The Future Cocoa Farmer: Soil Quality in Existing Traditional, Organic and Hi-Tech Conventional Cocoa Production in Ashanti Region of Ghana

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PREFACE

This thesis report was written in partial fulfilment of the requirements for the degree of Master of Science in Organic Agriculture of Agro-ecology specialization. The goal of this study is to do an in-depth physical soil analysis of three different types of cocoa farming systems namely; "Traditional, Organic and Hi-tech conventional cocoa farms using a procedure called "Visual Soil Assessment" (VSA). This entails investigating the relationship between VSA scores within the different farms, and also finding out the relationship between VSA and yield in the three farms. Find out the correlation between chemical analysis and VSA analysis. Likewise identify the incentives and challenges farmers face in soil fertility management. The study was carried out as part of the long term project of ProEco Africa (2013-2016) on producing comparative scientific evidence on productivity, profitability and sustainability of organic and conventional farming system in Atwima Mponua district of Ghana. The research is also to further contribute to Agro Eco- Louis Bolk institute concept of future cocoa farmers in Ghana.

My learning goals for this thesis were to gain practical and field experience on cocoa production, understand soil quality management of cocoa production. And also acquire in-depth knowledge about the VSA procedure. This thesis has indeed made me improve more on my personal skills, such as my interviewing skills, critical reasoning skill, research skills and most importantly have learnt how to be more independent. Not only did I achieve my learning goals, I have been able to acquire skills and the right motivation necessary to achieve my career goal to be "an organic/sustainable cocoa producer".

My utmost appreciation goes to my main supervisor Ir. Kees, Van Veluw for his contribution during my research work and his inputs towards the success of this research. I am very grateful to my second supervisor Ing. Boudewijn van Elzakker of Agro Eco- Louis Bolk Institute, for the wonderful opportunity given to achieve my aim of doing my thesis around cocoa, without him this research would not have been possible. To him I say a very big thank you. I will also like to express my gratitude to Professor Budu of University of Ghana, Legon for allowing me to be part of the ProcEco Africa project.

My sincere appreciation goes to the entire staffs of Agro Eco- Louis Bolk Institute, Kumasi chapter, for their inputs during my field work and for the kind gestures during my stay at the institute's guest house. And most especially Mr. Israel Kuadzi for his wonderful support during and after the field work.

I will not forget the farmers that made their farms available for the VSA procedures to be done on their farms and spending their precious time with me for the discussion. And my warm thank you goes to the documentation officer Mr. Enoch and my translator Christabel they both made the field work less stressful.

I wish to acknowledge my parents, siblings and friends back home for their encouragement and prayers and during my study time away from home.

I will forever remain grateful to the Netherlands government for providing this wonderful opportunity through Netherlands Fellowship Programme (NFP) to study my masters in Wageningen, The Netherlands.

Furthermore, I will like to thank the entire Nigerian students in Wageningen University; they have indeed made me feel at home away from home and most importantly Dr. Nuruden Alimi and Oluwatosin for their moral supports. And to my Ghanaian brothers, Edem and Fusta you guys are the best. I will not forget my dear friend Alabi Olusola, a brother from another mother, to him I say I big thank you for been there for me.

Above all, I will like to give thanks to Almighty God for His grace, mercy and strength for me to carry on through my programme.

SUMMARY

Ghana was once the highest producers of cocoa in the world in the early 1970s and it contributed immensely to the country's Gross Domestic Product (GDP). Due to problems like pest and disease, soil deterioration, nutrient deficiency and all other factors, many farmers have abandoned cocoa production. As a result of not low profit from the crop, this makes the country to drop to the second producer of cocoa. Cocoa production in Ghana is still largely cultivated by smallholder farmers and mostly based on traditional methods of farming. Majority of the plots are between 2-3ha and the yields are constantly low. The attitude of farmers towards their farms in term of soil management and general farm practices are regarded as crucial problems of Ghanaian cocoa farmers. However, a simple and complementary technique needs to be established, to serve as early warning on soil degradation. This will provide awareness and direct contact as a practical approach to encourage farmers on better soil fertility management among cocoa farmers.

The objectives of the research is to investigate the relationship between Visual Soil Assessment (VSA) scores within the different farms typologies, find out the relationship between VSA and yield in three types of farms. Then check for the correlation between chemical analysis and VSA analysis. Equally identify the incentives and challenges farmers face in soil fertility management, find out what they do and the reason why they do them. And also to contribute to Agro Eco- Louis Bolk institute concept of future cocoa farmers and serve as a test run for the ProcEco Project on the aspect of soil fertility.

The research was carried out in four communities of the Atwima Mponua district in the Ashanti region of Ghana, namely; " Tano Odumasi"," Gyereso", "Pasuro" and "Anansu" community. The typology of farms used in this research includes Traditional, Organic and Hi-tech conventional cocoa farms. Three separate farms were selected at every farm typology, except for one of the community where one degenerated farm was selected summing up to four farms for that community, making a total of 37 farms. Besides that, productive and none productive tree were selected on each farm, making a total of 72 VSAs, plus the abandoned cocoa farms, summing up to 73 VSAs. Accessibility and size of farm were the criteria considered when selecting these farms.

Graham Shepherd in 2008 introduced the Visual Soil Assessment (VSA) procedure that was used in this research. The VSA procedure gives a simple, quick and accurate method to evaluate soil quality. The most essential component of the VSA procedure is the "drop shatter test". The drop shatter test involves dropping the block from a height of approximately 1 metre. The procedure inspects 10 soil parameters for soil quality. It offers a flexible scoring for each of the parameter (0-2) and the score is subjected to the soil quality observed. Alongside the VSA procedure, the farmers were engaged in a discussion to determine their motivation towards soil fertility management. This was carried with the aid of a checklist questions and with the help of the translator. Furthermore, purposeful soil and leaf sample were gathered in all the farms for analysis from the productive and none productive tree at each of the selected farms.

After the field work and chemical analysis of the purposeful soil and leaf analysis the VSA scores were subjected to statistical analysis. Analysis of variance (ANOVA) was used to determine significant differences between farms and communities. The statistical analysis was done not to present that VSA is potential procedure to predict soil chemical properties, but to show that it is a useful tool for soil quality, and that it could aid as initial warning for cocoa farmers.

The VSA scores were investigated separately and were later combined. For the productive tree of the selected farms, it was discovered that the Traditional Productive tree (TPT), Organic productive tree (OPT) and Hi-tech conventional productive tree (HTCPT) have comparable VSA score in all the four communities. However, the test shows there were significant differences between OPT and THPT with a P value of 0.04. Whereas, under none- productive tree, that there were significant differences between farm types ($F=4.49$, $P=0.02$). And the significant different was between ONPT and TNPT with the same P value of 0.04. Also, the mean VSA scores shows that there were no significant differences between farm types ($F=5.21$, $P=0.13$) but the differences between communities are discovered to be significant ($F=7.01$, $p=0.02$). So, the VSA score was further compared within communities and the mean VSA score between Tano Odumasi and Anansu was found to be 5.28 and this was significantly different with P-value 0.01.
It was further discovered that the soil of Pasoro community was too sandy and not the ideal soil for cocoa production.

It was found out that there is a weak correlation between VSA indicators and yield. And it was made known that VSA indicators are not likely to limit cocoa production and that other farm practices will influence yield.

The correlation between chemical analysis and VSA analysis could not be answered in this research, due to financial constraint, but the few results of the chemical soil and leaf analysis of the selected farms were compared with recommended standards. The available Phosphorus present in all the soil samples ranges from 0.51- 5.82 mg/kg, while the Potassium in the soil varies between 29.23- 169.59. However, the Calcium content in the soil samples, it ranges from 1.89-10.41 cmol/kg. Likewise, the Magnesium content for the selected farms ranges from 0-53 - 4.67 cmol/kg.

It was also discovered that in Pasoro community, the Hi-tech conventional productive tree leaf sample has the highest percentage of Nitrogen in all the selected farms (2.47%). While the percentage Potassium for all productive tree leaf samples were higher than none productive tree leaf sample for all farm types in all the communities with an exception in Tano Odumasi, where the traditional none-productive tree has higher percentage of Potassium than the traditional productive tree. Correspondingly, the highest percentage of calcium content was present in both Hi- tech conventional productive (0.96%) and none-productive tree leaf samples (0.94%) of Pasoro community. The percentage Magnesium content varies between 0.22% - 0.41%. While the percentage Phosphorus content for all the cocoa leaves observed to be between range of 0.11 and 0.15%. It could be observed that there are wide ranges between the chemical results; these could be as a result of selecting the soil and leaf samples from different farm type and at different communities.

However, the VSA procedure substantiates the fact that it can be used as a tool to recognize areas where compaction and drainage might affect growth of tree. The result from all the VSA scores for the selected farms shows that most of the farms examined have slightly moderate VSA scores. While other farms shows to have poor and very poor VSA scores, whereas few farms have good VSA score. It was observed that most of selected farmers have lazy attitude towards their farms and they hardly replenishes the soil with any form of fertilizer to restore lost nutrients.

Farmers complained about lack of loans to buy input, but it was perceived that even if they have these loans they spend them on other personal needs. Money is the major motivation for farmers when it comes to soil management applications, and one can conclude that more is taken away from the soil than what is actually placed by farmers of the selected communities. Farmers hardly do as they were told by extension officers and they do, it only for short period of time. Farmers do not undertake soil fertility management practices, such as composting and applying of crop residue. The conclusions of the study shows that the VSA procedure can be adopted by cocoa farmers and could help as a technique to forecast soil quality and also serve as initial warning on soil degradation.

It is recommended that extension officers should instigate better soil quality among farmers especially during trainings. Planting of leguminous trees as shade trees will help fix Nitrogen in the soil and also serve the purpose of shade trees. Various methods could be employed to discharge knowledge to farmers, so that they could change their attitude towards their farms. For instance, officer could assist the extension officers to remind farmers of good farm practices, since it was observed that farmers tend to respect these field officers a lot. And because the VSA encompasses direct interaction with farmers, it could serve as a contact point to discus with farmers and this might lead to change of attitude of the farmers.

Keywords: Visual Soil Assessment, Traditional, Organic, Hi-tech conventional, Productive and None Productive trees.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

VSA	Visual Soil Assessment
TF	Traditional Farm
TPT	Traditional Productive Tree
TNPT	Traditional None Productive tree
OF	Organic Farm
OPT	Organic Productive Tree
ONPT	Organic None Productive Tree
HTCF	Hi-tech Conventional Farm
HTCPT	Hi-tech conventional Productive Tree
HTCNPT	Hi-tech Conventional None Productive Tree
AE/LBI	Agro-Eco Louis Bolk institute
GDP	Gross Domestic Product
ICCO	International Cocoa Organization
EOA	Ecological Organic Agriculture
IFOAM	International Federation of Organic Agricultural Movements
MOFA	Ministry of Food and Agriculture
COCOBOD	Ghana Cocoa Board
NGO	Non-Governmental Organization

1. INTRODUCTION

Cocoa is often referred to as food of the gods and it belongs to the family *Steruliacaea* and genus *Theobroma*. Cocoa was introduced to Ghana in 1876 by Tetteh Quarshie from Fernando Po (now Equitorial Guinea). He cultivates the beans on his farm and grows several seedlings then established cocoa nurseries. Those trees are regarded as the parent trees of Ghana's cocoa industry (Howes, 1946). From there, cocoa farming was able to extent to the Ashanti, Brong Ahafo, Central, and Western regions of the country (Robin Dand, 1997).

Cocoa is basically categorized by three cultivars: Criollo, Forastero and Trinitario. It is one of the most treasured crops in the world. It is planted worldwide on about 8.2 million hectares, by approximately 58 countries, and worth more than US$4 billion annually (Bhattacharjee and Kumar, 2007). According to the International Cocoa Organization (ICCO) more than 14 million people are directly involved in cocoa production.

Cocoa is the basic ingredient of chocolate and other products such as: cocoa liquor, cocoa butter, cocoa cake and cocoa powder. Cocoa is a well-modified agro-forestry crop that developed well in hot and rainy climates with intensive cultivation clustered between 0 to 20 degrees north and south of the Equator, which sometimes called the "Coco Belt" (Hermann, et. al. 2006). Cocoa has been the most important subsector in the economic growth and development of Ghana and quite a number of West African countries, compared to other agricultural produce (Duguma et al., 2001). Furthermore, Ghana used to be the leading world cocoa producer until the 1970s, it was the country's main foreign exchange earner, instituting as far as 45% in the 1960s (Essegbey and Ofori-Gyamfi, 2012). About 4.6 million tonnes is produced worldwide, while Ghana is the second-largest producer of cocoa in the world, with 18% of the world production. 45% of Ghana's Gross Domestic Product (GDP) comes from agriculture and it hires more than half of its workforce (Trade Reforms and Food Security Project: Ghana, FAO, 2013). Ghana is behind next-door neighbour, Cote D'Ivoire which accounts for 32% of the world production of about 1.3 million tonnes (figure1) (FAOSTAT, 2013)[1].

The harvesting season in Ghana is between October - February/March, although there is also a smaller or light midcrop cycle, which happens around April/May to mid -September (GAIN, 2012). Since 2002, cocoa output has followed a general upward trend. It has observed that this due to higher producer price and most especially the liberalization of internal marketing, coupled with government backed rehabilitation programs to control pests and disease, fertilizer credit facility and the privatization of input supply to farmers (CIRG 2007). Cocoa production in Ghana is still largely based on smallholder farmers. About 700,000 households are growing cocoa mostly on plots of 2-3ha using small plantations (ICCO, 2007). While the yields are still low, as a result farmers are not getting the full benefits for growing the crop.

[1] http://faostat3.fao.org/faostat-gateway/go/to/browse/Q/QC/E (Accessed on 29/10/2014)

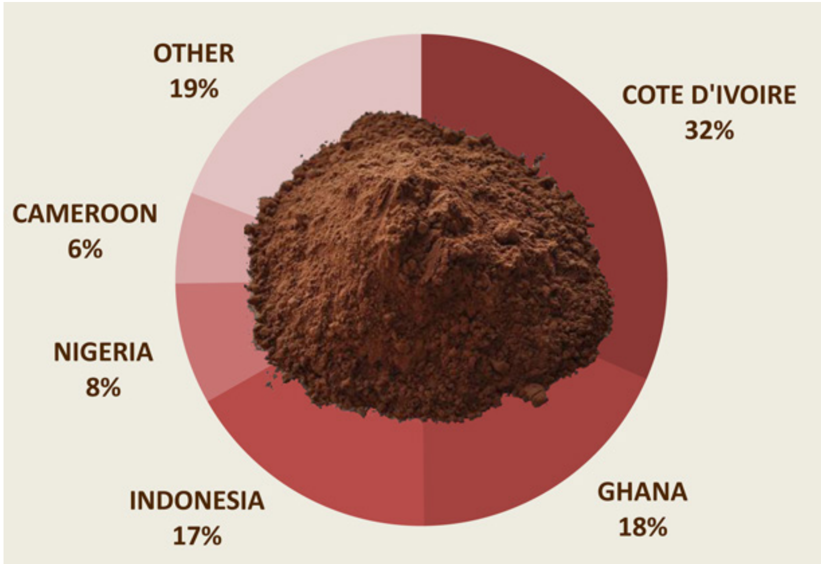

Figure 1: World cocoa producers

Ghana previously cultivated the “Amazons” and “Amelonado” cocoa varieties, hybrid varieties were later introduced to replace the older varieties. In this agenda, the government has implemented policies to restructure the cocoa in the late 90s, the policies focuses mainly on increasing yield to keep the stature of Ghana being the world leading producer of premium quality cocoa, by encouraging the use of agrochemicals and other inputs (Ntiamoah and Afrane, 2008). As of 2002, 57% of farmers from the three main areas of production were already cultivating hybrid varieties (Vigneri, 2009). The major advantage of the hybrid varieties is that it produces more fruit per pod and also bears fruit earlier in three years instead of five years compared to the older varieties (Kolavalli and Vigneri, 2011).

The total planted area of cocoa in Ghana decreased from 1.82 million ha in 2008 to 1.63 million in 2009 and has remained the same till date, but the production is gradually increasing with estimated output of 700020 tons in 2011, while the yield continues to increase in the last six years ranging from 420 kg/Ha in 2007 to 550kg/Ha in 2012 (FAOSTAT, 2013)[2]. Despite the continuous growth of cocoa yield in Ghana, the yield has been on the average 25% lower than the average yield level of the ten largest cocoa producing countries and nearly 40% less than the average yield level of Côte d’Ivoire (Mohammed et al, 2012). Some of the reasons for this include the predominately old age trees, pests and diseases such as black pod and mistletoes, less investments into cocoa farming, less attention to soil fertility and also the absence of row planting of cocoa trees (Mohammed et al, 2012). Furthermore, the Ghana cocoa board (COCOBOD) also reported that some of the factors responsible for the decline include; old age of the farms and illiteracy level of many cocoa farmers which leads to the delay in adoption of new technologies with respect to disease and pest control, small hectares of farms, hostile land tenure system, insufficient planting materials, inadequate husbandry practices, low credit facilities for farmers, absence of well-defined rehabilitation policies and consistent absence of remunerative domestic producer price (COCOBOD Special Report, 1994).

[2] http://faostat3.fao.org/faostat-gateway/go/to/browse/Q/QC/E (Accessed on 29/10/2014)

Like every other cocoa farmers in the world, cocoa farmers in Ghana depend on rain. It is still mostly based on traditional methods of farming with cutlass and hoes, which are characterised by low levels of productivity and low yields. The most favourable conditions for cocoa farming are those in which there is sufficient rainfall in the previous night followed by sunny day, these gives rise to healthy looking trees with fully filled pods (GAIN, 2012).

The cocoa farmers that were worked with in this research are the farmers from the ProEco Organic Africa project. The ProEco Organic Africa project started in 2013 and it's proposed to end by 2016. The aim of the project is to produce comparative scientific evidence on productivity, profitability and sustainability of organic and conventional farming system and to support policy related activities which contribute to Ecological Organic Agriculture (EOA) mainstreaming. The project is being implemented simultaneously in Ghana and Kenya. In Ghana, the project is being implemented by the university of Ghana's college of Agriculture and consumer sciences, Agro-Eco Louis Bolk institute (AE/LBI), and the directorate of the Ministry of Food and Agriculture (MOFA), Ghana. The International Federation of Organic Agricultural Movements (IFOAM) is also handling together with the partners in Ghana and Kenya on the policy related issues of the project.

ProEco Organic Africa in their own definition gave the typology of the farmers as follow;

Organic Certified- Organic agriculture principles are followed on established/stable organic farms. The fields or farms that are still under conversion to organic are not included in this category. They are characterized on the market place by; certification done, organic labels which can originate from; third party certification or from participatory guarantee systems.

Organic Non-Certified - Organic agriculture principles followed on established/stable organic farms. The fields or farms that are still under conversion to organic are not included in this category as well. No certification due to a number of reasons such as high costs in relation to target markets (e.g. lack of premium at the local vs distant markets) or no mandatory certification required by target market, other reasons. Organic complaint traditional agriculture (TOA) but not organic by default are included here.

Conventional High- Heavy reliance on purchased external inputs such as fertilizers (chemical and organic), pesticides (herbicides, insecticides, fungicides, acaricides, etc.) antibiotics and hormones in livestock production, comparable to conventional systems in the western world and stems from the green revolution of the 1960s. Includes integrated agriculture in which non-organic chemicals are used to a large extent.

Conventional Low- uses external inputs but does not heavily rely on them. The following categories are also included; traditional low-input agriculture and integrated agriculture in which non-organic chemicals are used to as lesser extent.

For simplicity and clarification of terms, the organic certified and non-certified will be regarded as just organic, the conventional high as hi-tech conventional while the convectional low as traditional farmers. And they are further redefined as follow;

Traditional Cocoa Farmers - The traditional cocoa farmers are generally relaxed famers, characterized with high density of tree, irregular weeding , little or no pruning, infrequent disease and pest control, irregular harvesting, very little shade management is practiced. They just plant and allow nature to do the rest. These types of farmers apply any type of fertilizers, when they have access to them. For example free or subsided fertilizers from the government. They are majorly characterized with low yield with average yield of 32- 46.8 kg per acre (½ or ¾ of a bag).

Organic Cocoa Farmers- This category of farmers follow proper weed management; undergo regular pruning, good shade management, and frequent harvesting. Overall, they exclude the use of inorganic fertilizer, pesticides, and follow strictly the guidelines for organic production. Their average Yield is about 125 kg per acre (2 bags).

Hi-tech Conventional Cocoa Farmers- Hi-tech conventional cocoa farmers follow regular spacing at 3m by 3m, practice regular weed management, shade management, pest management is about once a year, they practice frequent pruning, fertilizer application is usually once a year and they rely heavy on it, frequent harvesting is also done. The average Yield is about 196 kg per acre (3 bags).

Here the classification of productive tree and none productive used as part of the research is presented. Productivity of the tree selected is based on several factors such as, the amount of pods present or early harvested on the tree. Physical appearance of the tree, that is in term of the extent of leaves, stems available on the tree. The farmers were allowed to determine a productive or none productive tree as the case maybe, coupled with what is observed and a final selection is made.

I. **PRODUCTIVE TREE**- productive cocoa tree is classified as a tree that is physically healthy in term of leaves and stems available with large number of cocoa pod present on the tree. And it has been productive in the last three years. The number of cocoa pod should be above 20.
II. **NONE PRODUCTIVE TREE**- None productive cocoa tree is categorized as a tree that is not physically healthy in term of leaves and stem, with no or few number of pods present on the tree. And it has been unproductive in the last three years. The number of pod should be less than 20.

1.1 PURPOSE OF RESEARCH

The key purpose of the research is to do an in-depth physical soil analysis using visual soil assessment (VSA) procedures, which will be explained later in the methodology part of this report (chapter 3.2-3.4). At the same time carry out the chemical analysis of the soil. The samples were tested for amount macronutrients present in the soil (N, K, Ca, Mg, P and S). And then compare the results between standards. Then at the end discover farmer's motivation toward better soil management. To find out what farmers do in term of soil fertility, the reasons why they do it, and why are certain practices implemented by some farmers and not by others? This will be based on a topic list interview. This research is considered relevant at the moment in Ghana, where farmers have been regarded as mining the soil for many years. So, therefore this research could be relevant in the following ways;

- Contribute to Agro Eco- Louis Bolk institute concept of future cocoa farmers.

- Contribute to the awareness of better soil management in cocoa production.
- Understand farmer's perception on better soil fertility and factors possible to embrace better soil management.
- Help trainers/facilitators to develop programs and incentives that will readily be adopted by farmers.
- Validate the VSA procedure on cocoa farm.
- And information gathered can also be used to determine future research properties.

The native language of the project area is Twi; therefore this research is restrained by my inability to communicate directly with the farmers during the VSA procedures except with the use of a translator.

1.2 AIM

The aim of the thesis is listed below;

1. To investigate the relationship between VSA within the farms, and relationship between VSA and yield in the three farm types.
2. To identify the incentives and challenges farmers face in soil fertility management.

1.3 RESEARCH QUESTIONS

1. What are the differences between VSA score of the three farm types?
2. What is the relationship between VSA and yield?
3. What is the correlation between chemical analysis and VSA analysis?
4. What are the incentives and challenges farmers face (three farmers) during soil fertility management?

1.4 HYPOTHESIS

1. There are differences between farm types and high tech conventional cocoa farms will have less VSA score than other farms, while organic farms will have better VSA score.
2. Better VSA score equals greater yields but farm practices also influences yield.
3. The higher the VSA, the better the chemical analysis.
4. Farmers faces a lot of challenges in improving the soil fertility and there are no or insufficient incentives, especially for traditional farmers to improve soil fertility.

2. LITERATURE REVIEW

2.1 CHARACTERISTICS OF COCOA

The Cocoa tree is a shade loving tree, which can grow up to 8-12 meters, and its pods can be between 15- 40 cm long. The stem is usually straight (Beer, et. al, 1998). The cocoa tree has a well-defined root system, which consists of a thick tap and a lateral root that lies in the top 20 cm of the soil; these lateral roots are the core channels for water and nutrients (Wood and Lass 2008). De Oliveira Leite and Valle in 1990 discovered in their research that the first 30cm of the soil depth is where 85% of cocoa root are found. Thong and Ng (1978) also established that its lateral roots are found between 0-30cm of the soil layer making cocoa a surface-root feeder. But in the tropics, most of the nutrients are in the top 25cm of the soil. Nutrients are removed from cocoa ecosystem through yield (beans and husk), immobilization in stems, branches and leaching below rooting area (figure 2). Majority of nutrients in cocoa ecosystem are lost through harvest of beans and husks. Nutrient lost through husk is less, compared to nutrient lost through beans; this is as a result of husks being strongly affected by the type of fruit and the environment than it affects cocoa beans (Wessel, 1985).

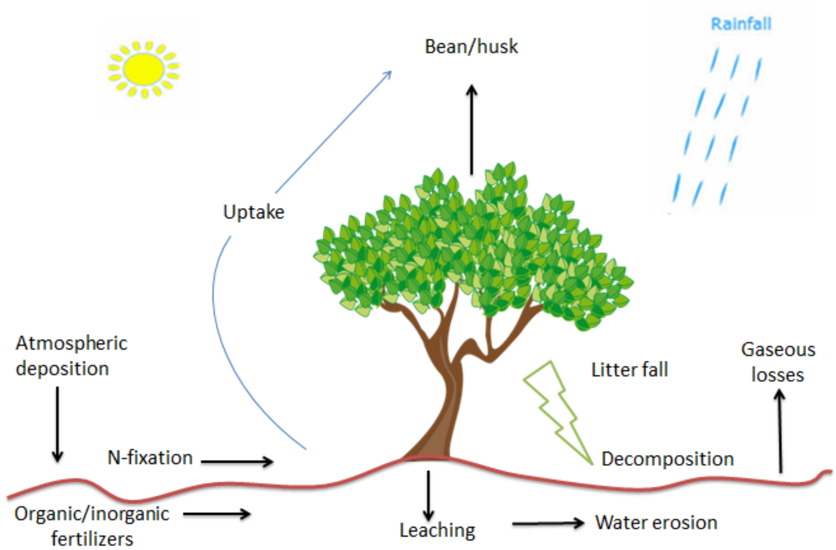

Figure 2: Nutrient cycle in cocoa ecosystem

Muoghalu and Odiwe (2011) stated that 1000 kg dry Cocoa beans on average removed about 20 kg N, 41 kg P and 10 kg K from the soil (Table 1) .While nutrients are added to coca ecosystem through organic or inorganic fertilizer, symbiotic and asymbiotic N fixation, atmospheric deposition and weathering of parent material. The transfer of nutrients involves rain wash, and fine-root turnover and litters. The litters in cocoa ecosystem are divided into two, litter from shade and cocoa trees, which includes flowers, fruits, stems and leaves (Beer et al., 1998; Schwendenmann, 2010)

Table 1: Nutrient removal from Nutrients (kg) Removed by 1000 kg Dry Cocoa Beans

Country	Beans			Husk			Total			
	N	P	K	N	P	K	N	P	K	References
Malaysia	20.4	3.6	10.5	10.5	1.3	10.5	31.0	4.9	53.8	Thong and Ng (1978)
Venezuela	39.3	n.a	n.a	31.4	n.a.	n.a.	70.7	n.a	n.a	Aranguren et al (1982)
Costa Rica	21.3	4.2	10.5	14.8	1.8	27.2	70.7	n.a	n.a	Heuveldop et al. (1988)
Brazil	22.0	n.a	n.a	12.0	n.a	n.a	34.0	n.a	n.a	Santana et al. (1982)
Nigeria	22.9	3.9	8.5	15.4	1.8	68.4	38.3	5.7	76.9	Wessel (1985)
Ivory Coast	22.1	3.0	7.5	13.2	1.8	43.0	35.3	4.8	50.5	Snoeck&Jadin (1992)
Cameroon	19.2	4.4	10.6	15.0	1.9	62.0	34.2	6.3	72.6	Boyer (1973)
Ghana	33.0	2.1	8.1	**n.a**	**n.a**	**n.a**	**n.a**	**n.a**	**n.a**	Malavolta and Carbral (1986) and Afrifa.et.a l 2009.

Modified from Hartemink, 2005. NUTRIENT STOCKS, NUTRIENT CYCLING, AND SOIL CHANGES IN COCOA ECOSYSTEMS: A REVIEW. Note: n.a= Not available.

The appropriate soil for cocoa production depends on both the soil type and soil phase (Adams & Mckelvie, 1955). Soil type is determined by the geology and topography condition of the soil. It is defined by the amount of sand, silt or clay present on the soil, while soil phase is the historical understanding of soil and previous land use. Few centimetres of a tropical forest soil is well-known to store nutrients, these nutrients are rapidly released to preceding crops for many years. However, Ofori-Frimpong (1999) highlighted that the smallholder cocoa farms in Ghana is based on the use of fertility accumulated by the forest. Ofori-Frimpong (1999) further stated that cocoa established from virgin forest soil will enjoy this fertility and may not require fertilization for several years. Furthermore, it is important to note that the continuous removal of vital plant nutrients, through harvesting over long period of time without replenishment could be one of the reasons of decrease of yield on cocoa farms. And since soil is the major source of nutrient to cocoa in Ghana, the non-application of fertilizer will results to nutrient mining which leads to soil degradation in cocoa growing regions and subsequently decline in yield (Appiah,et.al 1997).

Plant needs eighteen different nutrients or chemical elements, to complete their life cycles. Two out of the nutrients (carbon and oxygen) comes from sunlight through photosynthesis, the fifteen other plant nutrients are derived from the soil (Oldham, 2011). Inadequate nutrients will hinder or end the plant growth, which leads to decrease in yields and lower profitability for farmers. However, lack of access to this nutrient by root will also limit or end plant development, decrease yields and lower profits, while too much of nutrients will increase environmental risks (Oldham, 2011). Therefore, available nutrient and rate of uptake by plants has to be in harmony. Furthermore, farmers need to work hard to understand the relationship between nutrients and soil fertility and understand what goes on within the soil to reduce undesirable situations, because soil life plays a major role in nutrient management. Agricultural management usually changes this situation, such as proper soil management with additional nutrients may be required to meet up with economical production.

Spending time to observe the soil structure and soil health is important for commercial farming (Shepherd & Webb 2002.). Although, analysing the condition of the soil is not usually an easy task. The state of the soil is not the same at farms all year round; it varies with depth and it also depends on climatic conditions of the area and general farm practices employed (McBratney, et.al, 1992).

However, soil degradation together with pest and disease infestation has led to the abandoning of cocoa farming to other favour crops in many parts of the eastern and Ashanti region of Ghana. These shift further resulted to demise of cocoa production, as the fewer trees that are supposed to provide shade for cocoa are cut down for new crops that does not require shade (Appiah,et.al, 1997). Appiah et.al (1997) further suggested in their paper that adequate, functional and up to date soil test facilities should be provided for cocoa farmers. Coupled with proper application of fertilizer been integrated with pest and disease control measures for realization of maximum profits.

Low soil fertility is considered as an important cause for low productivity of many crops (Sanchez, 2002). It has not received equal amount of research attention as compared with soil erosion. Reason could be due to soil fertility deterioration is less visible and less enormous, and more difficult to evaluate. Evaluating soil fertility deterioration is difficult because most soil chemical properties either change very slowly or have large seasonal fluctuations. This deterioration includes; nutrient mining, nutrient depletion, acidification (decline in pH), loss of organic matter and increase in toxic elements (e.g. Al, Mn) (Hartemink, 2006).

A good soil structure has numerous benefits. it allows the root system of crops go much deeper into the soil, it provides a better water supply, permitting the roots to have access to varieties of nutrients in the soil, it drains more quickly, while soil with poor soil structure has high tendencies of runoffs; the danger of runoff is excessive when poor soil structure is close to the soil surface, and it also results into poor crop yields (Mäder,et.al, 2002). The cause of poor soil structures arises when pressure is applied at the surface of a wet or soft soil. The pressure squeezes the soil units and decreases the pore space inside the soil units, while a dry soil will endure the pressure without distorting the soil structure. Soil can be restructured by natural fracturing process, cultivation and by biological activities (Think-soils, a practical guide for digging a hole, 2010). Furthermore, Soil fertility denotes the capability of soil to support and supply essential plant nutrients to plants in appropriate proportions for plant growth. The fertility of a soil depends on the three major interacting characteristics, the chemical, physical and biological characteristics of the soil. Physical characteristics of the soil also depend on the organic matter content of the soil. Organic matter helps to bind soil particles together to form larger aggregates. The greater the organic matter in the soil the better the soil structure (Soil-health).[3]

[3] http://www.sare.org/Events/National-Conference-on-Cover-Crops-and-Soil-Health. (Accessed 28/10/2014).

3. MATERIALS AND METHODS

3.1 BRIEF DESCRIPTION OF THE AREA

In this chapter, the method that was used in this research will be described in details and the modifications that were made will also be presented. The research was carried out in Atwima Mponua district, which is one of the 26 districts of the Ashanti region. It is located in the south-western part of the Ashanti region of Ghana, and it lies in the wet semi-equatorial forest zone of Ghana, having an area of approximately 894.15 square kilometres with 'Nyinahin' as its capital is about 45km from Kumasi.

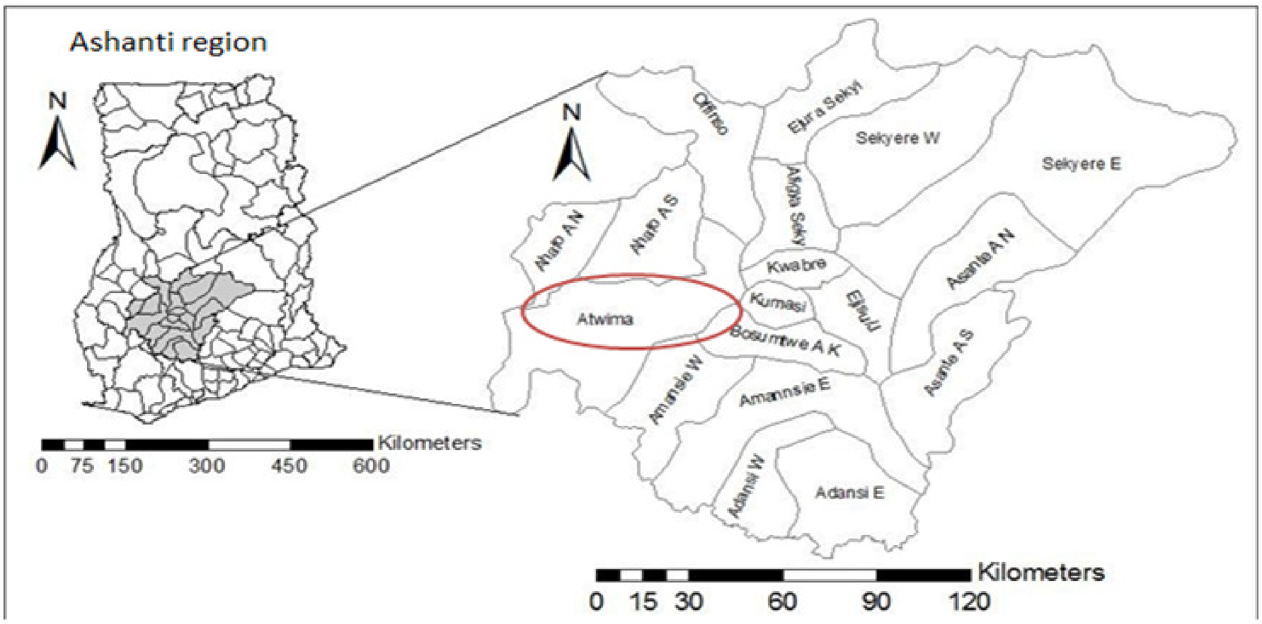

Figure 3: The map of Ghana showing the Ashanti region with Atwima Mponua Source: ealthgeographics.com

Atwima Mponua lies between longitudes 2° 00‟W and 2^{o}32‟W and latitude 6^{o}32‟N and 6^{o}75‟N. The district is positioned between three administrative regions of Ghana and has a population of 108,235 made up of 55,719 males and 52,516 females. The population of Atwima Mponua is scattered in about 323 settlements. There are approximately 2000 farmers and, the district is the leading cocoa production in the Ashanti region. Ashanti zone contributes a great amount to the total coco production in Ghana (Zeitlin, 2006). The average farm size is 1.2 hectare. Like every other soil in Ghana, the soil in the region is suitable for agriculture, with undulating topography separated by plains and slopes with average height of 76 meters above sea level. The average annual rainfall is about 170cm- 185cm per year the major rainfall season is between March and July with its climax in May, while the minor rainfall begins in August slowing down in November, with an average minor annual rainfall of 100cm- 125cm per year, while the annual temperature is between 27^{o}c-31^{o}c. The climate in the district is suitable for the all other kind of cash and food crops and vegetable such as; cola, oil palm, maize, cocoyam, onions, eggplants etc.[4]

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[4] Source; http://atwimamponua.ghanadistricts.gov.gh/ (Accessed 15/10/2014)

As earlier mentioned, the project is small part of the ongoing project of ProEco Africa (2013-2016) in Atwima Mponua district. ProEco classified the farmers as organic certified, organic non-certified, conventional low and conventional high, this classification overlaps with my categorization of cocoa farmers it was further redefine into traditional, organic, Hi-tech convectional farmers. (See introduction). With the exception of degenerated cocoa farm was analysed a little deeper, on the point of physical soil analysis, chemical analysis and to also discover farmer's motivation toward better soil management,) to determine what the farmers do and why they do it, this will be based on a semi- structured interview.
A narrative description of soil structure and general soil life in high and low yielding situations in each of the farm is given. This was done using the Visual Soil Assessment (VSA) produce introduced by Graham Shepherd in 2008 – "The visual soil assessment for orchards". VSA procedures can simply be regarded as digging of holes. While conducting the VSA procedure the farmers were engaged in a discussion, to determine what the farmers do and why they do it, their motivations towards better soil management and their various constraints/challenges on their farm and other questions related to general soil fertility. After which one community was selected for community meeting (Figure 4).

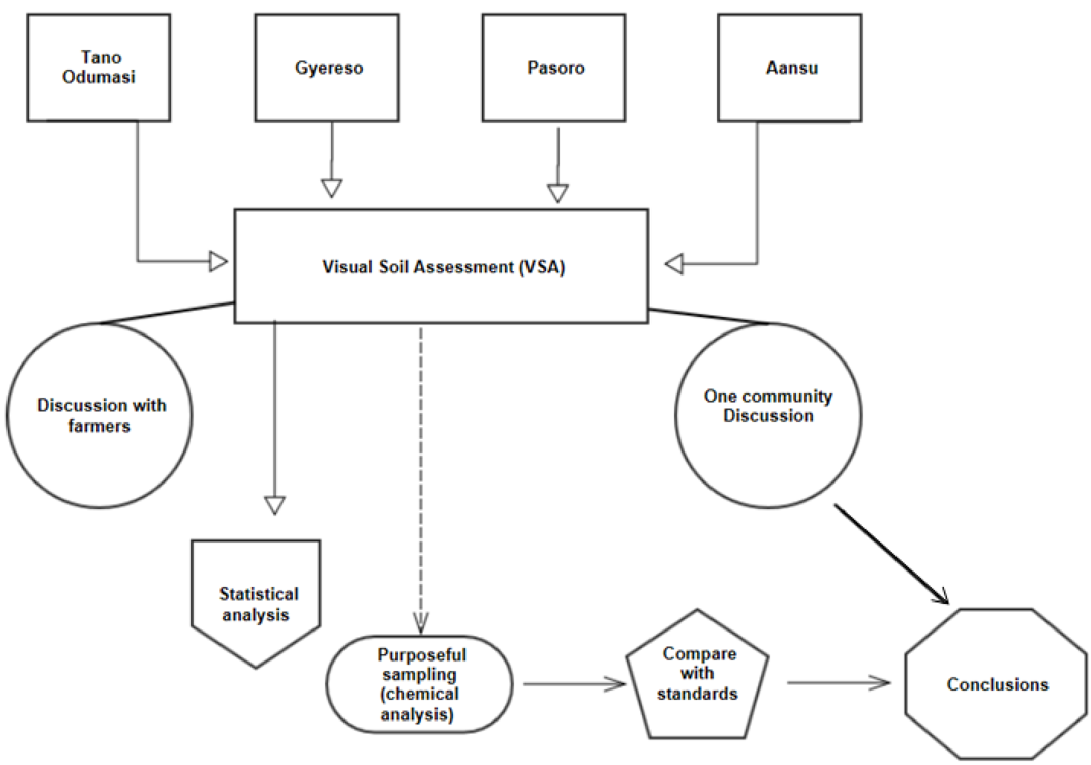


Figure 4: Systematic Diagram of the Methodology

3.2 JUSTIFICATION FOR VISUAL SOIL ASSESSMENT

Nowadays, only the chemical soil analysis of plant available nutrients are commonly used to determine the fertility of a soil while other aspects of soil fertility such as organic matter content, soil structure and general soil life are often neglected (Silvia,et.al., 2005). There has also been emphasizes to document the effects of soil and land management systems on ecological soil functions, using sensitive indicators and simple and appropriate scientific methods have to be defined, which are able to show the influence of management systems on soil vitality (Beste, 2003). So, therefore it is interesting for this project not just to focus on laboratory soil analysis which is often not the sole parameters for determining soil quality but also focus more on the physical analysis of the soil "Visual Soil Assessment" (VSA).

The conservation of a good soil quality is essential for the economic and ecological sustainability of crops. Failure in soil quality can have great impact on tree growth, fruit quality, yield and the general process and running of the crop. Particularly, a decline in soil physical properties can take significant time to correct (Shepherd. et.al 2008). Not enough attention is given to the basic role of soil quality in efficient and sustained production. The effect of soil condition on the gross profit margin and the long-term planning needed to sustain good soil quality and the effect of land management decisions on soil quality.

VSA gives a swift and simple method to assess state of the soil and plant performance. The VSA method can also be used to assess the suitability and limitations of a soil for pipfruit, stonefruit and various types of crops. Soils with good VSA scores will usually give the best production with the lowest establishment and operational costs (Shepherd. et.al 2008). The VSA procedures include one key test called the" drop shatter test" which involves dropping the block of soil from a waist height approximately 1 metre. This procedure is further explained in the methodology part of this report (Chapter 3.4.1).

Through VSA, the crop root growth and the soil structure are studied in the top soil and upper sub soil, soil moisture, size, aggregates and arrangement of soil particles as well as the soil colour, and root growth are also easily studied[5]. The relationship between soil fertility and farm management are considered. Only few tools are used during VSA and one of the major tools used is a common spade. The spade is use to dig out soil pit and to take a 200 mm cube used for the drop shatter test. A plastic basin to contain the soil in the cause of the drop shatter test. A heavy duty plastic bag to spread the soil, once the drop shatter test has been done, small knife to examine the potential rooting depth and to check for the presence of hard pan, water bottle to evaluate the soil textural class, a tape to measure the potential rooting depth also, VSA field guide to compare photographs in the guide and a pad of scorecards to make record scores for each indicator.

The final result of this method is good to judge the quality of the management done by the farmers and the effects of previous practices on the soil. Tillage systems, crop rotations are significant factors to determine the result of spade diagnosis (Goerbing, 1947). To avoid the risk of losing or missing important details during a VSA it is essential to make pictures for reference purposes

[5] http://www.boprc.govt.nz/media/100514/3580_land_management35_soil_structure_forweb_allpages. (accessed 1/2/2015)

3.3 FARM SELECTIONS

The ProEco's project was carried out in four communities in the Atwima Mponua district namely; " Tano donasi"," Gyereso", "Pasuro" and "Anansu" community. Three farms were selected at every farm typology and community level, while additional one degenerated farm was selected in Anansu community, making a total of 37 farms (Table 2). The farms in all the four communities were selected randomly based on size and accessibility. The size of the farm was put into consideration during selection to have fair comparison. The selected farms are between 1-7 acres.

Table 2 : Total number of farms selected

COMMUNITIES	TRADITIONAL COCOA FARM	ORGANIC COCOA FARM	HIGH-TECH COCOA FARM	DEGENERATED FARM
TANO DOMASI	3	3	3	-
GYERESO	3	3	3	-
PASURO	3	3	3	-
ANANSU	3	3	3	1
Total	12	12	12	1

3.4 METHOD FOR PHYSICAL ANALYSIS (VSA)

The VSA procedure was followed strictly, all the 10 indicators were carefully done after the doing the drop Shatter test.

3.4.1 THE DROP SHATTER TEST

In the VSA procedure one of the most important activities is the drop shatter test. The drop shatter test involves dropping the block of soil (20 cm cube) from a waist height on the heavy duty plastic bag for a maximum of three times depending of the texture of the soil and the extent at which the soil breaks after the first drop. After the drop/shatter test the scorecard was systematically work through in assessing each indicator. This was done by comparing the soil alongside with the photographs and descriptions presented in the VSA field guild. The best condition to carry out the VSA procedure or the drop shatter test is when the soil is slightly wet.

Prior to the main procedure 5holes were dug in two of the farms to serve as a trial and standardization process for the procedure. In addition, it serves as a way of developing the technical standards that were used. This trial also enhanced repeatability of the procedure in practise and further set conditions and methods that were later used in this project. The VSA procedure has never been done on a cocoa farm before, not to talk of been carried out around productive and none productive trees. So, for this reason, some methodologies were developed during the trial. For example, the 50 cm distance from the bottom of the tree was developed. Because it was found out that the root of the cocoa tree was hindering the spade from going down up to 30 cm at the very bottom of the tree, but it was observed that at 50 cm distance it was quite easy to get to the required depth. It was like that for the entire cocoa tree that was examined.

Two holes was dug at each of the farms around productive and none-productive tree, 50cm from the bottom of the tree making a total of 2 holes per selected farm and one for the degenerated farm, making a grand total of 73holes in all the 37 farms.

3.4.2 VSA SCORING

VSA for orchards is centred on the 10 soil indictors for soil quality. A visual score (VS) is given to each of the indicators, the score varies from 0-2 (Where, 0 = poor, 1 = moderate and 2 =good) depending on the soil quality observed. The soil sample is compared with the photographs available in the VSA field guide. The VS is flexible, if any of the sample been assessed is not totally in line with the photograph presented but falls between two photographs, an intermediate score is given. For example, 0.5, 1.5. Since some soil indicators are more important than others, VSA offers a weighting factor for the indicators. The weighting factor varies between 1 and 3 depending on how important the indicator is. The given VS are then multiplied by the given weighting factor to given the total VS ranking. The overall VS ranking gives the complete soil quality index score of the soil sample. The VS ranking is then compared with the range rating scale at the bottom of the VS card to conclude whether the soil sample is Poor= 0-15, Moderate= 15-30, or Good =above 30 (Appendix A).

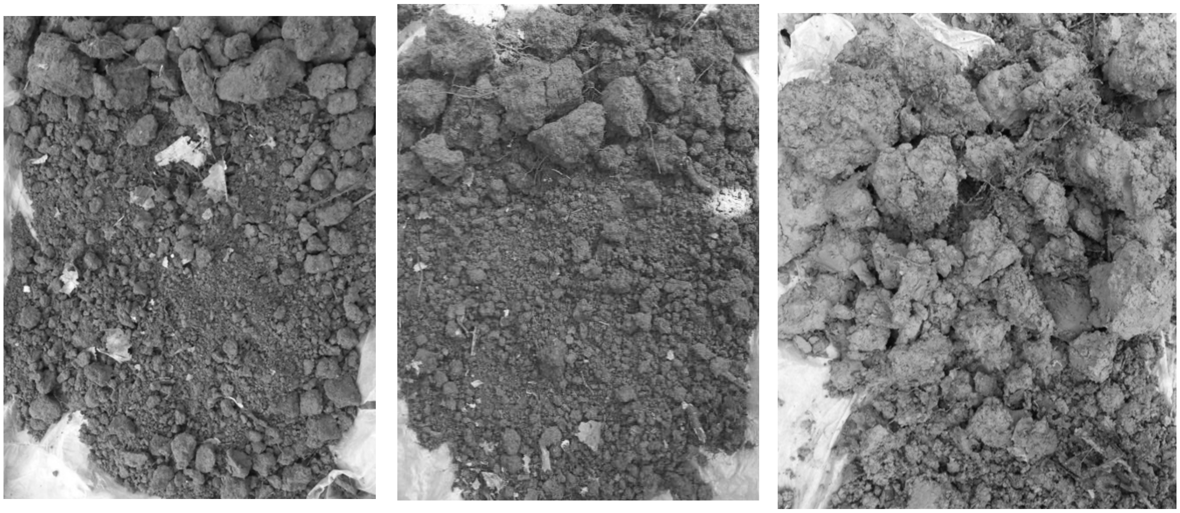
3.3.3 MODIFICATION TO THE VSA PROCEDURE

The VSA procedure and the scoring system was strictly followed but with following modifications. In the original procedure it was proposed that the assessment should be done within 200 mm depth of the soil but this was changed to 30 cm. This change was necessary because of the clear evidence that coca roots are mostly found at 30 cm depth, while nutrients and must activity take place at this depth. In addition, in assessing the soil structure, the drop scatter is involved which requires the block of the soil to be dropped at least three times from waist height (approximately one metre) into a plank wood place in a bucket. In this project, the block soil was dropped on 500 mm nylon. Another modification that was made to the procedure was replacing soil ponding indicator with soil smell indicator on the scorecard. Soil ponding is the length of time for water to remain on the surface after rainfall. This was almost impossible to measure because it does rain every day in the community and the few times it rained there were no waterlogging after few days of rainfall in all farms visited.

The same VSA procedures were repeated at all the farms and for all corresponding holes. Below are the detailed explanations of how the 10 indicators were examined;

SOIL TEXTURE- About half size thumb of soil sample was taken from the topsoil; it was then rubbed thoroughly on the palm with the help of the thumb to get maximum stickiness. Little drop of water is added to the soil depending on the moisture contain of the soil. The texture of the soil is then assessed according to the condition stated in the VSA procedure.

SOIL STRUCTURE - After the Shatter test, the soil is then separated apart based on their aggregates made from the test, they are then arranged from bigger aggregates to smaller aggregates. The bigger aggregates of the soil are moved to the upper end and smaller aggregates to the lower end of the plastic bag (Figure 5). The distributions of the aggregate were than compared to the photographs presented in the VSA field guild and the soil samples were scored accordingly.



Good condition Moderate condition Poor condition

Figure 5: Soil structure showing good, moderate and poor condition

SOIL POROSITY – A spade full of soil was removed for 30cm depth from the side at which the hole was dug, big lumps of soil was break into half and was examined critically for porosity of the soil. Furthermore, numbers of soil from the large aggregate from the soil structure test were also used to further examine the soil porosity. It was then compared with the three photographs presented in the VSA field guild.

SOIL COLOUR- A handful of soil from the topsoil and also from the soil structure test was taken and compared using the photographs presented.

NUMBER OF SOIL MOTTLES- About 10cm by 15cm at 30cm depth from the side of the hole was taken and compare with the photographs to check for the percentage of the soil mottle present in the soil (Figure 6).

Figure 6: Soil Mottles

EARTHWORM- Earthworm were sorted and counted, from the soil sample used in assessing the soil structure. The number of earthworm was recorded as the number per block of soil (20cm). Meanwhile, earthworm are usually recorded per square meter, a 20cm block of soil equals 1/25m2, so therefore to the get the number of earthworm per square metre , the number of earthworm in the block of soil is multiplied by 25. The length and type of earthworm were also noted and then compared with the class limit presented in the VSA field guild.

SOIL SMELL- A hand full of soil was taken from the same soil sample and break into half. Then the soil is placed close to the nose and three deep sniffs was taken and this was critically compared with the criteria given in the VSA field guide.

ROOTING DEPTH- A hole was dug to identify the depth restraining the root system, as the hole was been dug the presence of the roots channels and worm channels were been observed. After which the maximum length at which the root could be observe is measured and then compared the visual score for the rooting depth.

SOIL CRUSTING AND COVER- To determine the crusting level on the farm, the degree of surface crusting and surface cover was observed based on the visual evidence by comparing with the criteria presented in the VSA field guild (Figure 7).

Poor Condition

Good condition

Figure 7: Soil Crusting and cover for poor and good condition

SOIL EROSION- The degree soil erosion of the farms was also assessed based on the current visual evidence and most essentially asking the farmers how their farms looks like compared to the current state. Then to reach a conclusion the current state of the farm were then compared with the criteria presented in the VSA field guild (Figure 8).

Figure 8: Soil Erosion

HARD PAN- The hole dug to assess the potential rooting depth was use to examine the presence of hardpan, a knife was use to jab the side of the soil profile , starting from the top then systematically and rapidly down to the bottom of the hole. How easy and how difficult it was to jab the knife into the soil down the soil profile was observed. The very compacted soil is tight and really firm to the knife, with high degree of penetration resistance. After identifying, the position at which the possible hardpan is was measured and the resulting length was compared with the criteria. Furthermore, a large size of soil sample was removed from the point to reassess the soil for porosity, number and colour of mottles and soil structure.

3.5 SEMI- STRUCTURED INTERVIEW

While carrying out the VSA procedure, the farmers were engaged in discussions, to determine what the farmers do and why they do it, their motivations towards better soil management and their various constraints and challenges related to soil fertility were asked. Furthermore, the farmer were alongside enlighten on better soil management and were equally shown the difference in soil of productive and none productive trees. They were shown and also ask to observe themselves to see the difference in the soil. It was observed that most none-productive tree soil usually compacted with shallow rooting depth. In between, farmers were directly advised on what to do. The dissuasion was made possible with the help of the translator using the checklist questions (See Annex for checklist questions).

3.6 METHOD FOR CHEMICAL ANALYSIS OF THE SOIL SAMPLES

Soil and leaf samples were collected in the four communities during the month of October to mid November 2014. Soil samples of non-productive tree and productive tree were taken at 30 cm depth from these farms at 50 cm from the bottom of each tree at 5 different points around the tree using a soil auger to make a sub samples (Appendix B). The sub samples were then mixed to make a composite sample. The samples were then transferred into a clean labelled polyethylene bags to avoid any form of contamination. Two soil and leaf samples were taken from each farm (i.e. soil and leaf samples for non-productive and productive tree). The same procedure was then repeated in all the selected farms. So, therefore, there were 18 soil samples per communities and 72 soil samples in all.

3.6.1 SAMPLES (SOIL AND LEAF) SELECTION AND PREPARATION

Due to cost of analysing all the 72 soil and leaf samples, only 7 soil sample and 7 leaf samples were selected for analysis. For this reason, the samples were then selected based on farm level and community level. The farms were selected based on their VSA result.

Table 3: Sample Selection for Chemical Analysis

Communities	Farm types	Soil(productive and none- productive)	Leaf (productive and none-productive)
Tano Odumasi	Traditional farm	2	2
Pasoro	Organic farm	2	2
Gyereso	Hi-tech conventional farm	2	2
Anansu	Abandoned farm[6]	1	1
Total		7 Soils samples	7 Leaf samples

The samples were then transferred to soil the laboratory for analysis. Then the following procedures were undertaken: Prior to the chemical analysis; samples were air-dried, then later crushed and sieved through a 2 mm sieve. The fine samples were used for analysis. The chemical analysis carried on the soils included testing for Marco nutrient (N, K, Ca, Mg, P and S) and they were analysed using the following methods; the Nitrogen was determined using the procedure proposed by Bremner, 1965 to attain the point. While Potassium was measured using the Toth and Prince's method to present the amount of Potassium in the soil with neutral ammonium acetate of 1 molarity with the aid of flame photometer (Toth and Prince, 1949). Exchangeable Calcium and Magnesium was measured using the EDTA titration procedure established by Cheng and Bray (1951), this procedure was chosen because of its simplicity, speed and accuracy. Phosphorus was done using the Bray's method to determine the available P of the soil; the method involves the formation of specific coloured compounds while adding suitable reagents to the solution (Bray and Kurtz, 1945). The available Sulphur was analysed using the procedures modified from Singh, et. al (1999). This involves the use of a spectrophotometer.

3.7 STATISTICAL ANALYSIS

VSA indicators were subjected to statistical analysis using SPSS (18 software package) the analysis of variance (ANOVA) to determine significant differences between farms and communities. Bonferroni method for pairwise comparison was further used to check for mean differences between farm and

[6] Abandoned Cocoa farms are that has been abandoned over the years reason (more than five years) might be as a result of inability of farmers to management farm due to old age, or because the farm is no longer productive and has been producing less yields in the past years and the farmer decided to ignore it and focus on other part of the farm. And it was selected for the purpose of chemical analysis.

communities. This was used because it is interesting to check the contrast between one or more VSA mean scores. The aim of statistical analysis was not to present that it is possible for VSA to predict soil chemical properties. But to show that it is useful indicator for soil condition, and that it could serve as early warning for farmer. Furthermore, the procedure is cheap and fast to carry out and it require very little technicality, then to show the strengths and weaknesses of the method. Poor physical properties can have wide range of causes.

4. RESULTS

4.1 VSA RESULTS

The VSA score for all 72 holes and estimated yield for all selected farms are presented in the table below, before further analysis is been done (Table 4 and 5).

For in-depth analysis and to answer research question one; what are the differences between VSA score of the three farm types? The productive tree and the none-productive were analysed separately and later combined (Mean). While the differences between farm types and differences within community levels were also compared. Only the significant differences between the trees were presented in the below (Table 6).

Table 4: VSA Score for All 73 holes

VSA	TANO-ODUMASI						GEYERSO						PASORO						ANANSU					
	Traditional		Organic		Hi-Tech		Traditional		Organic		Hi-Tech		Traditional		Organic		Hi-Tech		Traditional		Organic		Hi-Tech	
	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod	Prod	Non-prod
1	24	28	31	32	22	25	28	24	30	32	28	28	24	29	20	22	24	23	19	19	32	28	15	25
2	29	26	32	27	29	28	31	31	31	33	28	27	27	26	24	24	27	27	31	14	26	27	24	21
3	32	26	28	30	27	28	32	33	21	28	17	20.5	23	20	29	23	21	27	22	18	29	29	14	16
Mean	28±4	26±1	30±2	29±2	26±4	27±2	30±2	29±5	27±5	31±3	24 ± 6	25 ±4	24±2	25±5	25±5	23 ±1	24±3	26.±2	24±6	17±3	29±3	28±1	17±5	21±5
Over-all farms	27±3		30±2		26±3		30±3		29±4		24±5		25±3		23±3		25±3		21±6		28±2		19±5	

Note: VSA has no unit (Poor= <15,Moderate= 15-20 and Good= >30).

Overall farms = mean of productive tree + None proudctive tree /2.

Table 5: Estimated Yields (bags)

Yield (Bags)	Tano-Odumasi			Geyerso			Pasoro			Anansu		
	Traditional	Organic	Hi-Tech	Traditional	Organic	Hi-Tech	Traditional	Organic	Hi-Tech	Traditional	Organic	Hi-Tech
1	8	20	24	2	11	20	9	15	28	4	7	10
2	2	18	26	9	13.5	18	9.5	18	30	5	9	12
3	7	12	23	10	15	25	4	20	35	4	10	15

Note: The amount of yeild was from the estimated value from farmers in bags per 4-5 acres

4.1.1 PRODUCTIVE TREE

The Test of Between-Subjected Effects for productive tree shows that there were significant differences between farm types (F=4.18, *P*=0.03) and none between communities (F=48.66, P=0.67). The test further indicates that there were no interaction between farm type and communities under productive tree (F=1.15, *P*=0.36). This simply implies that traditional Productive tree (TPT), organic productive tree (OPT) and Hi-tech conventional productive tree (HTCPT) have the similar VSA score within all the four communities and they are all performing the same. The mean VSA score for TPT, OPT and HTCPT in all the four communities are 26±4, 27±4, and 23±5 respectively.

Table 5, also shows that the VSA score of OPT is 4.6 higher than the VSA of HTCPT and this difference was significant with a *P*-value of 0.04. Furthermore, Table 5 shows that the differences in the mean VSA score between OPT and TPT, HTCPT and TPT were 0.71 and -3.92 respectively but none of these differences was significant.

4.1.2 NONE PRODUCTIVE TREE

The Test of Between-Subjected Effects for none productive tree showed that there were significant differences between farm types (F=4.49, *P*=0.02) and there was also significant differences at community levels (F=8.58, *P*=< 0.05). The test similarly indicate that there were interaction between farm types and communities (F=3.36, *P*=0.02), and hence, it shows that there is further significant differences between communities. The mean VSA score for Traditional none-productive tree (TNPT), Organic none-productive tree (ONPT) and Hi-tech conventional none-productive tree (HTCNPT) are 24±6, 28±4 and 25±4 respectively.

Table 5, shows that under none- productive tree, the VSA score of ONPT was found to be 3.30 higher than the VSA score of TNPT; this difference was significant with a *p*-value of 0.04. Furthermore, the table shows that the difference in the mean VSA score between ONPT and HTCNPT, HTCNPT and TNPT were 3.13 and 0.17 respectively but there are no significant differences.

Table 6: Mean differences for productive tree and None- Productive

Farm Types	Mean Value	Farm Types	Mean Value	Mean Difference	Significant Difference	P-VALUE	95% confidence interval for difference (Lower bound, Upper bound)
PRODUCTIVE TREE							
Traditional productive tree	26±4	Organic productive tree	27±4	-1	ns	1	(-5, 3.7)
Traditional productive tree(n=12)	26±4	Hi tech conv. productive tree	23±5	3	ns	0.1	(-0.52, 8.4)
Organic productive tree	27±4	Traditional productive tree	26±4	1	ns	1	(-3.7, 5)
Organic productive tree (n=12)	27±4	Hi tech conv. productive tree	23±5	5*	sg	0.04	(0.2, 9.1)
Hi tech conv. productive tree	23±5	Traditional productive tree	26±4	-4	ns	0.1	(-8.4, 0.52)
Hi tech conv. productive tree(n=12)	23±5	Organic productive tree	27±4	-4*	sg	0.04	(-9.1, -.2)
NONE-PRODUCTIVE TREE							
Traditional none productive tree	24±6	Organic none productive tree	28±4	-4*	sg	0.04	(-6.5, -0.1)
Traditional none productive tree(n=12)	24±6	Hi tech conv. none productive tree	25±4	-1	ns	1	(-3.4, 3)
Organic none productive tree	28±4	Traditional none productive tree	24±6	4*	sg	0.04	(0.1, 6.5)
Organic none productive tree(n=12)	28±4	Hi tech conv. none productive tree	25±4	3	ns	0.1	(-0.1, 6)
Hi tech conv. none productive tree	25±4	Traditional none productive tree	24±6	1	ns	1	(-3, 3.4)
Hi tech conv. none productive tree(n=12)	25±4	Organic none productive tree	28±4	-3	ns	0.1	(-6, 0.1)

Note: *p*-value ≤ 0.05- significant and - *P*-value≥0.05- not significant.
ns =not significant and sg= significant

4.1.3 OVERALL FARMS

Both productive and none productive tree were later added together then divided by 2 to get the mean VSA score for all farm types, to get the overall performance per farm. (Productive tree + None-productive tree)/2 = Mean VSA score. The Test of Between-Subjected Effects for mean VSA for all the tree types shows that there were no significant differences between farm types (F=5.21, *P*=0.13) but the differences between communities are significant (F=7.01, p=0.02). The test also indicate that there were no interaction between farm type and communities (F=2.41, *p*=0.06).

The mean VSA for Traditional farm (TF), Organic farm (OF) and Hi-tech conventional farm (HTCF) are 26±4, 28±4 and 24±4 respectively. In addition, the VSA score for mean VSA for OF was found to be 2.00 higher than the VSA of HTCF; this difference was significant with a *P*-value of 0.01, while the differences in the mean VSA score between OF and TF, HTCF and TF were 2.00 and -1.88 respectively but none of these differences was found to be significant.

Table 7: Mean differences for overall farm

Farms	Mean Value	Farms	Mean Value	Mean Difference	Significant Difference	P-VALUE	95% Confidence Interval for Difference (Lower Bound, Upper Bound)
Traditional farm (n=24)	26±4	Organic productive tree	28±4	-2	ns	0.3	(-5.1, 1.1)
Traditional farm	26±4	Hi tech conv. productive tree	24±4	2	ns	0.4	(-1.2, 5)
Organic farm	28±4	Traditional productive tree	26±4	2	ns	0.3	(-1.1, 5.1)
Organic farm (n=24)	28±4	Hi tech conv. productive tree	24±4	4*	sg	0.01	(0.8, 7)
Hi tech conv. Farm	24±4	Traditional productive tree	26±4	-2	ns	0.4	(-5, 1.2)
Hi tech conv. Farm (n=24)	24±4	Organic productive tree	28±4	-4*	sg	0.01	(-7-0.8)

Note: *p*-value ≤ 0.05- significant and - *P*-value≥0.05- not significant.
ns=not significant and sg= significant

4.1.4 MEAN DIFFERENCES BETWEEN COMMUNITIES

All the VSA score of the farm types were put together to get overall performance per community. The mean VSA score for Tano Odumasi, Gyereso, Pasoro, and Anansu are 28±3, 28±5, 24±3 and 23±6 respectively.

However, the significant differences between communities and farm types were further investigated. Anansu community was set as the reference community (Appendix C). It was found that there was a significant difference between Traditional farms in Gyereso when compared with Traditional farms in Anansu community which has a *p*-value of 0.04. But there were no significant differences when traditional none productive trees in other communities were compared. Furthermore, it was found that there was significant differences between organic none productive tree of Pasoro community and organic none productive tree of Anasu communities, which has *p*-value of 0.01. But there were no significant differences when organic none productive trees in other communities were compared.

Table 8: Mean Differences for the Communities

Communities	Mean	Communities	Mean	Mean Differences	Significance Difference	*P*-VALUE	95% Confidence Interval for Differences Lower Bound Upper Bound
Tano Odumasi	28±3	Geyerso	28±5	0.0	ns	1	(-3.8, 4.2)
	28±3	Pasoro	24±3	4	ns	0.1	(-0.4, 7.6)
	28±3	Anansu	23±6	5*	sg	0.01	(1.3, 9.3)
Geyerso	28±5	Tano Odumasi	28±3	-0.0	ns	1	(-4.2, 3.8)
	28±5	Pasoro	24±3	3	ns	0.1	(-0.6, 7.4)
	28±5	Anansu	23±6	5*	sg	0.01	(1.1, 9.1)
Pasoro	24±3	Tano Odumasi	28±3	-4	ns	0.1	(-7.6, 0.4)
	24±3	Geyerso	28±5	-4	ns	0.1	(-7.4, 0.6)
	24±3	Anansu	23±6	1	ns	1	(-2, 5.7)
Anansu	23±6	Tano Odumasi	28±3	-5*	sg	0.01	(-9.3, -1.3)
	23±6	Geyerso	28±5	-5.1*	Sg	0.01	(-9.08, -1.1)
	23±6	Pasoro	24±3	-1	ns	1	(-5.7, 2)

Note: *p*-value ≤ 0.05- significant and - *P*-value≥0.05- not significant.
ns- not significant and sg- significant

From Table 8, the mean VSA score between Tano Odumasi and Anansu was 5.28 and this was significantly different with *P*-value 0.01; similarly the mean VSA score of Gyereso was 5.08 higher than Anasu and this was significantly different with *P*-value 0.01. The mean VSA score between Tano Odumasi and Gyereso, Tano Odumasi and Pasoro, Gyereso and Pasoro were not significantly different.

4.1.5 GRAPHICAL PRESENTATION OF ALL VSA INDICATORS FOR PRODUCTIVE AND NONE PRODUCTIVE TREE

The VSA of all 10 indicators for productive and none productive tree were however compared, from the graph below, it can be observed that the VSA indicators for the productive tree appear to be generally doing better than the VSA indicators for none productive trees of the selected farm, except at the number and colour of soil mottles where the none productive tree are slightly doing better.

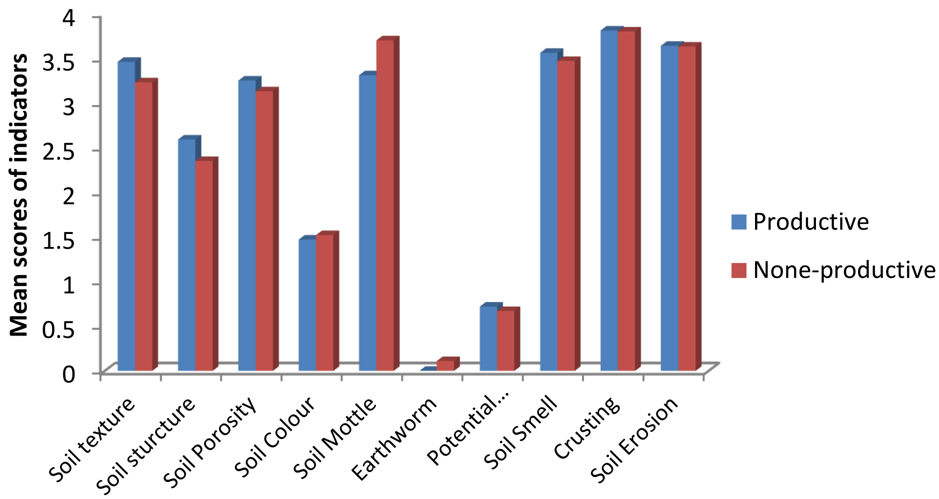


Figure 9: VSA indicators of Productive tree Vs None Productive tree

4.2 CORRELATION BETWEEN VSA AND YIELD

To answer research question two, which is the correlation with VSA and yield? The yield values were from the yield estimates given by farmers. The correlation between VSA and yield were done for all farm types and also between community levels. The yield is measured in bags per 4-5 acres of farm.

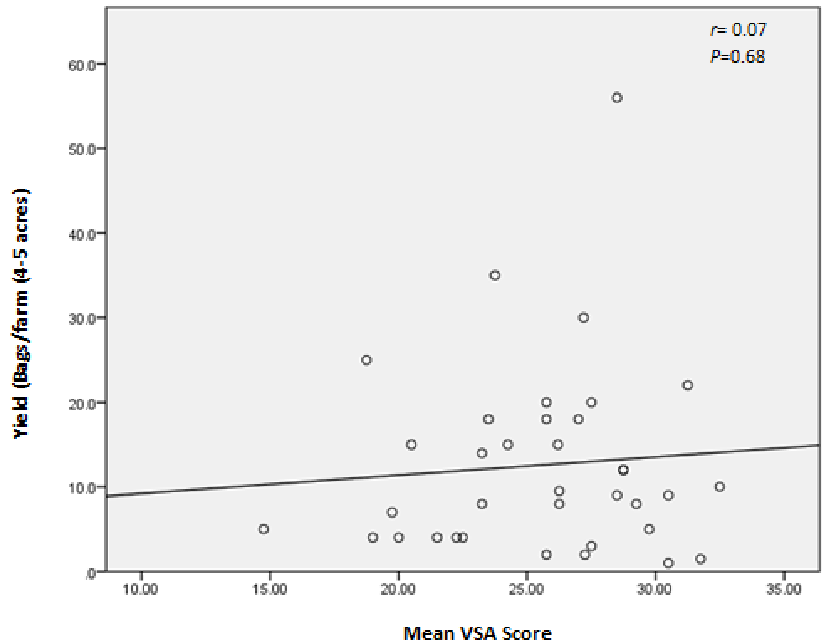


Figure 10: The correlation between VSA score and yield

From the graph above, the correlation between VSA and yield (bags) is 0.070 and this relationship is not significant with a p value= 0.069. This shows that there is weak correlation between them VSA score and the estimate yield.

Table 9: The Correlation between VSA and all 10 Indicators

Indicators	Soil texture	Soil structure	Soil Porosity	Soil Colour	Soil Mottle	Earthworm	Potential Rooting	Soil Smell	Crusting	Soil Erosion
Correlation with yield	0.03	0.14	0.06	-0.07	-0.05*	0.03	0.04	-0.22*	0.06*	0.002

Note: *=Shearman correlation Coefficient Note: Significant= >0.70, Not significant

Furthermore, statistical difference between all ten indicators and the estimated yields was checked, the results shows that all the values were less than 0.70 and hence not significant, which means none was found to have a strong correlation with yield.

4.3 CHEMICAL ANALYSIS

One soil and leaf sample was selected per community for chemical analysis, with the inclusion of one abandoned cocoa farm.

4.3.1 SOIL SAMPLES

Table 10, shows the chemical analysis for the selected farm. The Nitrogen content for Tano Odumasi productive and none productive traditional trees have Nitrogen content 0f 0.16% and 0.14% respectively, this implies that Tano Odumasi has the highest amount of Nitrogen content but except for Hi-tech conventional productive tree in Pasoro communities. Furthermore, the available Phosphorus present in all the soil samples ranges from 0.51- 5.82 mg/kg. While the Potassium in the soil varies between 29.23- 169.59, making the organic productive tree soil of Gyereso farm to have the highest amount of Potassium in the soil and the None productive tree of Gyereso have the lowest amount of Potassium.

However, the Calcium content in the soil samples, it ranges from 1.89-10.41cmol/kg. With Tano Odumasi traditional productive and none productive tree having the highest value of 9.88cmol/kg and 10.41 respectively. Making it the highest amount of Calcium and Gyereso Organic none productive tree having the least amount of Calcium content. Likewise, the Magnesium content for the selected farms ranges from 0.53-4.67 cmol/kg, Tano odumasi has the highest amount of Magnesium content and Pasoro having the lowest content. Out of all the seven cocoa trees investigated only, the abandoned cocoa farm has the low amount Sulphate present in the soil when compared to others.

4.3.2 LEAF SAMPLES

Furthermore, from Table 9, it shows that the Hi-tech conventional productive tree leaf sample in the Pasoro communities has the highest percentage of Nitrogen in all the selected farms (2.47%). While the percentage Potassium for all productive tree was found to be higher than none productive tree for all farm types in all the communities except for Tano Odumasi which the traditional none-productive tree has higher percentage of Potassium than the traditional productive tree. The highest percentage of calcium content was found in both Hi- tech conventional productive and none-productive tree leaf samples of Pasoro community with 0.96% and 0.94% respectively, while the lowest was found in traditional none productive tree of Tano Odumasi and in organic productive tree of tree of Gyereso communities where there values equals 0.60%. The percentage Magnesium content varies from 0.22% - 0.41%. The percentage Phosphorus content for all the cocoa leaves observed to be between the same range of 0.11 and 0.15%. The lowest percentage of Sulphur was found in the abandon farm in Anasu community.

Table 10: Soil and leaf chemical analysis

Chemical Soil	Tano Odumasi (Traditional Farm)						Gyereso (organic Farm)						Pasoro (Hi tech conventional Farm)						Anansu (Degenerated farm)					
	N	**P**	**K**	**Ca**	**Mg**	**S**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Productive Tree	0.2	0.5	61	10	5	192	0.1	2	170	4	1	168	0.1	6	45	5	2	112	0.1	2	44	5	1	24
None productive Tree	0.1	3	29	10	4	140	0.1	3	38	2	1	92	0.01	2	39	2	1	148	-	-	-	-	-	-
Recommended Value	0.09	0.2	-	7.2-11.3	0.80	-	0.09	0.2	-	7.2-11.3	0.80	-	0.09	0.2	-	7.2-11.3	0.80	-	0.09	0.2	-	7.2-11.3	0.80	-
Leaf	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Productive Tree	2	0.2	0.4	1	0.3	1	2.1	0.1	0.3	0.6	0.3	0.4	2.5	0.1	0.3	1	0.2	0.5	2	0.1	0.5	1	0.2	0.2
None Productive Tree	2	0.1	0.5	1	0.4	1	2	0.1	0.2	1	0.4	1	2	0.1	0.2	1	0.4	0.1	-	-	-	-	-	-
Recommended value	2.6	0.2	2.0	0.60	0.05	-	2.6	0.2	2.0	0.60	0.05	-	2.6	0.2	2.0	0.60	0.05	-	2.6	0.2	2.0	0.60	0.05	-

4.4 DISCUSSION WITH FARMERS

Figure 11: Discussion with farmer while carrying out the VSA procedures

Here the outcomes and findings from the discussion with farmers are presented in relation to research question four. The discussion was guided by a list of checklist questions (Appendix D). The checklist helps to keep an eye on the conversation but not necessarily followed the order that they were written.

As earlier mentioned, while carrying out the VSA procedure, the farmers were engaged in a discussion with the help of the translator. Typically the VSA procedure should not last for more than 40minitues, but with the discussion it lasted for about 1 hour to 1 hour 30mintues. All the selected farmers were happy that their soil is been examined. "Nobody has come to check my soil before and I am still surprised that you are here"[7] .

The selected farms were between 5 to 10 hectares and the age of the farms were between 10 to 30 years of existence. All selected farmers said their farms were either re-established cocoa farm[8] or secondary forest before been used for cocoa farm. All the farmers planted at stalk and none of the farms undergo land preparation before planting, but in the recent times farmers have started to transplant from nursery. Tano Odumasi and Anansu farms were seen to be close to river bodies, Tano River and Anasu River respectively. In both communities the traditional farms are closer to these rivers, making them vulnerable to soil erosion sometimes. During the rainy season the Tano and the Anansu River erode to the nearby farms causing them serious problem, such as water erosion which damage their cocoa trees. "The major challenge on my farm is that the Anansu River overflows to my farm during rainy season".[9]

[7] Mr Ajoah Ofree, a traditional farmer in Tano Odumasi community.
[8] Renewed cocoa farm after long period of been abandoned.
[9] Mr Kwame , traditional farmer in Anasu community

The perception of farmers in term of soil fertility varies, the traditional farmers were found not to be satisfied with the current status of the soil, and the major constraint they all complained is about to improve to buy inputs to improve their soil. Most traditional cocoa farmers complained of not having money to buy fertilizer, to hire labour and also complained about lack of access to input loans. The opinion of organic farmers differs, majority of them were satisfied with the current status of their soil, while some were not satisfied. Whereas, the Hi-tech conventional cocoa farmers agreed to be satisfied with the current state of their soil, but will like to improve it.

Most farmers, especially the Hi-tech cocoa farmers complained of receiving very little or no training on soil, pest management and are all willing to attend trainings if provided for them. Organic cocoa farmers generally agreed of attending meetings but some of them complained of not having enough time to do so.

It was also found out that majority of the farmers do not throw pods around, all they do is break the cocoa pods on a particular spot, and some of the excuses they gave for this practice is that, the empty pods are used to estimate the amount of bags from each harvest, especially for farmers that hire labour for breaking of pods. But when further asked if they throw the pods around afterwards, they could not give a convincing answer. "I was told that throwing healthy cocoa pods around on the farm is good for the soil, I did sometimes, but I rarely do it now."[10] One of the organic farmer claimed that he is not aware that he has to throw healthy pods around the farm or bury infected pods far away from the farm.

The farmers were further questioned if they have seen any changes in amount of yield, a large number of the organic farmers' agreed that they have noticed some changes in yield in the last few years, while the traditional farmers complained bitterly on the drastic decrease in yield. And more or less all Hi-tech conventional farmers consider their yield to remain the same in the last few years.

It was observed that most of the Hi-tech conventional cocoa farmers in the selected communities were found to be better than the other farm types when it comes to replacement of nutrients. They apply chemical fertilizers on their farms at least once in 1-3 years. Unlike the traditional and organic cocoa farmers who hardly nourish the soil, some were found not to add anything to the soil in the last 10-15 years of farming on the same. This practice cut across all the selected communities, only for few organic farmers that were given free poultry dropping in Anansu community, when the organic project started in 2012 and they have not applied any fertilizer since then. Furthermore, farmers give priority to spraying of pesticides, they believe it's better to spray than to add nutrient to the soil. And they consider spraying as the only way to increase yield. "I know spraying and adding fertilizer are both important but I prefer to spray to prevent diseases than to add fertilizer to the soil, so I maintain what the soil gives me"[11]

[10] Mr Ekuya Esibo (organic cocoa –Gyereso community

[11] Mr Koffi Owusu Hi- tech conventional farmer Anansu community

It was further observed during the discussion that farmers copy and follow the trends of other farmers they presume to be doing better than them. “I once saw my neighbour throwing pods around in his farm, and I did the same thing, but when he stopped I also stopped”[12]

Wide range of the farmers does not have clear intention on how to improve soil fertility. They hardly have any concrete plan to foster soil management. They rely on the government and extension officers to come tell them what to do time to time and even wish the government could come do it for them. Even though the knowledge is not lacking, they hardly do as told. During the discussion with the purchasing clerk of Pasoro community, he said “Some farmers are just lazy and do not see their farm as a business, they don’t want to put anything into the farm and want to get more, as for me I have decided to work hard on my farm”.[13]

All the farmers pointed out that funds to hire labour, access adequate farm implements (cutlass, boots) and input loans are their main challenges when it comes to soil fertility. A large number of farmer also complained of not having the strength to work on farms for too long, as they are getting old and becoming weak. Majority of the farmer’s children are away in the city and not interested in cocoa farming. Aside from money and loans, farmers also complained about pest and diseases as those factors that hinder their yield. Black pods and insects such as capsids are examples of the pest and diseases that are prominent in the selected communities.

When farmers were asked what kind of support they think cocoa farmers in the community needs, better part of the farmer want money to be provided for them while some agreed that training on how to have improved soil is essential.

4.4.1 COMMUNITY MEETING

After various discussions with all selected farmers in the communities, one community meeting was held in Gyereso. Gyereso was selected, because the scheduled community meeting coincided with their periodic meeting, which makes the farmers readily available. Another reason for the community meeting was to use the opportunity to see farmer’s attitude towards trainings and also to meet with the other farmers that their farms were not selected for the VSA procedure. And to further hear their views on better soil management. About 25 farmers attended the community meeting; all types of farmers were present ranging from Traditional, Organic and the Hi-Tech conventional farmers.

The most interesting thing is that the farmers have different views when it comes to soil fertility, some were very satisfied with their soil, while some were extremely sad about the current state of their soil. Another striking thing that was observed during the meeting was that, large number of the farmers shows little interest in knowing about soil fertility, while some are very keen on how to better improve their soil. Most of the organic farmers said they have also noticed changes in the yield, while some said they have not notice any positive change in yield. This is similar to what was observed while carrying out the VSA procedure with other farmers. The challenges presented were not different from what have been mentioned before by other farmers.

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[12] Mr Ekuya Esibo organic farmer Gyereso community

[13] Mr Akwa David Purchasing clerk Pasoro community.

In the course of the community meeting, it was noticed that some farmers left the meeting after some minutes, and it was later discover those farmers left because there were no refreshment available at the venue and no money was going to be shared to them after the meeting.

It was during the meeting that one of the farmers Mr Effong, made it clear that training is not the main thing that is lacking for farmers is lacking but the attitude of the farmers themselves towards training. He said “The government/ the extension officers are trying their best in training, but sometimes farmers are not serious with training, they just go for the sake of going and do not apply what they are taught. Even, some farmers keep the manuals and booklet given to them under their beds.”[14] Another farmer also said she believed that the farmer needs monitoring and enforcement. “I think some people should be elected among us to go around to be checking what farmers are doing on their farms”[15] .

[14] Mr Effong Hi-tech conventional farmer of Gyereso community during the community meeting
[15] Mrs Isiaka organic farmer of Gyereso community during community meeting

4 DISCUSSIONS

In this chapter, It is important to note here that the Visual Soil Assessment (VSA) procedure that was used in this research has not been done before in a cocoa field and also it has not been done for productive and none productive trees. So it is difficult to find lots of articles/previous research to back up the findings in this research.

The VSA procedure appeared to be considerably quick and serves has a good tool to access soil quality on cocoa farms, which can be done on a vast variation of soils. However, it should be noted it gives best results when the soil is not too dry or not too wet. The 37 selected farms were sampled and analysed for approximately 6 weeks. The procedure proves useful in recognizing areas where compaction and drainage might affect growth of tree. Another key advantage of this procedure is that, it provides a summarized and standardized description of soil in three levels (poor, moderate and good). Furthermore, the VSA procedure has been accepted by researchers and the Food and Agriculture Organization (FAO) is one of the front liners in propagating the procedure and have sponsored series of projects in which the procedure is been used.

One of the limitations of this procedure is that it is subjective; it is totally dependent of the person carrying it out. The procedure also has to do with the observer sense organs, for example part of the procedure involves smelling and looking carefully at soil porosity, so any impairment of the nose or the eye could lead to authentication of results. Hence, the person with any of these sense organ defect should not carryout this procedure or should be assisted with a person without the deficits. Furthermore, as an organic student, who is more on the organic side; this could also serve as a weakness to some of the findings and might tend to be biased. And it is advisable that one should keep an open mind while carrying the VSA procedure.

The results from all the VSA scores for the selected farms shows that majority of the farms have slightly moderate VSA scores, some have poor and very poor VSA scores, while few of the farms have good VSA score. This implies that, if the moderate soil remains like that and nothing is been done, they might tends to start falling into poor VSA score in near future. And this will lead to soil degradation and all other consequences associated with soil degradation.

From the position of productive tree it was observed that the difference between organic productive and Hi- tech conventional productive tree is significant. The reason for this difference could be because of the use of organic fertilizer on organic farm and chemical fertilizer on conventional farm for a long period of time. Vigneri in 2008 also observed that the use of chemical fertilizer among cocoa farmers in the cocoa production regions of Ghana have increased from 10 percent to about 50 percent, from 1991 to 2007, it is believe to continue to increase (Vigneri, 2008). Chemical fertilizers acidify the soil invariably reducing the amount of earthworm present in the soil. Furthermore, the organic fertilizer has been proved to enhance soil properties, especially to improve soil structure but it is slowly released to the plants making it available to plant when needed[16]. These findings support the hypothesis that was presented, that Hi-tech convectional farm will have the worst VSA result. This does not mean that the Hi-

[16] http://ieassa.org/en/tag/organic (Assessed 20/2/2015)

tech productive trees are not doing well compared to other productive tree in the selected communities since these differences are not significant.

The none-productive tree at different farm levels shows that, the differences between organic none productive tree and traditional none-productive only appears to be significant. What this means is that organic none-productive tree is still doing better, but this time better than the traditional none-productive tree in the selected communities. One of the reasons for this could also be from the use of organic fertilizer in the organic farm too. Because all the traditional farms analysed in this research rarely apply any kind of fertilizer on their farm. It will be expected that the organic none productive tree will as well be doing better than the Hi-tech conventional none productive tree, but this is not the case. It could be that the Hi-tech conventional farmers focus more on none productive tree to attain a productive status. However, these results further supports the hypothesis that organic farms will have better VSA score compared to the Hi-tech conventional farms. However, as expected the overall VSA score of the Productive tree is doing much better than the none-productive tree of the selected farms. The productive trees have better soil texture, soil structure, potential rooting depth, and soil smell. Nonetheless, the None productive tree have better soil mottle.

Overall, at the community level, it was observed that Tano Odumasi is better than all the communities in term of the VSA score but only significant when compared with Gyereso community. The reason for this could as result of the linear arrangement of these communities. When coming from the city (Kumasi) Tano Odumasi is the first community. It is very possible that they benefit more from new technologies than others. The free pesticides spraying and free fertilizer programs by the government gets to them first, before going to the rest of the other communities. The distance between Tano Odumasi and Anasu community for example is approximately 14 km. Extension officers/government agencies might find this far, coupled with bad roads networks which leads to the other communities and might even be totally inaccessible during rainy season. On the other hand, Tano Odumasi has better road networks and the farms are easily assessable. For instance, when sharing free fertilizers for farmers, Tano Odumasi is usually the first community to start receiving them and might finish before getting to the rest of the communities. However, these factors did not play a role when selecting the communities.

It was revealed in this research that, the VSA result of each of the ten indicators shows weak correlation with yield. The total VSA scores also show that there is no positive correlation between VSA and yield. This simply means that VSA indicators are unlikely to limit cocoa production. The VSA procedure did not clearly give a certain level at which a score will limit production and but any VSA score below 15 is poor and it appears bad for the soil. Ball and Douglas (2003) in their work on assessing soil structural rooting and surface conditions on arable organic farms using spade diagnosis, a procedure very similar to VSA ,they established that structural properties of the soil is not limited to crop production. Furthermore, Shepherd et al. (2002) also reached the same conclusion in their VSA research on 33 organic farm soils in England. They also found that good soil structure does not necessarily mean increase in yield, but offers other positive impacts, such as water retention, soil infiltration and aeration. This is totally the opposite of what was presented in the hypothesis part of this report that a good VSA score will lead to better yield. Other factors such as, pruning, good shade management, and pest and disease control contributes to increase in cocoa yield. Boateng in 2003 described that pests and diseases are also factors that leads to decline in soil fertility. While poor agronomic practices also contribute to decrease of cocoa yield (COCOBOD, 2003). However, the estimated yield value presented by the farmers might not be a true representation of the actual yield value; the farmers might underestimate or overestimate. In a report by MIT and Harvard University they found out that cocoa farmer generally overestimated or underestimated their yield by about 40-60% (Hainmueller et al., 2011). Though, the organic farmers yield estimate is more reliable, than the rest of the farm types because of record keeping through the well-coordinated organic programme in the selected communities.

Research question three of this report, which is to find the correlation between chemical analysis and VSA analysis could not be answered due to financial constraints to analysis all the soil and leaf samples. The research question was to further validate the VSA findings. Nevertheless, the few soil samples that were analysed were compared to chemical standards from different articles to check whether the amount of nutrients present in the soil is below or under critical/recommended values.

When the calcium content of all the selected farms was compared to the recommended calcium content of a cocoa farm, it was observed that Tano Odumasi traditional farm has satisfactory calcium content for cocoa production (10.41- 9.88 cmol/kg for both trees respectively), when compared with critical amount of calcium in the soil for cocoa production which is between 7.2- 11.23 cmol/kg (Aikpokpodion, 2010). Hence, the application of calcium fertilizer is necessary in other farm types.

Pasoro Hi-tech conventional none productive tree has Magnesium content of 0.53 cmol/kg and was the only sample that was found to have less than the recommended value for Magnesium for cocoa soil which is 0.80 cmol/kg (Lombin and Fayami, 1979). All other farms have values higher than the recommended Magnesium value for cocoa production. Furthermore, it was observed that all productive trees in all farm types and communities have higher Magnesium values than none productive tree and abandon farm having low high Magnesium content. The deficiency of Magnesium in Pasoro Hi-tech conventional none productive tree could be related to high sand content observed in the community , this might have some effect on the soil Magnesium leaching down the soil in presence of high amount of rainfall. Molindo et.al (2009) carried out an experiment in nine different temperate and tropical soils and discovered variation in the distribution of Magnesium; silt fraction of the soil contained about 22 to 42%, clay contained 51-70% of the total Magnesium present, while sand contained 0.1-11% of the total Magnesium present. This could explain the low amount of Magnesium content in Pasoro community. The percentage Phosphorus content for all the cocoa leaves observed to be between the same range of 0.11 and 0.15% and was slightly below the critical value for foliage in cocoa of 0.2% of Phosphorus (Egbe and Obatolu 1989).

Again, Tano Odumasi traditional soil samples have the amount of Nitrogen that is higher than the critical level for Nitrogen (0.09%) for cocoa production presented by Egbe and Obatolu 1989. While Pasoro organic productive tree Nitrogen value equal to the recommended value. The Nitrogen content of the selected farms is expected to be higher in all the selected farms, because the rate of Nitrogen removed by cocoa beans from the soil is less than in the litters. According to a review done by Hartemink in 2005 about nutrient cycling in cocoa ecosystem in Venezuela, Costa Rica, Malaysia and Cameroon, it was observed that the amount of Nitrogen in the litter cocoa was almost twice the amount removed by

cocoa yield. But the reverse was observed in the other selected communities. Furthermore, one will except the Hi-tech convectional farm to have the highest amount of Nitrogen because of their heavy reliance on chemical fertilizers, but it has been found that inorganic fertilizer have slight or little effect on the soil under shaded coca management (De Geus, 1973 and Wessel 1985). Whereas, Phosphorus content in the selected farm was also found to be extremely low than the critical level of Phosphorus content in cocoa soil which is 10 mg/kg. The Potassium content of the selected cocoa leaves varies from 0.15-0.45% which is really low compared to the critical level for Potassium of 2.0% except in cocoa leaf. While the Calcium content in all the cocoa leafs of the invested farms in all communities to be within and above 0.60% which is the recommended level for calcium content in cocoa leaves (Egbe and Obatolu 1989). Magnesium content in the leaves of the entire selected farm of all the communities were below the recommended level of Magnesium in Cocoa leaves which is 0.05% (Thompson and Troeh, 1978). While looking at the table for soil sample results it can be observed that the amount of Magnesium is higher than the recommended value in the soil and the amount of Magnesium in leaves is lower than the recommended value, this could be as a result of immobilization of Magnesium within trees (Wessel 1985). Huge amount of Phosphorus in the cocoa ecosystem is present in the vegetation and in the leaves, and the amount of Phosphorus is still very low and the amount lost in the soil is largely removed by cocoa beans (Ogunlade and Aikpokpodion, 2006). Furthermore, they reported that, the leaves that fall in the cocoa field is not enough to supply the amount of Phosphorus needed for optimal yield.
It could be observed that there are wide ranges between the chemical results of the selected farms; these could be as a result of choosing the soil and leaf samples from different farm type and at different communities.

During the field work, it was observed that most farmers were generally lazy towards their farms and hardly replenishes the soil with any form of fertilizer to restore lost nutrients. They like freebies, this could be as result of the free fertilizers and free spraying system provided by the government in the past years. They are so used to it and some of the farmers do not see reason while they should spend their money on inputs. Because of the attitude of these farmers towards their farms, one will think the farmers have other sources of income other than their cocoa farms, but it is not usually the case for many of the farmers. It is only most of the traditional farmers that were observed to have other occupation such as bricklayer or work as labourer in other farms.

It was also noticed that the organic farmers shows better attitude to their when compared to the other types of farmers. Reason was that, they showed inquisitive nature when the VSA procedure was be done. And they seem to have more knowledge towards better soil management and other farm practices. This could be as a result of the series of training received by the organic cooperative group.

Furthermore, in Anasu community, it was observe that the organic farmers in the community were more conscious of the organic principles than the rest of the other organic farmers; this may possibly because of the presence of the organic agency office located in the community. The office is located in a place where the farmers could see the office while going to their farms in the morning, this may serves a constant reminder for the farmers to implement organic principles. It was noticed that most of these farmers are afraid of been sanctioned from the organic group. So, it could be concluded the most of the organic farmers become organic because of the premium they get and not necessarily for other benefits of organic system. This should not be the case, since being organic farmer should be willingness to do it, and ought not to because of the premium involved.

It was pointed out by most of the farmers that the VSA procedure was done on their farms, that less attention is placed on soil management during training. And they all think they need more training on better soil management. However, on the contrary while speaking to one of field officers, it was made to be clear that attention were actually given to soil management during training, but that farmers hardly implement what they were taught during training. And if they do, it is only for sometimes and they will drop it and go back to their old ways of doing things.

Farmers complained about lack of access to loans, but it was observed that even if they have access to these loans they spend them on other personal needs other than on their farms. Furthermore, majority of the organic farmers complained not having access to organic poultry droppings even when they the money to buy them. When asking farmers about whether they have noticed changes in term of yield in the past few years, there were differences in opinion between the three farm types, only the organic farmers were claimed they have seen positive changes in yield.

During the field work and while carrying out the VSA procedure on the selected farms, it was observed that Pasoro community has a very sandy soil. Making the soil less favourable for cocoa production, the idea soil for cocoa is loamy or clay soil. However, the farmers in this community have recognized this and some of the cocoa famers decided to collectively reduce the problem. By contributing money in groups to buy poultry droppings to enhance the soil fertility and hence increase yield. Pasoro commountiy is the only community where farmers were found to be doing this.

5 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The aim of the research was to investigate the correlation between Visual Soil Assessment (VSA) and yield in three different farms (traditional, organic and Hi-tech conventional cocoa farms), to determine whether there are relationships between VSA score and yield. Also check if there is correlation between chemical analysis of the soil and yield. Then identify the incentives and challenges farmers face in soil fertility management.

It can be concluded that there are differences between the VSA scores of all farm types, while the organic farms are doing better compared to other farm types. Furthermore, there were differences at community levels; Tano Odumasi VSA score was also doing better than the rest of the communities. However, it could also be concluded that VSA do not solely determine yield but other factors such as tree management also contributes to increase in yield.

The correlation between chemical soil analysis and the VSA scores could not be established in this research and to investigate whether a good soil chemical result will mean a good VSA score and vice versa. This was due to financial constraint to carry out the chemical analysis. Nevertheless, from the result of the purposeful chemical analysis of the selected farms, Tano Odumasi, was doing better than the rest of the communities. Similarly, the community also has an overall better VSA scores compared to all other communities. But this is not enough evidence to conclude that a better VSA score means a good chemical result. Large amount of both soil samples and VSA procedure needs to be done to logically affirm if better VSA results to good chemical results.

It was also discovered that farmer's biggest motivation is money, when it comes to good soil management implementations. Raising farmer's market share would be a way to also help boost their motivation to better soil management. When the price of cocoa is too low, and too low to meet their basic input and labour cost. Farmers becomes less motivated towards farming, even tend to reduce planting activities and other soil management activities on their farms. In extreme cases, farmers are less motivated to harvest. On the contrary, when cocoa price goes up, farmers will tend to increase farm management through improved soil fertility, tree management and other farm practices.

The application of both organic and inorganic fertilizer is low in Ashanti region, especially in the four selected communities. Farmers do not undertake basic soil fertility management practices, such as composting and applying of crop residue. So therefore, it could be conclude that the farmers are taking more than they are putting back into the soil.

The findings of the study shows that the VSA procedure can be adopted by cocoa farmers and could serve as a tool to predict soil fertility and also serve as early warning on soil degradation. Majority of the farms examined falls under moderate soil quality index, and if care is not taken these will end up having poor soil quality index, which is derogatory to the soil.

When looking at the future prospect of cocoa production in Ghana, the demand for cocoa is continually increasing, bringing pressure on cocoa farmers to produce more, invariably putting pressure on farmers' means putting pressure on the soil. So therefore, the government, NGOs, Research institutes and other players involved in cocoa production should also focus more on the soil, if they want increase in cocoa production.

The younger farmers contacted in this research shows more enthusiasm towards their soil, and are curious to know more about their soil than their older counterparts. This has always been the case and it a long standing challenge for cocoa production. Hence cocoa farming needs to be made economically attractive for more youth to venture in cocoa farming.

6.2 RECOMMENDATIONS

From the conclusions, the following recommendations are proposed; due to the fact that farmers do not pay attention to soil management, it would be valid to say that extension officers should encourage farmers to pay more attention to soil fertility especially during trainings.

Special attention should be given to Pasoro community because of the high content of sand in the soil; the ideal soil for cocoa cultivation is loamy soil or better still clay soil. The use of organic poultry dropping will help enhance the soil in this region. Simple techniques should be employed such as spreading healthy pods around, turning over leaf residues contribute a lot to soil fertility. Turning over the leaf residues speeds up the rate of decomposition and will also increase the rate at which nutrients from the leaf is released to the soil. Furthermore, farmers in other community could emulate what is been done in Pasoro community, by contributing money to buy bulk of poultry dropping and then shared among themselves than complaining of not having access to it.

Farmers living close to the farm can rear chickens. The farmers do not have to bother about housing the chickens because they can easily sleep on the tree. The chicken can also live freely on the farm. While searching for food by scratching the soil, they help turn over the soil and also increase the rate at which the leaves decay. Likewise, the chickens dropping is directly added to the soil and the farm might not need to buy poultry droppings again. However, these chickens can also serve as extra income for the farmers. As local chicken breeds are in high demand in Ghana and tends to be more expensive than the poultry feed ones.

Planting of leguminous trees as shade trees will help fix Nitrogen in the soil and also serve the purpose of shade trees. And the farmers can also sell this tree as timber later on, which will serve as a long term investments for them too.

Different approaches could be used to transfer knowledge to farmers, so that they could have attitudinal change towards their farms. For example, officer can serve as a constant reminder to the farmers, because it was observed that farmers tend to respect these field officers as they see them as government officers. Furthermore, because VSA involves direct contact and observation of the soil with farmers, it serve as a contact point to discus with farmers and this might lead to change of attitude of the farmers.

The unavailability of fund is one of the major constraints to prove detailed chemical soil analysis for this research, which invariably is not enough to make valid statements on the chemical aspect of this research. Some therefore, I recommend that whoever is willing to carry out this type of research in future should have sufficient funds available before the commencement of the research.

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APPENDICES

APPENDIX A: VISUAL SOIL ASSESSMENT SCORE CARD

VISUAL SOIL ASSESSMENT (VSA) SCORECARD

Farm type: **Land owner:** **Soil type:**

Tree type: **soil classification:** **Date:**

☐ Textual gro☐upper 1m): ☐ Sandy ☐ Loamy ☐ Silty Clayey Other			
Moisture condition: ☐ Dry ☐ Slightly moist ☐ Moisture ☐ Very moisture ☐ wet			
Seasonal weather condition ☐ Dry ☐ Wet ☐ Cold ☐ Warm ☐ Average			
Visual indicator of soil Quality	**Visual Score (VS)** **0 = poor condition** **1 = Moderate Condition** **2 = Good condition**	**Weighting**	**VS Ranking**
Soil texture		X 3	
Soil structure		X 2	
Soil porosity		X 3	
Soil colour		X 1	
Number and colour of soil mottles		X 2	
Earthworm (Number =) (Average size =)		X 3	
Potential rooting depth(mm)		X 2	
Surface ponding		X 2	
Surface crusting and surface cover		X 2	

Soil erosion (Wind/water)		X 2	
SOIL QUALITY INDEX			
Soil assessment	**Soil quality index**	**Soil assessment**	**Soil quality index**
Poor	< 15	Poor	< 15
Moderate	15-20	Moderate	15-20
Good	>30	Good	>30

APPENDIX B: OTHER PICTURES

Taking soil samples at 50cm
from the bottom of the cocoa tree

showing the root depth at 30cm

Materials for VSA procedures

Drop scatter test

Community meeting with the farmers in Gyereso

APPENDIX C: THE INTERACTION BETWEEN FARM AND COMMUNITY UNDER NONE PRODUCTIVE TREE

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	20.500	1.755	11.683	.000	16.879	24.121	.850
[Farm=1]	-3.500	2.481	-1.410	.171	-8.622	1.622	.077
[Farm=2]	7.333	2.481	2.955	.007	2.212	12.455	.267
[Farm=3]	0[a]	.	.	.	.	.	.
[Community=1]	6.500	2.481	2.619	.015	1.378	11.622	.222
[Community=2]	4.333	2.481	1.746	.094	-.788	9.455	.113
[Community=3]	5.133	2.481	2.069	.050	.012	10.255	.151
[Community=4]	0[a]	.	.	.	.	.	.
[Farm=1] * [Community=1]	2.667	3.509	.760	.455	-4.576	9.910	.023
[Farm=1] * [Community=2]	7.833	3.509	2.232	.035	.590	15.076	.172
[Farm=1] * [Community=3]	2.833	3.509	.807	.427	-4.410	10.076	.026
[Farm=1] * [Community=4]	0[a]	.	.	.	.	.	.
[Farm=2] * [Community=1]	-5.000	3.509	-1.425	.167	-12.243	2.243	.078
[Farm=2] * [Community=2]	-1.500	3.509	-.427	.673	-8.743	5.743	.008
[Farm=2] * [Community=3]	-10.300	3.509	-2.935	.007	-17.543	-3.057	.264
[Farm=2] * [Community=4]	0[a]	.	.	.	.	.	.
[Farm=3] * [Community=1]	0[a]	.	.	.	.	.	.
[Farm=3] * [Community=2]	0[a]	.	.	.	.	.	.
[Farm=3] * [Community=3]	0[a]	.	.	.	.	.	.
[Farm=3] * [Community=4]	0[a]	.	.	.	.	.	.

a. This parameter is set to zero because it is redundant.

APPENDIX D: CHECK LIST QUESTIONS

1. What is the size of your farm?
2. What is the farm used for before?
3. Do you do any land preparation before you plant?
4. Is your farm close to a river/water body?
5. How will you describe the amount of rainfall on your farm?
6. Can you estimate the fertility of the soil on your farm?
7. Do you prune your cocoa tree?
8. Do you do any tillage system?
9. Do you own livestock? Do you allow them to walk freely on your farm?
10. How will you estimate the fertility of your soil?
11. Have you received any training about soil fertility in recent times?
12. Have farm officer/ extension officer come to check the fertility of soil lately?
13. Are you satisfied with the current fertility of your soil?
14. Will you like to improve the soil fertility?
15. Can you describe what you do to maintain soil fertility on your farm?
16. Can you describe any problem you have had in connection to the soil fertility on your farm?
17. Do you intend to plant more cocoa in the future?
18. How do you view the fertility of your soil in the future?
19. What strategies to you intend to employ to improve the soil fertility?
20. What kind of support do you think cocoa farmers need to improve their soil fertility?