic conditions of the local people, while benefiting the rural households in terms of income generation.

5.5 The challenges facing *Voacanga* farmers in the Assin South District

Voacanga farming like any other type of farming is confronted with several challenges. The study found that, the main challenges facing farmers in the study area include poor marketing (26.7%), farm theft or stealing of pods from tree stands in the farm (25%), lack of technical information or poor extension services (20%), lack of access to credit (16%), farm theft and access to credit (13.3%), inadequate labour and poor marketing (10%), land acquisition challenges (8.3%) as well as inadequate labour (3.3%). The prevalent among them are discussed as follows:

Land acquisition challenges

There are two main ways of acquiring land for farming in the study area. These are by inheritance and by lease. Ownership by inheritance is through succession where land is passed on from generation to another without conditions while lease is legal contract which allows someone exclusive possession of another's land for specific time in return for payment. It is worth mentioning that greater proportion of farmers owned the land themselves (72%). Land acquisition by leasehold is sometimes characterised by conditions such as sharing of produce between the farmers and the landlord as well as initial token. The results are consistent with Kotchi (1989) and Brafo – Insaidoo *et al.*, (2008) *in* Ghana who observed that acquisition of land is a problem for ecofarming practices for tropical smallholdings since this has encouraged the small scale farmers to simply exploit land resources and not to invest in long term improvement of its quality. The system does not allow land use as collateral for bank loan. Similarly, Nankani (2009) observed further that complex and uncertain land tenurial relations seem to hamper private investments in Ghana's agriculture as recent work by Goldstein and Udry (2008) and earlier by Besley (1995), has suggested. Goldstein and Udry (2008) found, for example, that investment and hence productivity in agriculture in Akwapim was held back by farmers who lacked political power and were uncertain about their property's security during fallow periods; and that such restraints, according to Nankani (2009) if true for the whole country, would be worth some 2% of GDP (Gross domestic product).

Tenure conditions though create a worry for farmers in general, what pertains in the study area is favourable because most of the *Voacanga* farmers owned the land themselves and this gives a good indication for *Voacanga* farming in the district.

Poor extension services

The extension services department of Ministry of Food and Agriculture provides agronomic information to farmers in general on crops like cocoa, oil palm, rubber, banana, cereals, root and tuber crops etc. On the other hand, there is little or virtually no information on *Voacanga* cultivation. This lack of access to technical information on the plant from agricultural extension services department poses a challenge to development of *Voacanga* farming. Farmers in the area are compelled to depend on information from other farmers as a means of learning appropriate practices. Extension information can have a significant impact on agricultural management practices and profitability. Molua (1996, 2003) in Cameroon reported that access to extension information and the rate at which extension service personnel visit farmers lead to an increase in farm productivity and farm profit.

Poor marketing

Marketing is generally a problem faced by farmers. The challenges related to or associated with marketing (26.6%) as identified by farmers included variation in prices or low prices sometimes for their produce. This may be attributed to seasonality and probably to non-existence of standard marketing board for farmers which allow the middlemen to dictate prices. The results are in line with ACORD (2010) studies in Isingiro District in Uganda where small scale banana farmers are confronted with marketing challenges such as low prices for their produce, high taxes especially for traders who transport bananas to Kampala, high costs of transport, variations in price depending on seasonality, poor road networks, poor quality products, internal competition among farmers and middlemen who take half of the profits and leave the farmer with very low prices.

Lack of access to credit

According to Shepherd (1997) and Awotodunbo (2008) in Nigeria; credit determines access to all of the resources on which farmers depend. Credit serves as a source of funds to farmers that can be utilised in production process. Only 8.3% of respondents in the study area access loans from financial institutions such as banks. The 88.3% and 3.3% respondents (farmers) depend on personal savings and family assistance respectively to skip bank bottlenecks and problems of collateral security. Farmers who access loans from banks can be attributed to their ability to develop good savings habit to provide surety. Both the 88.8% and 3.3% farmers can be ascribed probably to the fact that they do not have collateral to enable them to access loans from banks. This is consistent with Adewale and Ogunniyi (2000) who observed in Nigeria that few rural farmers have developed bank savings habit that most of the farmers, in addition, did not benefit from the bank credit facility for farming activities but rather depend on other sources apart from banks. In a similar manner, Ogundeji (1998) reported that agricultural business like any other business can be financed through personal savings, friends or family assistance, partnership, bank loans, private placements, credit terms, hire purchase and cooperative societies. The results support the claim of Adewale and Ogunniyi (2000) that rural banking scheme have not been very successful in granting credit to rural farmers. Lack of access to credit or finance among farmers is generally a problem that is recognised by the Government of Ghana. The results are in agreement with GOK (2008) and Ali- Olubandwa *et al.,* (2011) in Kenya who reported that lack of access to credit to finance inputs and capital investment is a main cause for low productivity in agriculture. While the Agricultural Finance Corporation (AFC), the Cooperative Bank of Kenya and the co-operative movement, have made considerable efforts to provide affordable credit to farmers, the high interest rates charged by these organisations make it impossible for most farmers to access credit (GOK, 2008).

One of the strategies of reducing this challenge facing farmers is that buyers usually pre-financed the business by issuing advanced money to some of the trusted customers. According to them, the pre-financing is meant to entice farmers and to ensure regular supply of the produce. It is also done to bail off customers from financial difficulties. However, pre-financing as a customer care strategy has turned out to be a disincentive. Some of the farmers who are pre-financed sometimes divert the produce to different buyers.

5.6 Challenges facing local buyers in the Assin South District

The main challenges facing local buyers of *Voacanga* in this area are transportation difficulty, inadequate labour and lack of direct link with marketing companies. These challenges slow down efforts to stimulate growth of the local market due to cumulative results of many constraints. The key informants made comments to these effects and have been discussed as:

Transportation difficulty

Majority of the buyers buy the produce (*Voacanga* seeds and pods) from farm gate usually located in remote areas with poor and inaccessible roads. The risks posed by transportation are related to poor road conditions which sometimes render some roads impassable, particularly during rainy season as well as unavailability of transport. The results are consistent with the studies by Nankani (2009) who found that rural infrastructure such as road has influence on growth and poverty reduction. The author highlighted that, the experiences of Indonesia, China, Vietnam and Bangladesh demonstrate the power of rural infrastructure such as roads to improve growth and reduce poverty. The impact on agricultural productivity and on the growth of the even non farm rural economy can be profound. For example, Vietnamese experience suggests that living in a rural community with roads increased the probability of escaping poverty by about 70% compared to being in a non-road community.

Inadequate labour

Voacanga pods like cocoa require cracking to extract the seed content for drying. This is labour intensive and in view of this more hands or labourers are needed to extract seeds manually since there is no known mechanical method of seed extraction at the moment. Insufficient labour to extract heaps of pods in the peak seasons is a source of worry for buyers who process seeds before disposal.

Lack of direct links with marketing companies

Voacanga is bought by large pharmaceutical companies in Europe such as Germany and France for preparation of medicaments. The companies have local agents who front for between them and local buyers. The local buyers do not have direct links to the companies. Unlike cocoa which has standardised marketing board, *Voacanga* cannot boast of any to streamline prices even though there is ready market. This allows the commodity to be traded by individuals which is characterised by irregularities. The result is consistent with ACORD (2010) studies in Uganda on banana farmers where unfair internal competition among middlemen has resulted in price variation and low profit for farmers.

5.7 Soil physical parameters

Land-uses significantly affected the sand, the clay and the silt fractions of the soils. The sand and silt percentages decreased with the depth whereas the clay percentage increased with it, which was a sign of clay translocation (Agoume and Birang, 2009). Clay accumulation in the sub-soil could result in reduced porosity, increased water retention and reduced drainage. Kauffmann *et al.*, (1998), Voundi-Nkana and Tonye (2002) found that continuous cropping and intensive land-use affected the particle size distribution and that these changes were related to cultivation time. On the contrary, Shepherd *et al.*, (2000) observed no effect of land-use systems on soil particle size distribution. The differences might be due to differences in soil type, crops cultivated and climatic conditions of the different environment. Land-use types can have a significant impact on soil texture which, in turn, impacts on the soil fertility status of a given area.

According to Davidson and Ackerman (1993) land management for agriculture often results in soil particles desegregation, thereby increasing soil bulk density. Bulk density increased following the conversion of forest (secondary forest) to cultivated fields. King and Campbell (1994) as well as Fisher (1995) observed in a tropical forest in Zimbabwe that bulk density increased from natural forest (primary and secondary forests) to cultivated fields. The results showed that natural / secondary forest had lower bulk densities compared to *Voacanga* plots. The high bulk densities experienced by *Voacanga* plots especially the 5-year-old can be related to loss of organic matter and compaction while the lower bulk density for natural / secondary forest may be attributed to its higher soil organic matter. The results agree with Yao *et al.*, (2010) who reported an average low bulk density of 0.61gcm^{-3} in secondary forest than the cultivated areas (0.90 gcm^{-3}) in Mid-West Côte d'lvoire. Brown and Lugo (1990), Davidson and Ackerman (1993), Rosell and Galantini (1997), Batjes and Dijkshoon (1999) as well as Feller *et al.*, (2001) reported higher bulk densities from primary forests (1.2–1.4 gcm^{-3}) to cultivated areas (1.5 gcm^{-3}). The authors examined many soil profiles around the world before reaching this conclusion. Birch and Friend (1956), Foster (1981) as well as Bird *et al*., (2000) made similar remarks on soils from South and East Africa.

5.8 Soil chemical parameters

5.8.1 Soil pH

The effect of soil pH is profound on the solubility of minerals and nutrients. Assessment by Ololade *et al.*, (2010) on cocoa production in Ondo State in Nigeria revealed that, most minerals and nutrients are more available in acid than alkaline soils.

The various land-uses showed significant decrease in pH with secondary forest having lower pH compared to *Voacanga* plots. The soil pH can be considered as acidic to neutral. Juo and Manu (1996) found that growing vegetation tended to decrease pH with low nutrient stocks. This phenomenon may be related to cations uptake by plants with subsequent release of H^+ ions, organic matter decomposition into organic acids, increased carbon levels through root respiration and nitrification. The results agree with Ololade *et al*., (2010) in Ondo state in Nigeria who reported differences in soil pH with depth in cocoa plantations as a result of variability in the years of establishments.

5.8.2 Soil Organic Carbon and Nitrogen concentrations

The amount of organic carbon in soils represents a balance between primary productivity, as influenced by environmental conditions (Parton *et al*., 1987; Yonker *et al*., 1988; Bulluck *et al*., 2002) and biologically-mediated decomposition processes (Sanginga *et al*., 1992; Schroth *et al*., 2002). SOC and N concentrations were greater in the top soil depths than deeper in the profile across all the land-uses. SOC concentrations in the 0 – 10 cm soil depth were high in the secondary forest followed by *Voacanga* fields. This may be probably due to plant cover and the return of litter to enhance organic carbon input (Brady and Weil, 2002).

Similar to SOC, total nitrogen content also decreased with depth. In all the land-uses with the exception of 15-year-old plots, soil leaching might have occurred. This may be one of the reasons for the reduction in total nitrogen concentration. Another possible reason is that removal of the vegetation cover and disturbance of soil surface by land-use affect soil temperature and soil moisture, thereby accelerating biological decomposition of soil organic matter, increased nitrogen mineralisation, possible volatilisation and leaching. This is consistent with reports of Islam and Weil (2000) in Bangladesh as well as Lemenih (2004) who stated that conversion of forest vegetation to different land-uses could cause total nitrogen to decrease. Mojiri *et al*., (2011) reporting on studies conducted in Lordegan, Western Iran emphasised that the reduction in total nitrogen may have resulted from a combination of lower carbon inputs (because of less biomass carbon return) and greater carbon losses.

5.8.3 Basic cation concentrations

Generally, the concentrations of exchangeable Ca^{2+}, Mg^{2+} and K^{+} (0 – 50 cm depth) levels increased along the chronosequence most probably because of nutrient pumping effect of deep rooting *Voacanga* trees.

Effective cation exchange capacity (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) is one of the basic indices of soil fertility. High fertile soils are characterised by high ECEC. The ECEC parameters ranged from 3.25 cmol (+) kg^{-1} at 30 – 50 cm soil depth to 8.87 cmol (+) kg^{-1} at 0 –10 cm soil depth in the secondary forest. According to Quansah (Personal communication, 2011), ECEC of the study soils can be rated as low (low < 10, moderate 10 – 20, high > 20). Significantly, the values for ECEC in *Voacanga* plots increased with years of establishments compared to secondary forest. The low ECECs across all the land-uses can be that the adsorption capacity of these soils is humus-dependent. Menzies and Gillman (1997) and Voundi-Nkana *et al.*,(1997) reporting on studies conducted in humid forest zone in Cameroon emphasised that low and variable character of the ECEC occurred as a result of dominance of low–activity clay components such as kaolinite, Fe and Al (hydro) oxides in those soils. They highlighted that this might have resulted from the higher degree of weathering of rock constituent minerals. In such soils, a large part of the plant nutrients and about 90 percent of the capacity of the soil nutrient retention depends on soil organic matter (Vitosh, 1998). Buol *et al.*, (1975) noted that soils with ECEC of 4 me/100 g or less had limited ability to retain nutrient cations. The ECEC level in the 15-year-old *Voacanga* can be related to soil organic matter or organic carbon (Aghasi *et al*., 2010). It can therefore be stated that, the build-up of soil organic matter by different ages of *Voacanga* from 10-year-old plots to 15-year-old plots is the contributory factor for enhanced ECEC. However, Lemenih (2004) investigated the effects of land-use on soil quality in Ethiopia and reported that land-use can cause decreased in ECEC.

5.8.4 Total soil organic carbon stock and total nitrogen stock

Investigation by Tate (1987) indicated that land-use and soil management have a marked effect on the soil organic carbon stock as a result of interaction between organic matter input and mineralisation mediated by soil micro-organisms and other factors. The results indicate a trend of significantly increasing total soil carbon stocks from the 10 to 15-year-old *Voacanga* plots though mean concentrations remained relatively stable. Though one would have expected an increase in stocks from 5 to 10-year-old plots, the reverse was the case. The probable reason may be due to wider spacing and low plant density or population. This might have resulted in low litter to augment carbon inputs. However, between 10 and 15 years carbon accumulated at the rate of 1.40 mg $ha^{-1}yr^{-1}$. Assuming this trend continues and if all plantations are to adopt closer spacing (4.2 m x 4.2 m), it would not be surprising for carbon to accumulate to near pre-conversion levels.

Though stocks under secondary forest showed low carbon gain than *Voacanga* fields with less or greater age, other studies conducted indicated that soil carbon storage (excluding roots) increases significantly with secondary forest age, and can approach matured forest levels after 80 years of regrowth (Silver *et al*., 2000).

Among the *Voacanga* plots, the highest total organic carbon stock occurred on 15-year-old site followed by 5-year-old site. In the 15-year-old, the high organic matter build up as a result of greater litter production from the plants can account for this. On the 5-year-old site, the decaying roots from the felled and burnt vegetation may have contributed to soil organic matter following conversion to agriculture. Kotto-Same *et al.*, (1997) reported similar results on carbon dynamics studies in slash-and-burn agriculture and land-use alternatives in humid forest zone of Cameroon. The dynamics of soil carbon following conversion to tree plantations like *Voacanga* could be due to a number of direct and indirect factors. For example, when forest is converted into tree plantations, soil organic carbon transformations are modified due to changes in substrate quality (Feigl *et al*., 1995), microbial community size is altered (Cleveland *et al.*, 2003) and soil porosity and water retention could change (Martinez and Zinck, 2004). The long-term effect of forest clearing on the amount of carbon stored in *Voacanga* plots and the direction of change may also be related to climatic condition and soil type, initial amount of soil carbon and the age of the *Voacanga* (Powers and Veldkamp, 2005).

Total nitrogen stocks unlike total soil organic carbon stocks showed a trend with high nitrogen stocks occurring in 15, 5 and 10-year-old plots respectively. Similarly, Singh *et al*., (2010) investigated carbon sequestration under the chronosequences of agroforestry and agricultural land-uses (12, 20, 30, 40 and 50 years) in Southern Ethiopia in Andic Paleudalf and reported that, the stocks of SOC and TN consistently increased with increasing chronosequence (from 12 to 50 years) of both land-uses, suggesting that with time a new equilibrium in SOC sequestration was attained. Similar to SOC stock, Singh *et al*., (2010) further highlighted that, the average value of TN stocks under chronosequences of agroforestry were slightly higher than those under agricultural lands.

5.8.5 Total basic nutrients stocks

The results indicated significant gains in total basic nutrients stocks across all the chronosequences of 5-year-old, 10-year-old and 15-year-old sites. The results showed increasing trend in total basic nutrients accumulation with duration after forest conversion. The available phosphorus stocks in the 0 – 50 cm soil depth averaged 28.13, 48.19, 88.42 and 21.24 kg ha^{-1} for 5, 10 and 15-year-old *Voacanga* plots as well as the secondary forest respectively. The 0 – 10 cm and 10 – 30 cm soil depths retained more phosphorus than lower depth across the land-uses. The available phosphorus storage distribution showed significant differences among land-uses. The general trend was for phosphorus stock to increase with increasing chronosequence age from 5 to 15 years. This is quite contrary to what was expected as phosphorus is likely to be exported through harvest. Phosphorus is also known to be fixed as organo-mineral complexes therefore unavailable. Increasing phosphorus stocks (and concentrations) could be due to retranslocation from below to above-ground pools. According to Hedley *et al*., (1982), organic phosphorus circulates rapidly between plant and soil through litter and its release through decomposition can be an important regulator of productivity. More phosphorus retained in the surface layers can be attributed to the release of organic bound phosphorus after burning and the subsequent release from decomposing litter. Phosphorus stocks for 0 – 50 cm soil depth for *Voacanga* plots was high. This can be attributed to good vegetation cover provided by the plants and it return to increase soil organic matter which might have probably resulted in high phosphorus stocks. Low soil temperature under the canopy also decreased soil organic phosphorus mineralisation and the potential loss of phosphorus as leaching (Shih *et al*., 1982). Wright (2008), reporting on studies in Florida emphasised that land-uses which have good canopy including forest systems, sugar cane cropping and turf grass promoted higher phosphorus stocks and lower oxidation rate.

The total potassium stock was high under *Voacanga* land-use. The results indicated that total potassium accumulated in the study soils is high. The highest storage of potassium stock in *Voacanga* land-use may be due to the ability of the plants to absorb potassium from subsoil layers and making it available to surface soil layers as well as the ability of the plant to form cover and barrier which in turns slow down the intensity of raindrops and thus reducing soil leaching (Aghasi *et al*., 2010).

5.8.6 Land-use change on soil degradation along the chronosequence

Soil degradation is the decline in soil quality caused by its improper use, usually for agriculture. It encompasses physical, chemical and biological deterioration. According to Charman and Murphy (2007) examples of soil degradation are losses of organic matter, decline in soil fertility, decline in structural condition and erosion. Generally, the response of degradation of soil properties following conversion of forest and subsequent cultivation were negligible than expected. The magnitudes and direction of change of overall indices of degradation (0 – 50 cm) along the chronosequence indicated that forest conversion to *Voacanga* cultivation did not lead to soil degradation. Rather total soil quality was observed to have improved. This is quite contrary to what was expected as land quality is expected to have declined at age 5 prior to canopy closure. The analysis of total soil quality which included parameters such as organic carbon, total nitrogen, available phosphorus, exchangeable Ca, Mg, K and ECEC at each stage of the chronosequence showed that the overall soil quality improved systematically from 5 to 15 years after forest conversion. This may be due to increase in organic matter content of the soils and the improvement in the nutrients-recycling mechanism due to the presence of deep-rooted trees (Pritchett and Fisher, 1987; Nye and Greenland, 1964), improved soil quality and reduced leaching.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the results obtained the following conclusions can be drawn.

I. The ages of respondents ranged between 25 – above 60 years with most of them between 47 – 60 years.

II. There were no standardised planting distances adopted by farmers. Adopted planting distances depended on farmers experience and recommendation from other farmers perceived as successful in *Voacanga* farming. The spacing has effects on total plant population per hectare, shade regime, litter fall and nutrient return which in turn influences weeds growth and their suppression.

III. Pruning is a major tree management practice in *Voacanga* plantations.

IV. Expected economic benefits in the form of income from the sale of seeds are the main motivating factor for farmers' decision to cultivate *Voacanga.* The integration of *Voacanga* in the general farming domain in the district would increase household income.

V. Slashing of undergrowth vegetation and its subsequent decay to augment nutrients input has been the main fertility management practices by farmers.

VI. The challenges facing *Voacanga* farmers are poor extension services, poor marketing, land acquisition challenges, inadequate labour and farm theft etc. On the other hand, challenges facing marketers' are transportation difficulty, inadequate labour, lack of direct links with marketing companies and diversion of farm produce.

VII. *Voacanga* cultivation leads to significant changes in soil physico-chemical properties. Conversion of secondary forest to *Voacanga* has significant positive impacts on the soil pH, particle size, bulk density, soil OC, exchangeable cations, carbon and nutrient stocks. The large proportion of SOC and TN concentrations were concentrated in the 0-10 cm soil depth. The concentrations in this soil depth in the study land-uses were significant. Chemical properties especially organic carbon is one of the important indicators of soil fertility.

VIII. In all the *Voacanga* land-uses, the gain in SOC stock was higher than the corresponding secondary forest. It ranged from 37.4 mg ha^{-1} in secondary forest to 48.3 mg ha^{-1} in 15-year-old *Voacanga* plot.

IX. The stocks of SOC increased with increasing duration after conversion of the forest to *Voacanga*. The reason for this high total SOC stock under these land-uses can be ascribed to the build up of organic matter through litter production from the stands while the decaying roots from felled trees and burnt vegetation is another factor for initial rise in total SOC stock for 5-year-old *Voacanga* plot. The high total SOC stocks suggest that, the cultivation of *Voacanga* with proven multipurpose functions has a potential for sequestering SOC.

X. Overall, soil quality did not decline with *Voacanga* cultivation.

6.2 Recommendations

Based on the findings of the study, the following recommendations should be taken into consideration;

1. There is the need to conduct long term research into agronomic practices (since no information exists) to generate data or information on the practices such as spacing and management for use in extension.
2. There is the need to conduct research into economic analysis of yield on per hectare basis to generate data or information on yield.
3. There is the need to sensitise farmers on how to make market survey to determine when, where and at what price to dispose the produce.

6.3 Recommendations for future studies

1. I recommend that in future studies carbon stable isotopes technique can be included as a tracer of soil organic carbon (SOC) turnover in *Voacanga* farming systems.
2. Research needs to be carried out to find out if there is the need for establishing a regulatory body owned by both the government and the farmers.

6.4 Limitations of the study

There are a number of limitations which need to be considered when interpreting the results of the study, though the results have provided useful data on *Voacanga* farming system and soil nutrient implications.

1. The design of the study combined farmers with small and large farm sizes. The likelihood is that, their perceived experiences may not be the same.
2. Since there were no standard planting distances, observed rates of carbon storage may not be a true reflection of the state as the different *Voacanga* population per hectare, under the different planting distances would impact on litterfall and shade regimes which ultimately affect carbon storage.
3. Apart from key informant method used, the research design should have encompassed fora or focus group discussion had it not been financial constraints.
4. The impacts of *Voacanga* on soil nutrient dynamics in this study covered only brief period of time not more than one year. The nutrient dynamics studied could be very different from the present values if repeated a year from now.
5. The design of the study should have covered more than a district so that greater generalisation can be made from the results.

REFERENCES

Acheampong, E. (2003). Sustainable Livelihoods of Forest Fringe Communities: Forests, Trees and Household Livelihood Strategies in Southern Ghana. PhD Thesis, University of Hull, UK.

Acheampong, E. and Marfo, E. (2011). The impact of tree tenure and access on chainsaw milling in Ghana. Ghana J. Forestry, vol. 27, 2011, 68-86**.**

Acquaye, D. (1997). Feasibility studies on economic and export potential of some selected medicinal plants in Ghana (*Griffonia*, *Voacanga* and *Annatto*).

Adewale, J. G. and Oguniyi, L. T. (2000).“Assessment of the Rural Banking Scheme in Ogbomo Zone of Oyo State”. Nigerian Agricultural Development Studies; Vol. 1, No. 1, Pp. 1 – 6, March.

Adaba, G. B. (2005). The role of agroforestry for sustainable forest use-case study of a community based initiative in the Kassena-Nankana District of Northern Ghana. Pp. 35.

Agency for Co-operation and Research in Development (ACORD), (2010). A Case study: Problems facing small scale farmers in Insingiro District, Uganda: Focus on bananas. Pp. 5.

Aghasi, B., Julalian, A. and Honarjoo, N. (2010). Decline in soil quality as a result of land use change in Ghareh Aghaj watershed of Semirom, Isfahan, Iran. African Journal of Agricultural Research Vol.6(4), Pp. 992-997, http://www.academicjournals.org/AJAR.

Agoume, V. and Birang, A. M. (2009). Impact of land-use systems on some physical and chemical soil properties of an Oxisol in the Humid Forest Zone of Southern Cameroon. Pp. 16.

Ali-Olubandwa, A. M, Kathuri, N. J., Odero-Wanga, D. and Shivoga, W. A. (2011). Challenges Facing Small Scale Maize Farmers in Western Province of Kenya in the Agricultural Reform Era. *American Journal of Experimental Agriculture 1(4): 466-476, 2011*. Pp. 4722.

Assin South District profile. (2006). Ministry of Local Government and Rural Development of Ghana.

Asare, B. A. (1986). A study of indigenous tenures relating to trees and forest in some parts of Ghana. BSc. thesis (unpublished). KNUST, Kumasi.

Awutodunbo, A. A. (2008). Appraisal of finance constraints to small scale farming in Agricultural Economics and Rural Development – 1 (2): Pp. 35 – 37.

Awono, A., Ndoye, O., Schreckenberg, K., Tabuna, H., Isseri, F.and Temple, L. (2002). Production and marketing of Safou (*Dacrryodes edulis*) in Cameroon and Internationally: Market development issues. Forest, trees and Livelihoods 12,125– 147.

Ayuk, E. T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki – Manga, T. and Zenkeng, P. (1999a). Uses and economic potential of *Dacrryodes edulis* (*Bruerseraceae*) in the humid lowlands of Cameroon. *Economic Botany* 53,292 – 301.

Ayuk, E. T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki – Manga, T. and Zenkeng, P. (1999b). Uses and economic potential of *Garcinia kola* and *Rocinodendron heudelotii* in the humid lowlands of Cameroon. Journal *of Tropical Forest Science* 11, 746 – 761.

Ayuk, E. T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki – Manga, T. and Zenkeng, P. (1999c). Uses, management and economic potential of *Irvingia gabonensis* in the humid low lands of Cameroon. Forest, ecology and management. 113, 1 – 9.

Balasimha, D. (2006). 15th International Cocoa Research Conference. Oral presentation on the performance of cocoa in relation to spacing and pruning regimes. Central Plantation Crop Research Institute Regional Station, Vittal-574243, Kamataka, India. Pp. 34.

Batjes, N. H. and Dijkshoorn, J. A. (1999). Carbon, nitrogen stocks in the soil of Amazon Region. *Geoderma* 89, 273-286.

Besley, T. (1995)."Property Rights and Investment Incentives: Theory and Evidence from Ghana." *Journal of Political Economy*, 103, No. 5: 903-937.

Bisset, N. G. (1985). Phytochemistry and pharmacology of *Voacanga* species. In: Leeuwenberg, A. J. M. (Editor) Series of revisions of *Apocynaceae* 15. Agricultural University, Wageningen, Netherlands. Pp. 81 -113.

Bisset, N. G. (1985). Uses of *Voacanga* species. In: Leeuwengerg, A. J. M. (Editor). Series of revisions of *Apocynaceae* 15. Agricultural University papers 85-3. Wageningen, Netherlands. Pp. 115 -122.

Birch, H. F. and Friend, M. T. (1956). The organic matter and nitrogen status of East African soils. *J. Soil Sci.* 7, 156-167.

Bird, M. I., Veenendaal, E. M., Moyo, C., Lloyd, J. W. and Frost, P. G. W. (2000). Effect of fire and soil texture on soil carbon in a sub-humid savanna (Matopos, Zimbabwe). *Geoderma* 94, 71-90.

Birgegard, L. (1993). Natural Resources Tenure*: A review of issues and experiences with emphasis on Sub-Saharan Africa*, Rural Development Studies No. 31, International Rural Development Centre (IRDC), Uppsala, Pp. 59.

Bos, M. M., Steffan-Dewenter, I. and Tscharntke, T. (2007). The contribution of cocoa agroforests to the conservation of lower canopy ant and beetle diversity in Indonesia. Biodiversity and Conservation 16: 2429-2444.

Bos, M. (2009). Carbon sequestration in organic cocoa agroforestry; a case study. The contribution of organic agriculture to climate change mitigation, IFOAM. Pp. 13.

Borger, J. (1998). Notes from Weed management Field Day, December, 1998. Forestry Tasmania.

Borger, J. (1999). Notes from Agricultural Weeds Workshop, April, 1999. Forestry Tasmania.

Brady, N. C. and Weil, R. R. (2002). The Nature and Properties of Soils. 13th Edn., Prentice Hall, New Jersey, ISBN: 0130167630, Pp. 960.

Brafo-Insaidoo, W. Anim, S. K, and Obeng, C. K. (2008). Economy of Ghana: Centre for continuing education, University of Cape Coast, Ghana. Pp. 104.

Brown, S., Gillespie, A. J. R. and Lugo, A. E. (1991). Biomass of Tropical Forests of South and Southeast Asia. Can. J. For. Res. 21:111- 117.

Brown, S. and Lugo, A. E. (1990). Tropical secondary forests. *J. Tropical Eco*. 6, 1-32.

Bruce, J. (1986). Land tenure issues in project design and strategies for agricultural development in Sub-Saharan Africa. LTC Paper 128. Land Tenure Centre, Wisconsin.

Bulluck, L. R. III., Brosius M., Evanylo, G. K., Ristaino, J. B. (2002). Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties in organic and conventional farms. *Applied Soil Ecology* 19, 147-160.

Buol, S. W., Sanchez, P. A., Cate, R. B. Jr. and Granger, M. A. (1975). Soil fertility capability and classification. A technical soil classification system of soil fertility management. In: Bornemisza E. and Alvarado A. Soil Management in Tropical America (eds) (Pp. 126 – 145). North Carolina University, Raleigh, NC.

Burkill, H. M. (1985). The useful plants of West Tropical Africa. 2nd Edition, Volume 1, Families A-D. Royal Botanic Gardens, Kew, Richmond, United Kingdom. Pp. 960.

Chapman, H. D. (1965). Total Exchangeable Bases. Ch. 58. In CA Black (eds) Methods of Soil Analysis. Part 2. Soil Science Society of America, Madison, WI.

Charman, P. E. V. and Murphy, B. W. (2007). Soils–Their Properties and Management, 3rd edn, Oxford University. Press in association with Department of Natural Resources.

Cleveland, C. C., Townsend, A. R, Schmidt, S. K. and Constance, B. C. (2003). Soil microbial dynamics and biogeochemistry in tropical forests and pastures, Southwestern Costa Rica. Ecol Appl 13: 314–326.

Collins, J. W. (1960). The Pineapple, Botany, Cultivation and Utilization. Leonard Hill (Books) Limited and Inter science publishers INC. New York. Pp. 146-147.

Collins, S. L. and Adams, D. E. (1983). Succession in grasslands: Thirty-two years of change in a central Oklahoma tall grass prairie. Vegetation, 51, 181–190.

Cunningham, A. B. (1997). An African-wide overview of medicinal plant harvesting, conservation and health care. In: Bodeker, G and Vantomme, P. (Editors). Medicinal plant for forest conservation and health care. Non–Wood Forest Products 11, F.A.O, Rome, Italy. Pp.158.

Davidson, E. A. and Ackerman, I. L. (1993). Changes in soil carbon inventories following cultivation of previously untilled soils. *Biogeochemistry* 20,161-193.

deTaffin, G. (1998). The Tropical Agriculturists: Coconut. Macmillan Education Ltd, London, Basin stoke. Pp. 32 – 37.

Dwetwiller, R. P. and Hall, C. A. S. (1988). Tropical Forest and the Global Carbon Cycle. Volume 239, No. 4835, Pp. 42 -47.

Encarta Dictionary (2009). Microsoft students with Encarta Premium 2009 (DVD). Microsoft Corporation, 2008.

Evans, H. (1951). Investigations on the propagation of cacao. *Trop. Agriculture, Trin.* 28; 14: 7 – 23

Evans, H. (1953). Recent investigations on the propagation of cacao. Report on Cacao research. (1945 – 51), Pp. 182 – 210.

Feller, C., Albrecht, A., Blanchard, E., Cabidoche, Y. M., Chevalier, T., Hartmann, C., Eschenbrenner, V., LarreLarrouy, M. C. and Ndandou, J. F. (2001). Soil organic carbon sequestration in tropical areas. General considerations and analysis of some edaphic determinants for lesser Antilles soils. *Nutr. Cycl. Agroecosyst*. 61, 19-32.

Feigl, B. J., Melillo, J. and Cerri, C. C. (1995). Changes in the origin and quality of soil organic matter after pasture introduction in Rondonia (Brazil). Plant Soil 175: 21–29.

Fisher, R. F. (1995). Amelioration of degraded rain forest soils by plantations of native trees. *Soil Sci. Soc. Am. J*. 59, 544-549.

Fortmann, L. (1985). 'The Tree Tenure Factor in Agroforestry with Particular Reference to Africa, *Agroforestry Systems* **2**(4) 229-251.

Ford-Robertson, F. C. (1971). Terminology of forest science, technology practice and products, FAO / IUFRO Multilingual Forestry Terminology series, No. 1, (Washing D. C: Society of American Foresters).

Foster, H. L., (1981). The basic factors which determine inherent soil fertility in Uganda. *J. Soil Sci*. 32, 149-160.

Garrity, D., Okono, A., Grayson, M. and Parrott, S. (2006). World Agroforestry into the Future. Nairobi: World Agroforestry Centre. Pp. 23 – 28.

Gee, G. W. and Bauder, J. W. (1986). Particle size analysis. *In*: Klute A. Methods of soil analysis (eds). Part 1, 2nd edition. Agronomy Monograph No. 9. American Society of Agronomy, Madison, WI, Pp. 383 – 411.

Geddes, L., Lunt, I. D., Smallbone, L. and Morgan, J. W. (2011). Old field colonization by native trees and shrubs following land use change: could this be Victoria's largest example of landscape recovery? *Ecological Management and Restoration* 12 (1), 31-36.

Genstat 9.2 for Windows, (2011). Analytical Software. Lawes Agricultural Trust (Rothamsted Experimental Station). Ninth Edition. Registered to: Team TBE 2006-08-01.

Gockowski, J., Weise, S. F., Sonwa, D.J., Tchtat, M. and Ngobo, M. (2004). Conservation because it pays: shaded cocoa agroforests in West Africa. IITA-HFC Yaoundé, Cameroon, Pp. 29.

Gockowski, J. (2001). Smallholder cocoa systems in the Moist Tropics of West and Central Africa: A Pathway to Sustainable Development. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Gockowski, J., Baker, D., Tonyi, J., Weise, S. Ndoumbe, M., Tiki-Manga, T. and Foaguegue, A. (1998). Characterisation and diagnosis of farming systems in the ASB forest margins bench mark of Southern Cameroon. Mimieograph. Yaounde, IITA Humid Forest Eco regional Centre.

Gockowski, J., Baker, D. and Tonyi, J., (1997). Characterisation and diagnosis of agricultural systems in the Alternatives to Slash and Burn forest margins bench mark of Southern Cameroon. Report to ASB Programme, IITA, Ibadan, Nigeria.

Goldstein, M. and Udry, C. (2008).“The Profits of Power: Land Rights and Agricultural Investment in Ghana.” *Journal of Political Economy*.

Government of Kenya (GOK), (2008). Ministry of Agriculture Strategic Plan (2008-2012). Nairobi, Kenya Government Printers.

Hamel, O. and Eschbach, J. M. (2001). Potential impact of the clean development mechanism in the future of perennial crops. International Conference on the future of Perennial Tree Crops, 5 – 9 November 2001. Yamoussoukro, Côte d’Ivoire. CIRAD, Montpellier, France.

Hartemink, E, A. (1998). Soil physical and chemical properties as indicator of sustainable land management under sugar cane in Papua New Guinea. Geodema 85: 283- 306.

Hartmann, H. T., Kester, D. E., Davies, F. T. and Geneve, R. L. (1997). Plant propagation principles and practices. Prentice hall ENG. Cliffs, New Jersey 07632, Pp. 27 391.

Harrington, J. F. (1970). Seed conservation of plant gene resources. In *Genetic Resources in Plants-Their Exploration and Conservation*, ed. O. H. Frankel and E. Bennett, IBP Handbook No. 11, Pp. 501-21. Blackwell Scientific Publications, Oxford.

Hedberg, I., Hedberg, O., Madati,P. J., Mshigeni, K. E., Mshiu, E. N. and Samuelson, G. (1982). Inventory of plants used in traditional medicine in Tanzania. I. Plants of the families Acanthaceae – Cucurbitaceae. Journal of Ethnopharmacology 6 (1) : 29 – 60.

Hedley, M. J., Stewart, J. W. B. and Chanbon, B. S. (1982). Changes in inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. *Soil Science Society of America Journal* 46 : 970 – 76.

Heimann, M. and Reichstein, M. (2008). Terrestrial ecosystem carbon dynamics and climate feedbacks. Nature 451: 289–292.

Herdrian, R. (2001) *Voacanga* thou. In: van Valkenburg. Plant Resources of South-East-Asia No 12 (2): Medicinal and poisonous plants 2. Backhuys Publishers, Leiden, Netherlands. Pp. 582 - 585.

Houghton, R. A. (1995). Carbon Flux to the atmosphere from Land-use changes 1850- 2005.

Intergovernmental Panel on Climate Change (IPCC), (2001). Summary for Policy Makers. In Climate Change 2001: Mitigation. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press: Cambridge, United Kingdom and New York, NY, U.S.A.

Intergovernmental Panel on Climate Change (IPCC), 2000). Land use, Land-use change, and Forestry-Intergovernmental Panel on Climate Change Special Report (eds. Watson, R.T., Noble, I. R., Bolin, B., Ravindranath, N. H., Verardo, D. J., Dokken, D. J.) Cambridge University Press, Cambridge.

International Society of Arboriculture (ISA), (2011). Pruning Mature Trees. Champaign, IL 61826-3129, USA. Pp. 1- 2

Inkoom, D. K. B. (1999). Management of non-reserve forest in Ghana. A case study of Mpohor Wassa East District. SPRING Research Series No. 24. University of Dortmund, Dortmund. Pp. 251.

Islam, K. R. and Weil, R. R. (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric. Ecosyst. Environ. 79, 9 – 16 .

Jankowicz, A. D. (2000). Business Research Project. U. K., 3rd Edition published 2000 by Thompson Learning. Pp. 207 – 269.

Johnson, E. A. and Miyanishi, K. (2008).Testing the assumptions of chronosequence in succession. *Ecology Letters* 11(5), 419-431.

Johnson, E. A. and Miyanishi, K. (2007). Testing the assumptions of chronosequence in succession. *Ecology Letters* 11(5), 419-431.

Juo A. S. R. and Manu, A. (1996). Nutrient effects on modification of shifting cultivation in West Africa. *Agric. Ecosys. Env*. 58, 49-60.

Kauffmann, S., Sombrooek, W. and Mantel, S. (1998). Soils of rainforests: characterisation and major constraints of dominant forest soils in the humid tropics. In: schulte A. and Ruhiyat, D. Soils of Tropical Forest Ecosystems (eds): Characteristics, Ecology and Management, Springer Verlag, Berlin, Pp. 9– 20.

King, J. A. and Campbell, B. M., (1994). Soil organic matter relations in five lands cover types in the Miombo region (Zimbabwe). *Forest Ecol. Manag.* 67, 225-239.

Koetke, W. H. (1993). The final Empire: The collapse of civilization and the seed of the future. 1st Portland, OR: Arrow Point.

Kontoh, I. H. (2008). Propagation of *Voacanga africana* cuttings for the protection of water bodies in the Transitional zone of Ghana. MSc. Dissertation. Department of Agroforestry. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Pp. 12.

Kotchi, J. (1989). Ecofarming practices for tropical smallholdings. Pp.1.

Kotto–Same, J., Woomer, P. L., Moukam, A. and Zapfack, L. (1997). Carbon dynamics in slash-and-burn agriculture and land use alternatives of humid forest zone in Cameroon. Agriculture, ecosystems and environment 65(1997) 245 – 256.

Knops, J. M. H. and Tilman, D. (2000)."Dynamics of soil nitrogen and carbon accumulation for 61 years after agricultural abandonment".*Ecology* **81** (1): 88–98

Kwarteng, J. A. and Towler, M. J. (1994). West African agriculture. Published by Macmillan Education LTD. Pp. 11, 303, 147 – 156.

Lal, R. (1996). Deforestation and land-use effects on soil degradation and rehabilitation in Western Nigeria. I. Soil physical and hydrological properties. Land degradation and Development, 7, 19 – 45.

Latham, P. (2004). Useful plants of Bas – Congo province, Democratic Republic of Congo. DFID, London, United Kingdom.

Leakey, R. R. B., Tchoundjeu, Z., Schreckenberg, K., Schackleton, S. E. and Schackleton, C. M. (2005). Agroforestry Tree Products (AFTPs): Targeting poverty reduction and enhanced livelihoods. *International Journal of Agricultural Sustainability*, vol. 3, No 1. Pp. 7.

Leeuwenberg, A. J. M. (1985). *Voacanga* Thou. In: Leeuwengerg, A. J. M. (Editor). Series of revisions of Apocynaceae 15. Agricultural University. Wageningen, Netherlands. Pp. 5-80.

Lemenih, M. (2004). Effects of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia, Doctoral Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. Pp. 66.

Levetin, E. and McMahom, K. (1999). Plant and Society. 2nd Edition. Pp. 314 – 333.

Lodge, D. J., Hawksworth, D. L. and Ritchie, B. J. (1996). Microbial diversity and tropical forest functioning. In: Biodiversity and ecosystem process in tropical forests. G. H. Orians, R. Dirzo and J. H Cushman, eds, springer-verlag. New York. Pp. 69 -100.

Lovett, J. C., Ruffo, C. K. and Gereau, R. E. (2003). Field guide to the moist forest trees of Tanzania. Centre for Ecology, Law and Policy, Environment Development, University of York, York, United Kingdom.

Maroyi, A. (2006). *Voacanga africana* Stapf. In: Schmelzer, G. H. and Gurib–Fakim, A. (Editors). Prota 11(1): Medicinal plants/plantes medicinales 1. PROTA, Wageningen, Netherlands.

Martinez, L. J. and Zinck, J. A. (2004). Temporal variation of soil compaction and deterioration of soil quality in pasture areas of Colombian Amazonia. Soil Till Res 75: 3-17.

Matson, P. A. (1997). Nox emissions from soil and its consequences for the atmosphere and biosphere. Nutrient cycling in Agro ecosystem 48:1-6.

Maurice, M. I. (1993). Hand book of African medicinal plants. Pp. 257.

Mehlich, M. (1984). Mehlich 3 soil test extractant. A modification of Mehlich 2 extractant. Communication in Soil Science and Plant Analysis, 15, 1409-1416.

Menzies, N. W. and Gillman, G. P. (1997). Chemical characterization of soils of a tropical humid forest zone: a methodology. Soil Science Society of America Journal, 61, 1355-1363.

Meyers, E. C. (2007). Policies to reduce emissions from deforestation and degradation (REDD) in tropical forests: an examination of the issues facing the incorporation of REDD into market-based climate policies. Resources for the Future, Washington DC.

Mojiri, A., Aziz, H. A. and Ramaji, A. (2011). Potential decline in soil quality attributes as a result of land use change in hill slope in Lordegan, Western Iran. African Journal of Agricultural Research Vol.7 (4), Pp 577 – 582. Pp. 22 – 57.

Molua, E. L. (1996). An economic analysis of farm enterprise combination and among food crop farmers in Southwest province of Cameroon. MSc. Dissertation. Unpublished. Department of Agricultural Economics and Extension Services. University of Benin, Benin City, Nigeria. Pp. 499.

Molua, E. L. (2003). The economics of tropical agroforestry systems: the case of agroforestry farms in Cameroon. Pp. 206.

Motsara, M. R. and Roy, R. N. (2008). A guide to laboratory establishment for plant analysis. Food and Agricultural Organisation of the United Nations, Rome, 2008, Pp. 22-57.

Mshana, N. R., Abbiw, D. K., Addae-Mensah, I., Adjanohoun, E. and Ahyi, M. R. A. (2000). Traditional Medicine and Pharmacopoeia: Contribution to the Revision of Ethnobotanical and Floristic Studies in Ghana. Organization of African Unity/Scientific, Technical and Research Commission, Nairobi, Kenya, ISBN: 978-2453-66-2.

Nankani, G. (2009). The challenge of agriculture in Ghana: What is to be done? Pp. 8. Nelson, R. (1999). "Carbon Sequestration: A Better Alternative." www.puaf.umd.edu/faculty/papers/nelson/nelson.

Ndoye, O., Ruiz–Perez , M. and Ayebe, A. (1997). The market of non- timber forest products in the humid forest zone of Cameroon. *Rural Development Forestry Network*, Network Paper 22c. London: *Overseas Development Institute.*

Neuwinger, H. D. (2000). African Traditional Medicine: a dictionary of plant use and applications. Medpharm Scientific, Stuttgart, Germany. Pp. 589.

Noss, R. F. (2001). Beyond Kyoto: Forest Management in a Time of Rapid Climate Change. *Conservation Biology*. 15(3):578-590.

Nye, P. H. and Greenland, D. J. (1964). Changing in the soil after clearing a tropical forest. Plant and soil, 21, 101 – 112.

Ogundeji, A (1998). How to Run a Small Scale Business, Able Press Publication, Nigeria. Pp. 40.

Ololade, I. A., Ajayi, I. R., Gbadamosi, A. E., Mohammed, O. Z. and Sunday, A. G. (2010). A Study on the Effects of Soil Physico – Chemical Properties on Cocoa Production in Ondo State. Modern Applied Science. Volume 4, No. 5. Pp. 36 – 38. (www.ccsenet.org/mas, 2011).

Olsen, S. R., Cole, C.V., Watanable, F. S. and Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular 939. U. S. Government Printing Office, Washington DC.

Parton, W. J., Schimel, D. S., Cole, C. V., Ojima, D. S. (1987). Analysis of factors controlling soil organic matter in Great Plain grasslands. *Soil Sci. Soc. Am. J.* 51, 1173-1179.

Personal communication with Gyesi, K. (2010). In God We Trust, P.O. Box 15. Nyankomasi Ahenkro, Central Region, Ghana .

Personal communication with, Quansah. G. (2011). Soil Research Institute, Kwadaso, Kumasi, Ghana, West Africa.

Pickett, S. T. A. (1988). Space-for-time substitution as an alternative to long term studies. In: Long-term Studies in Ecology (ed. Likens, G. E.). Springer, New York, NY, Pp. 110–135.

Powers, J. S. and Veldkamp, E. (2005). Regional variation in soil carbon and δ13C in forests and pastures of northeastern Costa Rica. Biogeochemistry 72:315-336

Pritchett, W. L. and Fisher, R. F. (1987). Properties and management of forest soils, 2nd Edition. Wiley, New York. Pickett, S. T. A. (1988) Space-for-time substitution as an alternative to long term studies. In: Long-term Studies in Ecology (ed. Likens, G. E.). Springer, New York, NY, Pp.110–135.

Pushpakumara, D. K. N. G. (2001). Environmental benefits of perennial crop farming systems. International Conference on the Future of Perennial Tree Crops, 5 – 9 November, 2001. Yamoussoukro, Côte d'Ivoire. CIRAD, Montpellier, France.

Pyle, R. M. (2008). Butterflies and Moths."Microsoft students 2009 (DVD). Redmond, WA: Microsoft Corporation, 2008.

Rahji, M. A. Y. (2000). "An Analysis of Agricultural Credit Approval/Loan Size By Commercial banks in South Western Nigeria". In Nigeria Agricultural Development Studies. Vol 1, No 1 Pp.16-25.

Regmi, N. B. (2003). Contribution of agroforestry for rural livelihoods: A case of Dhading District, Nepal. Conference paper (final draft) presented at the International Conference on "Rural Livelihoods, Forest and Biodiversity" to beheld in Bonn, Germany, on May 19 – 23.

Rehm, S. and Espig, G., (1991). The cultivated plants of the Tropics and Subtropics. Eugen Ulmer GmbH and Co.1984, Wollgrasweg 41, D–7000 Stuttgart 70, West Germany. Pp. 261.

Rio Summit. (1992). Earth Summit Agenda 21. The United Nations Programme of Action from Rio. Published by the United Nations Department of Public Information. Pp. 75-284.

Rosell, R. A. and Galantini, J. A. (1997). Soil organic dynamics in native and cultivated ecosystems of South America. *In*: Lal R., Kimbal J. M., Follet R. F.,

Ruf, F. and Zadi, H. (1998). Cocoa: From deforestation to reforestation. Paper contributed to the First International Workshop on Sustainable Cocoa Growing, 29 th March–3rd April, 1998. Panama, Republic of Panama.

Sanginga, N., Mulongoy, K., Swift, M. J.,(1992). Contribution of soil microorganisms to the sustainability and productivity of cropping systems in tropics. *Agric. Ecosyt. Environ*. 41, 135- 152.

Schmelzer, G. H. and Gurib – Fakim, A. (2008). African medicinal plants. Pp. 623.

Schreckenberg, K., Degrande, A., Mbosso, C., BoliBaboule, Z., Boyd, C., Enyong, L., Kanmegne, J. and Ngong, C. (2002). The social and economic importance of *Dacryodes edulis* (G. Don) H. J. Lam in southern Cameroon, *Forest, Trees and Livelihoods 12*, *15 – 40.*

Schulze, E. D., Wirth, C. and Heimann, M. (2000). Climate Change: Managing Forests after Kyoto. 289: 2058-2059.

Schroth, G. A., Gustavo, B., DaFonseca, C. A., Harvey, C., Gascon, H. L., Vasconcelos and Izac, A-M. N. (2004). Agroforestry and Biodiversity Conservation in Tropical Landscapes, Island Press, Washington, D.C, U.S.A.

Schroth, G. A, Sammya A. D. A., Teixeira, W.G., Haag, D.,Lieberei, R. (2002). Conversion of secondary forest into agroforestry and monoculture plantation in Amazonia: Consequences for biomass litter and soil carbon stocks after 7 years. *Forest Ecology and Management*, 163, 131-150.

Shepherd, G., Bureh, R. J. and Gregory, P. J. (2000). Land use affects the distribution of soil inorganic nitrogen in smallholder production systems in Kenya. Biology and Fertility of Soils, 31,348 – 355.

Shepherd, W. G. (1997). Market Power and Economic Welfare, Random House, New York, Pp. 51.

Shih, S. F, Rahi, G. S, Ozaki, H. Y, Smajstrla, A. G. (1982). Effect of water table and crops on soil temperature. Soil Crop Sci Soc Fl Proc 41:47–54.

Silver, W. L., Ostertag, R., and Lugo, A. E. (2000). The potential for carbon sequestration through reforestation of abandoned tropical agricultural and pasture lands. Restoration Ecology 8:394–407.

Singh, B. R., Wele, A. D. and Lal, R. (2010). Soil carbon sequestration under chronosequences of agroforestry and agricultural lands in Southern Ethiopia. 2010. 19th World Congress of Soil Science, soil solutions for a changing world. 1- 6 August 2010, Brisbane, Australia. Pp. 65.

Singh , K. and Balooni, K. (1995). Tree 'Growers Cooperatives: Farmers Forestry in India. *Journal of Forestry* 95(10): 32 – 35.

Smiley, G. L. and Kroschel, J. (2008). Temporal change in carbon stocks of cocoa-gliricidia agroforests in Central Sulawesi, Indonesia Systems 73: 219-231.

Solomon, D., Fritsche, F., Lehmann. J, Tekalign, M. and Zech, W. (2002). Soil organic matter dynamics in the sub-humid agro ecosystems of the Ethiopian highlands: Evidence from natural 13C abundance and particle size-fractionation. Soil Sci. Soc Am J 66: 969-978.

Sutherland, J. M. and Spreat, J. I. (1993). Nitrogen fixation by legume trees. In: N.S. Subba RAO and C. Rodriguez–Barrueco (eds). Symbiosis in nitrogen-fixing trees. New Delhi: Oxford and BH Publishing Co, Pp. 33 – 54

Tan, P. V. and Nyasse, B. (2002). Anti- ulcer compound from *Voacanga africana* with possible histamine H_{12} receptor blocking activity, Phytomedicine 7(6):509– 515.

Tate, R. L. (1987). Soil Organic Matter: Biological and Ecological Effects. Wiley, New York.

Technical Centre for Agricultural and Rural Cooperation (CTA, 2008). Understanding and confronting climate change. Pp. 3.

Tomkins, B. (1994). Chemical weed control in Radiata Pine Plantations. Reports prepared for the Victorian Plantation Corporation. Pp. 70.

Tomkins, I. B. (1996). Pesticides Manual, 1996, prepared for the Victorian Plantations Corporation, Amcor Plantations Pty. Ltd. And Australian Newsprint Mills Ltd.

Tona, L., Kambu, K., Mesia, K., Cimanga, K., Apers, S., DeBruyne, T., Preters, L., Totte, J. and Vlietink, A. J. (1999). Biological screening of traditional preparations from some medicinal plants used as anti diarrhoeal in Kinshasa, Congo. Phytomedicine 6(1): 59-66.

Tremblay, M. A. (1982). The key informant technique: a non ethnographic application in Burgess R. (ed.) Field Research: a source book and field manual London: Allen and Unwin.

Veldkamp, E. (1994). Organic carbon turnover in three tropical soils under pasture after deforestation. Soil Sci. Soc Am J 58: 175-180

Vitosh, M. L. (1998). Impact of agricultural management practices on C sequestration in forest-derived soils of the eastern Corn Belt. Soil and Tillage Research.47:243– 252. doi: 10.1016/S0167-1987(98)00112-3.

von Carlowitz, P. G. (1989). The role and place of multipurpose trees and shrubs in agroforestry. Paper presented at the ICRAF/DSO. International agroforestry course. 8-26 May, 1989. Nairobi, Kenya.

Voundi- Nkana, J. C. and Tonye, J. (2002). Assessment of certain soil properties related to different land – use systems in the Kaya watersheds of the humid forest zone of Cameroon. Land degradation and Development. Published online in Wiley Inter science (www.Interscience. Wiley.com) DOI: 10. 1002/Idc. 519.

Voundi-Nkana, J. C., Demeyer, A., Baert, G., Verloo, M. G. and Van Ranst, E. (1997). Chemical fertility aspects influenced by the mineralogical composition of some acid tropical soils of the forest zone in Central Cameroon. AGROCHIMICA, 41, 209-220.

Walker, L. R,, Wardle, D. A, Bardgett, R. D. and Clarkson, B. D. (2010). The use of chronosequence in studies of ecological succession and soil development. *Journal of Ecology* 98(4), 725-736.

Willey, R. W. (1975). The use of shade in coffee, cocoa and tea. Horticultural Abstracts 45:791 -798.

Wood, P. and Yapi, A. M. (2004). Rehabilitation of degraded lands in Africa: Lessons learned from selected case studies. Forestry Research Network for Sub-Saharan Africa (FORNESSA) and International Union of Forest Research Oganisation Special Programme for Developing Countries (IUFRO-SPDC).

World Bank, (2002). Reinvesting in African smallholder Agriculture: The Role of Tree Crops in Sustainable Farming Systems. World Bank, Washington, DC, U.S.A.

Wright, A. L. (2008). Soil phosphorus stocks and distribution in chemical fractions for long–term sugarcane, pasture, turf grass and forest systems in Florida. Nutr Cycl Agroecosyst (2009) 83:223–231.

www. Assinsouth ghanadistrict.gov.gh.

Yao, M. K., Angui, P. K. T., Konaté, S., Tondoh, E. J., Tano, Y., Abbadie, L. and Benest, D. (2010). Effects of Land Use Types on Soil Organic Carbon and Nitrogen Dynamics in Mid-West Côte d'Ivoire. European Journal of Scientific Research, ISSN 1450-216X Vol.40 No.2 (2010), Pp. 211-222. Euro Journals Publishing, Inc. 2010.

Young, A. (1991). Soil monitoring: A basic task for soil survey organisation. Soil use and management 7: 126 – 129.

Young, A. (1997). Agroforestry for soil Management. 2nd Edition. Published in association with: International Centre for Research in Agroforestry, Nairobi; Kenya. Pp. 20-35.

Yonker, C. M., Schimel, D. S., Paroussis, E., Heil, R. D. (1988). Patterns of organic carbon accumulation in a semi-arid short grass steppe. *Soil Sci. Soc. Am. J.* 52, 478-483.

APPENDICES

APPENDIX 1

QUESTIONNAIRE ON *Voacanga africana* FARMING SYSTEM IN THE ASSIN SOUTH DISTRICT: SOCIO - ECONOMIC AND NUTRIENT IMPLICATIONS

INSTRUCTIONS: Fill in as required and tick all responses given by the respondent.

Name of interviewer
[………………………………………………………………………………]

Date…………………………............. Community………………………

1. Name of farmer [..]

2. Sex; Male [ ], Female [ ]

3. Age

25 - 35years [ ]

36 - 46 years [ ]

47 - 57 years [ ]

Above 60 years [ ]

4. Level of education

Basic (J.H.S/M.S.L.C) [ ]

Second cycle (S. H.S) [ ]

Tertiary (University/Polytechnic/College of Education /Vocational Institutions etc [ ]

None [ ]

5. Are you a native or a settler?

Native [ ]

Settler [ ]

6. Ethnic origin

………………………………………………………………………………

………………………………………………………………………………

7. Do you own the land yourself?

Yes [ ] No [ ]

8. If NO how did you acquire land?

Lease [ ]

Purchase [ ]

9. Are you permitted to plant trees or tree crops on the land?

Yes [ ]

No [ ]

10. If YES what are the terms of sharing?

"*Abunu* '' system [ ]

"Abusan '' system [ ]

11. What is the size of your *Voacanga* farm?

Less than 1 hectare [ ]

From 2 to 4 hectare [ ]

From 5 to 7 hectare [ ]

From 8 to 11 hectare [ ]

12. What spacing did you adopt?

[…………………………………………………………………….]

[…………………………………………………………………….]

13. What is your source of spacing recommendation?

[……………………………………………………………………]

14. Do you intercrop at any stage of plantation development?

Yes [ ]

No [ ]

15. With the adopted spacing how long are you able to intercrop?

[……………………………………………………………………………]

16. What are the crops?

Maize [ ]

Plantain [ ]

Cassava [ ]

Yam [ ]

Others, specify [ ]……………………………………………………………

17. How long have you been in the *Voacanga* farming?

1—5 years [ ]

6—10years [ ]

11—15 years [ ]

18. Which planting material do you use for *Voacanga* propagation?

Seeds/seedlings [ ]

Cuttings [ ]

19. Where do you obtain the planting material from?

Own nurseries [ ]

From the wild [ ]

Purchase from nurseries [ ]

20. Give reason(s) for your choice.

(a) [……………………………………………………………………………]

(b) [……………………………………………………………………………]

(c) [……………………………………………………………………………]

21. If you use seeds do you subject the seeds to any pre- treatment?

Yes [ ]

No [ ]

22. If YES, how is it done?

....

………………………………………………………………………………..

23. Why pre-treatment is done?

………………………………………………………………………………

………………………………………………………………………………

24. When do you nurse?

[……………………………………………………………………………]

25. How long do seedlings stay in the nursery?

[…………………………………………………………………….……..]

26. When are they transplanted?

[……………………………………………………………………………]

27. Which tree management technique do you employ on your farm?

Pruning [ ]

None [ ]

28. Give reasons for your choice of tree management technique.

(a) [……………………………………………………………………………]

(b) [……………………………………………………………………………]

29. How frequent do you carry out the tree management technique(s) selected above?

[…………………………………………………………]

30. Which period or time do you harvest the fruits?

Major season [………………………………………… ……..]

Minor season [………………………………………………….]

31. What has been your seed yield level?

Low [ ] {specify…………………………………………………}

Medium [ ] {specify…………………………………………………}

High [ ] {specify…………………………………………………}

32. Do you think this can be improved?

Yes [ ]

No [ ]

33. If YES through what means or how?

……………………………………………………………………………

……………………………………………………………………………

34. Apart from seed harvests for sale what other benefits do you derive from the *Voacanga* farming?

Medicine/Fuel wood/ Seeds [ ]

Fuel wood / Seeds [ ]

Income (sale of seeds) [ ]

Medicine / Seeds [ ]

35. Have you observed any pests and diseases which affect the plants?

Yes [ ]

No [ ]

36. If YES what is the nature of the pest/disease that you have observed?

………………………………………………………………………………………

………………………………………………………………………………………

37. If any in which part of the year do they occur?

Rainy season [ ]

Dry season [ ]

Or both [ ]

38. Which part of the plant does the pest/disease occur?

Root [ ]

Stem [ ]

39. Do you adopt or employ any control measures?

Yes [ ]

No [ ]

40. If YES what is it?

……………………………………………………………………………

41. What other livelihood activities do you engage in?

Food crop farming [ ]

Trading [ ]

Artisan (carpentry, masonry etc) [ ]

Teaching [ ]

Others, specify […………………………………….]

42. What challenges do you face in your *Voacanga* farming activities?

Inadequate labour [ ]

Land acquisition challenges [ ]

Lack of access to credit [ ]

Poor marketing [ ]

Storage [ ]

Lack of technical information/ access to extension [ ]

Farm theft and lack of access to credit [ ]

Inadequate labour and poor marketing [ ]

43. What is the source of farm labour?

Family [ ]

Hire workers [ ]

Machinery [ ]

44. How do you finance your farming activities?

Personal savings [ ]

Family support [ ]

Money lenders [ ]

Loans from financial institutions [ ]

45. Do you experience labour shortage?

Yes [ ]

No [ ]

46. If YES, what time of the farming season?

Planting period [ ]

Weeding period [ ]

Harvesting period [ ]

47. Do you receive any extension services from the District Agric. Extension Department?

Yes [ ]

No [ ]

48. If YES, how frequent?

1---10 times per farming season or year [ ]

11---20 times per farming season or year [ ]

49. What type of information?

[……………………………………………………………………]

[……………………………………………………………………]

[……………………………………………………………………]

50. What type of post-harvest handling do you subject the fruits harvested to?

……………………………………………………………………………

……………………………………………………………………………

51. Do you have ready market for the produce?

Yes [ ]

No [ ]

52. If YES which agency buys the produce?

Individuals [ ]

Middlemen [ ]

Companies [ ]

53. Are you able to meet the existing demand for *Voacanga*?

Yes [ ]
No [ ]

54. If NO do you intend/plan expanding your farm?

Yes [ ]

No [ ]

55. Do you receive good price from the sale of seeds/pods?

Yes [ ]

No [ ]

56. What is the price in kilograms (kg) locally in Ghana?

5-----10 kg = GH¢……………………………………………..……………]

11----20 kg = GH¢……………………………………………….………….]

21----30 kg = GH¢……………………………………………….………….]

31----40 kg = GH¢……………………………………………….………….]

41----50 kg = GH¢…………………………………………..……...………..]

Others, specify……………………………………….………….…………….]

APPENDIX 2

KEY INFORMANT INTERVIEW GUIDE
TARGET: FOR SOME SELECTED MIDDLEMEN WHO MARKET/BUY *Voacanga* IN THE ASSIN SOUTH DISTRICT

1. How long have you been in the marketing of *Voacanga*?
2. What is your source of financing?
3. Do you pre-financed farmers/your customers?
4. What parts of the plant do you buy?
5. How do you handle the raw pods when bought?
6. How do you treat the extracted seeds for sale?
7. How much do you buy *Voacanga* pods or seeds from farmers?
8. Are you able to buy more?
9. How many bags of *Voacang*a can you buy in a season?
10. How much do you also sell the processed seeds of *Voacanga* to companies?
11. What challenges do you encounter?
12. What strategies or suggestions would you recommend to address the challenges?