www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

ASSESSMENT OF SPATIAL AND TEMPORAL AVAILABILITY AND QUANTITIES OF ORGANIC RESIDUES IN THE TAMALE METROPOLIS OF NORTHERN REGION OF GHANA

BY

AMIDU CHINNIA ISSAHAKU

(UDS/MHT/0011/14)

A THESIS SUBMITTED TO THE GRADUATE SCHOOL, UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE, GHANA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL HORTICULTURE

SEPTEMBER, 2020

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

ASSESSMENT OF SPATIAL AND TEMPORAL AVAILABILITY AND QUANTITIES OF ORGANIC RESIDUES IN THE TAMALE METROPOLIS OF NORTHERN REGION OF GHANA

BY

AMIDU CHINNIA ISSAHAKU

(UDS/MHT/0011/14)

UNIVERSITY FOR DEVELOPMENT STUDIES

A THESIS SUBMITTED TO THE GRADUATE SCHOOL, UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE, GHANA, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL HORTICULTURE

SEPTEMBER, 2020

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

DECLARATION

I hereby declare that this submission is my own work towards the MPhil. Horticulture degree and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, or any other university/institution, except where due acknowledgement has been made in the text.

Amidu Chinnia Issahaku	....	....
(Student)	Signature	Date
Dr. Shu-aib Jakpa Sumaila	....	....
(Supervisor)	Signature	Date
Prof. Abdul-Halim Abubakari	....	....
(Co-Supervisor)	Signature	Date
Prof. Abdul-Halim Abubakari	....	....
(Head, Department of Horticulture)	Signature	Date

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

ABSTRACT

This study was conducted to assess the spatial and temporal quantities of organic residues in the Tamale Metropolis. Stratified sampling technique was used to divide the Metropolis into four zones: Jisonayili, Vittin, Kalpohin, and Nyohini. Simple random sampling technique was used to select 90 people in the zones who generate organic residues and interviewed using administered semi-structured questionnaires. Data was gathered from the respondents as well as by weighing and recording the organic residues they generate. The data was analyzed using using Microsoft Excel and Genstat statistical packages and the results were interpreted using descriptive statistics and presented in the form of tables, histograms and pie-charts. The findings show that the total amount of organic residues produced in all the four zones in the Metropolis was 4932.2 tons yr^{-1}. An analysis of the results indicates that the zones significantly differed ($p < 0.05$) in the quantities organic residues produced, with Jisonayili producing the largest quantities of the residues (2937.3 tons yr^{-1}), followed by Nyohini (914.4 tons yr^{-1}), with Kalpohin producing the least (269.7 tons yr^{-1}). Costs incurred in obtaining organic residues also differed significantly ($p < 0.05$), with the cost of buying the organic residues being the highest (GhȻ 1317.50 ton^{-1}), followed by packing cost (GhȻ 799.00 ton^{-1}), with cost of transport (GhȻ 151.50 ton^{-1}) being the lowest. Further analysis shows that the uses differed significantly ($p < 0.05$), with the crop residues used as animal feed having the highest percentage (96.6 %) of the respondents, followed by residues used for domestic fuel (95.6 %). Organic residues used for the generation of electric power through the production of biogas was mentioned by the least percentage of respondents (26.7 %). Spatial and temporal availability of organic residues differed significantly ($p < 0.05$), with the September-November period (ranked first) mentioned by 53.3 % of the respondents as the period in which organic residues in the Metropolis are mostly available. This was followed by the December-February

www.udsspace.uds.edu.gh

period (ranked second) which was mentioned by 32.2 % of the respondents as the period of availability of organic residues. The least likely period of availability of organic residues in the Metropolis was identified by 14.4 % of the respondents being 'throughout the year'. Constraints related to availability, processing, management and utilization of organic residues differed significantly ($p < 0.05$), with transportation of crop residues from crop residue processing centres and food selling points to the house being the most pressing constraint (41.0 %). This was followed by difficulty in getting some crop residues because of lack of adequate quantities of crops for processing into residues (19 %). Infestation of crop residues by insects and pests (2.0 %) was the least ranked constraint by the respondents. On the basis of the findings of this research, it is recommended that the Ghana Government, through the Ministry of Food and Agriculture, should organize workshops and skills training programmes for the people in the Metropolis on the treatment and use of crop residues in making compost for increasing the soil fertility. This will not only help reduce the costs of improving the fertility of the soil as well as increase yields of crops but will also increase the knowledge and interest of the people in agriculture as well as crop residue management.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

ACKNOWLEDGEMENTS

I wish to express my enormous appreciation to the Almighty Allah, for guiding me in my entire academic life.

I will also like to sincerely thank my supervisor, Dr Shu-aib Jakpa Sumaila, who sacrificed his precious time to offer useful comments as well as guidance and direction on this thesis. I also wish to express my heartfelt appreciation to my co-supervisor, Prof. Abdul-Halim Abubakari, for his technical advice and useful input into this work. The contributions of other departmental lecturers are also greatly appreciated.

I thank the respondents in the Tamale Metropolis who willingly and patiently cooperated with me during the data collection stage of this research. Special 'thank you' also goes to Mr. Ziba Daniel and Mr. Seidu Mohammed for their help during the data gathering and analysis stage. I also thank the several crop residues processing centres, food sellers and individuals who provided immense support during my research.

Finally, I wish to express my appreciation to my family for the love and care they extended to me in the course my studies.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

EDICATION

I dedicate this research to my entire family, especially children; Chinnia Habuku Abiba, Amidu Issahaku Chinnia Jnr and Chinnia Ndaabomo Muhibatu as well as my loving wife Bipuah Sheitu.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

TABLE OF CONTENTS

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

LIST OF TABLES

Table **Page**

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

LIST OF FIGURES

Figure **Page**

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

LIST OF APPENDICES

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

LIST OF ACRONYMS

CRM	Crop Residue Management
DM	Dry Matter
EC	European Commission
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GPS	Global Position System
IFPRI	International Food Policy Research Institute
INF	Inorganic fertilizers
MoFA	Ministry of Food and Agriculture
NGOs	Non-Governmental Organizations
SCIS	Smallholder Crop-livestock Integrated System
SOM	Soil Organic Manure
SSA	Sub-Saharan Africa
UNESCO	Unity Nations Education Scientific and Culture Organization

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Agriculture continues to be one of the main sectors which provide employment for most people in Ghana as a result of over 60 % of the population of the country relying on agriculture and related activities as sources of their livelihoods (MoFA, 2011). Agriculture thus plays a vital part in promoting development and poverty reduction in Ghana (Egyir & Beinpuo, 2009). It is obviously the aim of farmers in Ghana to harvest high yields of crops as well as guarantee their nourishment or benefit as they rely on these crop yields for their sustenance.

Crop remains are a vital resource as a source of substantial amounts of nutrients for crop growth and also affecting soil, biological functions, chemical and physical properties as well as water and quality of the soil. When crop remains are incorporated into soils, their decomposition is capable of having negative and positive impacts on crop growth as well as the environment. This can only be accomplished by proper understanding of crop residues, the soil and its interactions and management factors which have effects on the processes of nutrient breakdown. Statistics on benefits as well as recoveries of nitrogen from crop remains demonstrate a significant amount occurs in crop remains, specifically leguminous leftovers and also increasing the continuing fertility of the soils. It has nevertheless been noticed that crop yields in a lot of the regions in the country have been on the decline. It is worth noting that, reduced yields of 1.2 t ha^{-1}, 11 t ha^{-1} and 16 t ha^{-1} in comparison with their possible yields of 5 t ha^{-1}, 28 t ha^{-1} and 37 t t ha^{-1} for main crops like maize, yams and cassava, respectively, are provided (MoFA, 2003 and SRI, 2003).

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Thus, the significance of this risk is very huge, resulting in food shortages and insecurity of food supplies, thereby making it necessary for the country to import huge quantities of food. One of the main aims for this predicament is the inability of the farmer to buy enough inorganic fertilizers and obtain sufficient information on how to apply organic fertilizer to their crops. The function of crop residues in maintenance of soil fertility is becoming progressively vital in conventional agriculture and organic farming. With the present high prices of chemical fertilizers, a lot of poor farmers have no alternatives than to adopt the incorporation of crop residues into soils on their farms. According to Tetteh (2004) and Fening *et al.* (2005), there is a growing desire in adopting the use crop residues in soil fertility improvement which can decrease the usage of chemical fertilizers and other external inputs. Serving as a huge untapped energy potential, crop residues could be used to produce biogas via anaerobic processes (Nordberg *et al.*, 1998). With inadequate amounts of farmyard manure at their disposal, farmers practising organic cropping to a large extent rely on residues of crops as their soil nutrient sources (Cormack *et al.*, 2003).

Chemical fertilizers are progressively becoming exorbitant to a lot of farmers as can be seen by the increasing prices in a farming season and limited amounts bought. Similarly, chemicals in fertilizers are a danger to the health of humans as well as the environment. Organic farming does not entail the usage of these inorganic (chemical) fertilizers which protect the public and the environment against the long-term impacts of these ‘harmful’ chemicals. A greater number of organic farmers depend on applications of organic manure, crop rotations, and/or cover crops to sustain and/or increase soil fertility (Kelly, 1990). These soil modification products maintain soil quality, and protect waterways or groundwater from possible nitrate pollution (Parr *et al.,* 1986).

www.udsspace.uds.edu.gh

Crop residues comprise all uneatable phytomass agricultural products: legume and cereal straws; stalks, leaves, sugar, tops of vegetables, tuber crops and oils; and the prunings and litter of fruit and nut trees. According to some assessments, more than 60 % of residues from crops are generated in countries with low incomes, and nearly 45 % of residues are from the tropical countries (Smil, 1999). Residues are put to a variety of uses including being used as animal feed, cooking fuels, and improvement in soil fertility. Regardless of the small energy amounts in crop residues (when compared to wood) and how bulky they are, residues serve as a vital source of energy in rural areas, such as in arid, deforested, and densely-populated areas in Asia and Africa. In addition, crop residues are fed to livestock, or retained on farms for animals to graze. In some parts of the world, certain traditional practices such as burning of residues are frequently carried out during land preparation for farming as well as destroy phytomass that could be harbouring pests or diseases.

Smil (1999) opined that in low income countries, approximately 25 % of residues are burnt; this assessment surges to 45 % when assessing their usage as fuel. Retaining crop residues on farms, land fallowing as well as composting form the main approaches to constituting soil organic matter necessary for preserving soil fertility in several systems of farming. Reduction in soil organic matter is frequently assumed to be the essential reason for decreases in production of food in Africa (Sanchez 2002; Antle and Stoorvogel, 2008). There is an increasing appreciation that soil fertility limitations in Sub-Saharan Africa (SSA) need joint applications of inorganic fertilizer and organic residues to at the same time solve the immediate nutritional needs and long-term upsurge in organic matter of the soil (Vanlauwe and Giller, 2006). Lately, approaches concentrating on organic resources and management of crop residues in particular have been extensively put forward as fragment of combined strategies for managing soil fertility. Nevertheless, their numerous benefits,

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

such as increased yields, management of crop residues will probably not be implemented owing to labour or land issues (Place *et al*, 2003).

1.2 Problem Statement

In the Sub-Saharan African area, agriculture is considered as an engine for economic growth (Badiane and Delgado, 1995). It has the potential to reduce rural poverty through increased food security and improved household income. However, most of the Sub-Saharan African countries are confronted with low agricultural productivity which is relatively stagnated in much of Sub-Saharan regions of Africa when compared with other developing parts of the globe (Frisvold and Ingram, 1994 and FARA, 2006). Incessant degradation in soil fertility is the greatest serious obstacle impacting on agricultural development. Syers *et al.* (1997) report that low soil fertility is a significant factor in degradation of soil and is perhaps the main reason for declines in crop yields. The yearly rates of reductions in nutrients from farmlands have been projected as 4.4, 0.5 and 3.0 million tons of N, P and K, respectively (Sanchez *et al.*, 1997). Henao and Baanante (1999), suggest that if nutrient reduction and degradation of land remain at present rates, it will be hard to envisage how farmers in Africa will be able to produce sufficient food for the rising human populations. Improving soil fertility is needed to increase agricultural productivity (Sanchez and Leakey, 1997). Previously, farmers achieved this by having long periods of fallow and opening new lands. Nevertheless, growing request for land, due to increase in human population, has destroyed these strategies for maintaining soil fertility (Kayuki and Wortmann, 2001).

Restoring soil fertility will probably be realized by using chemical and organic inputs. Insufficient supply, lack of stable prices for agricultural produce, inaccessible credit and low capital hinder

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

poor farmers from using chemical fertilizers. In Ghana, there is an on growing awareness in using crop residues for increasing productivity of the soil which can cut down on the use of chemical fertilizers (Tetteh, 2004 and Fening *et al.*, 2005). Using crop remains for improving soil fertility can increase yields of crops as well as decrease large importations of mineral fertilizers. Crop residues are abundant on farms after crop harvests and are important for managing soil fertility management through their immediate impacts on supply of nutrients as well as longer-term input into organic matter of soil (Karanja *et al.*, 2006). Yet, they are frequently discarded by elimination or burning which is every so often disapproved for fast-tracking organic matter losses and soil nutrients, accelerating carbon emissions and decreasing microbial activities in the soil.

In Ghana, farmers are not using crop residues as they are not sufficiently educated on nutritional importance of these residues or due to problems related to the time and method of application. Guaranteeing food security for the growing global human population is directly related to productivity and fertility of the soil. Soil with adequate plant nutrients is the greatest valued land natural resource which plays crucial roles for sustainable production in agriculture. This means the total sustainability and productivity of an agricultural sector depends largely on soil fertility and productivity. Crop residues also affect the soil directly or indirectly. Integrated efforts by soil scientists, environmentalists, agronomists, economists and ecologists, are required to design a systematic approach for high-quality management of crop residue system in order to enhance both agricultural productivity and sustainability (Wakene, 2001). Roy *et al.* (2003) report that agricultural productivity is declining and production of food cannot match up with human population growth. To be able to feed the increasing population, agricultural production needs to increase by not less than 3-4 % per year (Greenland and Nabhan, 2001). It is possible to achieve

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

this by farming on more lands (area expansion) or by stepping up productivity per unit land area (intensification). The first alternative has not been very feasible because of shortage of land. The only possible way of increasing productivity per unit land area is by improving on management of soil fertility together with improved agronomic practices (Sanchez *et al.*, 1997).

UNIVERSITY FOR DEVELOPMENT STUDIES

Regrettably, farmers in Ghana adopt cropping systems that can give them the highest return on their investments without considering the impact on the fertility of the soil. According to Ranamukhaarachchi *et al. (*2005), such a system, if continuously practised will eventually make agricultural production unstainable. It is palpable that improved and sustainable agricultural production requires productive, fertile soils. According to an FAO (1998) report, 24 % of soils could be confronted with moderate to extremely severe fertility problems and these could adversely impact on agriculture. The International Food Policy Research Institute (IFPRI) (2010) opines that, some of the main causes of nutrient reduction are farming without nutrient replenishment in the soil (nutrient losses as a result continuous cropping), taking away of crop residues from the farm, little input of fertilizers and improper nutrient application. As a result, in SSA countries, depletion of soil fertility is said to be the reason for reductions in food production (Sanchez *et al.*, 1997).

Despite working hard in seasons when rainfall patterns are good, most farmers in Ghana are unable to have good harvests to improve on their livelihoods. The main objective of this research was identify the processing centres in the Tamale Metropolis where processed residues or organic materials could be found, quantify these organic materials that are usually produced, over a period of time and the cost of obtaining these organic materials.

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

1.6 Justification for the Study

More than 70 % of poor people in Africa dwell in rural communities, and this pattern may continue for many years (Diao *et al.*, 2006). Agriculture provides livelihood for these people, and as such agricultural productivity is important for reducing poverty significantly. In Ghana, the Northern Region is said to be one of the key food-producing regions with a land expanse of 38,352 ha put to agricultural production. Approximately 60 % of people living in the Tamale Metropolis are involved in agriculture (Ghana District, 2012). Due to high levels of agricultural production in the Metropolis, huge amounts of crop remains, including maize stovers, rice straw and husk are left unutilized. Even though, farmers other uses for some of these crop residues, there is no documented information on the quantities of crop residues are available and could be converted into manure, animal feed and how much of these are put into other uses. Crop residues may provide substantial prospects for sustainable improvement of soil fertility due to the fact that they are relative much more stable.

A well-trained farmer with good support will work hard and use appropriate methods to improve the productivity of his soil to derive maximum economic benefits. A research on spatial and temporal availability of organic materials will bring great benefits to the region and to Ghanaian farmers in general. The study sought to add to the intellectual discourse on temporal availability of organic materials and their use by farmers in developing countries. The results of the study will first of all benefit farmers in the Tamale Metropolis in particular and those in developing countries with conditions similar to those in the Northern Region in Ghana in general. Other peasant farmers will get to learn and adopt skills and techniques that boost production and in effect good returns on their investment. With this, the menace of food insecurity, unemployment and poverty in the region will reduce. Finally, the Ministry of Food and Agriculture, agricultural institutions and

Non-Governmental Organizations (NGOs) in Ghana and beyond will also benefit from the results of this research.

1.3 Research Questions

To solicit responses and address the aim of the study, the following research questions were used:

1. What quantity of organic residues is produced in the Tamale Metropolis?
2. What is the current usage of organic residues by farmers in the Tamale Metropolis?
3. What is the cost at which these organic residues can be obtained from farmers in the Tamale Metropolis?
4. What periods within the year are organic residues readily available to farmers in the Tamale Metropolis?
5. What are the constraints associated with the availability, processing, management and utilization of organic residues in the Tamale Metropolis?

UNIVERSITY FOR DEVELOPMENT STUDIES

1.4 Objectives of the Study

1.4.1 General Objective

Generally, the study sought to investigate and quantify the spatial and temporal availability of off-farm organic materials in the Tamale Metropolis.

1.4.2 Specific Objectives

The specific objectives of the study were to:

1. Find out the quantity of organic residues produced in the Tamale Metropolis.
2. Examine the current usage of organic residues by farmers in the Tamale Metropolis.

www.udsspace.uds.edu.gh

3. Determine the cost at which organic residues can be obtained from farmers in the Tamale Metropolis.
4. Determine periods of organic residues are usually readily available to farmers in the Tamale Metropolis.
6. To identify constraints associated with the availability, processing, management and utilization of organic residues in the Tamale Metropolis.

UNIVERSITY FOR DEVELOPMENT STUDIES

1.5 Hypothesis

Alternative Hypothesis (H_A): There is a significant quantity and temporal availability of organic residues that could be found all year around in the Tamale Metropolis.

Null Hypothesis (H_o): There is no significant quantity and temporal availability of organic residues that could be found all year around in the Tamale Metropolis.

1.7 Scope of the Study

The study was undertaken within the context of quantifying the spatial and temporal availability of organic materials in the Tamale Metropolis which involves the sampling frame. It would be expected that for a study of such relevance and global in nature, the sampling frame should involve communities drawn from the entire nation. This was not done due to financial, logistical and time constraint, and as a result only the Tamale Metropolis was considered. The results of the study were however, contextualized, and its results were put in the appropriate framework of the Tamale Metropolis.

www.udsspace.uds.edu.gh

1.8 Limitation of the Study

Primary data collection in Ghana is a very difficult task to undertake. Problems such as confidentiality and lukewarm attitude on the part of interviewees or respondents were problems encountered in data collection process. However, this study gathered the needed information through the use of questionnaires. Although, the use of self-administered questionnaire was likely to create bias since it could have limited some aspects of communication, including facial expressions, gestures and body language, the data was critically and systematically examined to draw a wider understanding of responses of respondents.

1.9 Organization of the Research

The study is laid out into five chapters. Chapter 1 constitutes the background of the research, problem statement, objectives, and research questions. It also contains the significance of the research, limitation and organization. Chapter 2 presents the literature review on off-farm organic materials. It also looks at the operational definitions of key concepts and theories linked to the subject matter. Chapter 3 discusses the research methodology which consists of the research design, data sources, population, sampling procedures, instrumentation and data analysis procedure. It also covers the background of the research area. Chapter 4 comprises the presentation of findings, data analysis and discussion of the results. Finally, Chapter 5 gives a summary, conclusion and recommendations of the research for implementation and improvement.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the works of other authors on spatial and temporal availability of organic materials. Emphasis is placed on quantity of off-farm organic materials produced and current usage. Costs incurred using off-farm organic materials were reviewed. The agricultural sector plays a vital role in the general global economic development. Nevertheless, there is scanty data on how agricultural residues are managed. This may be due to the fact that the agricultural sector is not regulated. Leftover materials obtained from numerous agricultural processes are termed agricultural residues or wastes. For the United Nations (UN), agricultural residues normally consists of manure as well as other residues from farms, poultry farms and slaughter houses; wastes from harvests; fertilizer overflow from farmlands; pesticides which run into the air, water, salt as well as silt obtained from fields (OECD, 2001).

In the past thousand years, humans' quest to survive on unfavorable natural environments resulted in the overriding role of humans in using soils to increase the production of food and fibre. Earliest literatures from initial civilizations suggested that after humans started undertaking agricultural production, they made attempts to supply nutrients to soils to restore their fertility.

The persistent usage of inorganic fertilizers in the past forty to seventy years resulted in corresponding declines in the use of cover crops and organic fertilizers (Power and Papendick, 1985). Increase in crop production, especially cash grain crops, as well as more dependence on the importation of inorganic fertilizers in addition to pesticides to sustain crop growth have led to improved yields in grain crops and efficiency in labour. Nevertheless, these conventional

www.udsspace.uds.edu.gh

management processes have resulted in increase in erosion of soils, decline in soil organic matter and surface pollution (Reganold *et al.*, 1987). Till lately, we have been unsuccessful in recognizing the values of managing the sense of balance and cycling of energy, matter and soil productivity (Goh and Nguyen, 1992). Cognizance of the ecological facets of soil value and production of crops has been increased in recent years, which has resulted in residues, organic manures, as well as other organic matter regarded as sources of organic matter and nutrients of soils.

Crop residues are excellent natural resources of nutrients. Residue management is receiving a great deal of consideration because of its various impacts on soil physical, chemical and biological characteristics. The amounts of nutrients that could be given back yearly to soils as crop remains are significant and valuable. Biological fixation of nitrogen by leguminous crops in addition to the recycling of N fixation once leguminous crop remains are incorporated into the soil could be a critical N source to the organic nitrogen pool of the soil. Organic residues added to the soil decompose from which new products are formed. With the original residues and initial products going through more decomposition, they turn into dark brownish to black organic mass known as humus (Lehmann and Kleber, 2015). Gul *et al.* (2014) point out that some fungi and substances of plant origin that look like lignin are the core structures for building humid substances. According to Whiteside *et al.* (2012), the mechanism that led to increased in nitrogen composition in plants lignin residues ought to be accurately clarified. It has been clarified to a certain degree that amino acids and their products are stabilized contrary to microbial breakdown via polymerization of humid substances.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

2.2 Agronomic Residues

Agronomic remains are carbon-based resources produced as a byproduct in the course of crop harvesting and processing. Agronomic wastes generated during harvesting are either prime remains which are generated with the product during the processing period or secondary remains (Figures 2.1 – 2.6). Agronomic remains are mixed, differing in moisture levels, bulk density, particle size and distribution with respect to handling. Generally, they have low amounts of nitrogen, fibrous and differ with geographical site (Smith, 1987). Field residues or remains are not often utilized as erosion control material, fertilizers and fodders for farm animals. Just about half of these resources are burnt on the farm preceding the beginning of another farming season. Processing of residues offer high prospects of sources of energy. Biochemical composition of agronomic crop residues differs contingent on quite a lot of factors such as species, period of harvest, harvesting practices and physical composition of the residues (Cooper and Laing, 2007; OECD/IEA, 2010). Agronomic remains or residues are generated as a leftover product from crops such as wheat, maize and sunflowers. Formerly, small proportion of these agronomic remains or residues were utilized by farmers as feedstuff for farm animals while the remaining were worked back into soils or burnt to reduce the enormous amounts of biomass before growing the subsequent food crops. The benefit of utilizing agronomic remains is that it is not in competition with food production. It is projected that approximately one of residues is generated per ton of grain harvested (Virmond *et al.*, 2013).

The leftovers from the processing of grain crops such as rice, wheat and maize also serve as important resources of residues. These residues usually make up 50.0 % by mass of the biomass of grown crops in the US. With time, such resources have become a source of bedding for animals

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

or made to decompose on the farm. The new progress for use of residues is for ethanol production and electricity generation, and these have raised hopes for such residues to be used for both economic and ecological benefits. Significantly, the economy of the US can conceivably support up to 155.0 million tons of agronomic residues for producing bioenergy in 2030 (UCS, 2012) without the need for additional land requirements since these residues are by-products of major crops (USDA, 2006). Residues are recognized to play vital roles or advantages ranging from erosion control to mitigation as opposed to soil carbon depletion. The use for soil bioenergy production may have an adverse impact on these benefits, thus, their use should be subject to certain circumstances, and even then, only up to a specific extent. The amount of agronomic wastes that can be collected are subjective and depends on several circumstances in relation to the land. This should be considered as removal of too much residues can cause exposure of the farmland to erosion and less or no elimination of the residues can unconsciously prevent soils from drying up in the period of spring, thereby affecting the planting season.

UNIVERSITY FOR DEVELOPMENT STUDIES

Removal of residues or wastes for bioenergy can impact negatively on other agricultural practices. The environment could be worsened as a result of unnecessary exposure of the farm. In order to lessen the effect of this, farmers should employ several strategies. For example, they can use no-till farming and engage in cover cropping in order to decrease water pollution and soil erosion. This will enhance crop production and also provide abundant residues for bioenergy biofuel production (Wiggins *et al.*, 2012). In maize-growing areas, large amount of leaves and stalks of maize left over after they are harvested, are always available to produce ethanol. Maize residues or remains are abundant near existing amenities to produce and distribute ethanol made from maize

www.udsspace.uds.edu.gh

grain. Producing ethanol from maize grain and maize stovers at equivalent location may reduce the use of natural gas and electricity (Langholtz *et al.*, 2016).

Figure 2.1: Groundnut husk residues

Figure 2.2: Rice paddy residues

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Figure 2.3: Maize husk residues

Figure 2.4: Pito residues

www.udsspace.uds.edu.gh

Figure 2.5: Yam peel residues

Figure 2.6: Beans husk residues

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

2.3 Livestock Residues

Livestock can produce an enormous amount of manure (Figure 2.7 – 2.10), which is used for bioenergy production, and can also pollute water supplies in many locations. Luckily, on the smaller end of the animal production scale, agriculturalists convert manure into biogas using anaerobic digesters for both economic and environmental benefits. The biogas can be utilized to produce heat and power on the farmland. Anaerobic digesters for biogas production from manure may improve aquatic quality, decrease intolerable greenhouse gas from manure, and support farmers to fix nutrients in the soil. In the US, research results indicate that about 60 million tons of animal manure can be implemented to produce bioenergy by the year 2030 (UCS, 2012).

Processing of residues has been observed to be normally poor due to a wide diversity of processing methods producing different quantities of residues (Simonyan, and Fasina, 2013). The ratio of the main crop produce to the residues generated differs depending on a set of issues including variety, nutrient supply, moisture content, use of chemical and growth regulators. In reality, there are reasons which account for the use of certain residues for bioenergy production, and these include technical constraints, ecosystem functions, widespread availability, and domestic heating, animal fodders and fertilizer.

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Figure 2.7: Cattle dung as a residue

Figure 2.8: Droppings of sheep/goats as residues

www.udsspace.uds.edu.gh

Figure 2.9: Swan waste or residues

Figure 2.10: Poultry droppings as residues

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

2.4 Mineralization

The organic processes involved in the nutrient cycles are complex. The speed of mineralization depends on the nitrogen, soil moisture, temperature, fibre content, and degree of mixing with the soil. N is released quickly from plant remains when the content is higher than 1.5 %. Nutrients fixed by soil microbes and humus are released and available to crops. Nutrients from residues are not fully recovered by crops. Like inorganic nutrients, nutrients released from crop residue into the soil are vulnerable to losses such as leaching (N and S), denitrification (N), immobilization (N, P, K and S), and fixation (P and K). The existence of crop remains and nitrogen fixations has been shown to improve soil chemical, physical and biological characteristics. Mineralization always promotes N uptake by crops and decreases N loss. Although net immobilization is involved in mineralization, it does induce crop N uptake (Ailincâi *et al.*, 2012).

Soil micro- and macro-fauna build up and an increase in biological activities of soil have been reported when soil cover with plant remains are maintained and these improve soil physico-chemical properties (Wall, 2008). An increase in microorganisms in the soil facilitated by the presence of crop remains, ensures an increase in microbial breakdown of plant residues (Rengel and Singh, 2010). Ammonia volatilization affects the efficiency of plant cropping system and is also affected by environmental factors, including for instance soil pH, temperature and moisture (Olson-Rutz *et al.*, 2011). Crop residues preserve soil moisture and also prevent the sun from the direct heating of the soil surface which therefore reduces nitrogen volatilization (Schwab and Murdock, 2005). The amount of nitrogen that recycles into agricultural fields through residues can add up to 25-100 tons of nitrogen per year into soils (Mosier and Kroeze, 1998). Thus, there is the need to determine sink sizes and turnover rates of different quality residues and to increase the

www.udsspace.uds.edu.gh

efficiency of nutrient cycling from residues through various soil sinks, and ultimately to growing plants, with minimum loss from the system.

This may include development of practices to improve the immobilization of nutrients when plants are not growing and practices to increase nutrient availability when plants are actively growing. Data on the kinetics of decomposition of the crop residues and mineralization—immobilization turnover of different quality residues (leguminous and non-leguminous crops) is required to determine the actual amount of crop residues needed to sustain the soil productivity and to ensure environmental protection by minimizing nutrient losses and soil erosion.

UNIVERSITY FOR DEVELOPMENT STUDIES

2.5 Availability of Crop Residues to the Farmer

Studies have shown that crop residues are fibrous by-products obtained after crop cultivation or the crops have been harvested. Crop residue availability on or off-farm depends on levels of production, and several factors such as natural, social and economic ones that the farmer is confronted with (Tesfaye *et al.*, 2006). Timothy *et al.* (1997) indicate that land, crop, animal, ownership patterns as well as cultural practices determine availability of crop residues, and that the prospects for both market and non-market interactions also impact on access to the locally-produced residues by the farmer. Seasonal and rainfall patterns in a given year lead to inter-annum disparities in the production of crop residues and can as well have a significant impact on accessibility of the residues at a specific time within the year. A wide range of crop plants are grown on large stretches of land producing significant quantity of residues that are left in the field after every harvest (Figures 2.11 and 2.12). After being used in alternative ways such as cattle feed, organic manure, animal bedding and cooking fuel, approximately 234 million tonnes/year

www.udsspace.uds.edu.gh

(30 %) of crop wastes generated are available as residues. This enormous amount of crop remains has massive economic value. Roughly 500-550Mt of crop residues are produced on-farm and off-farm per annum from production of 122 Mt of rice, 71 Mt of maize, 110 Mt of wheat, 26 Mt of millets, 8 Mt of fibre crops, 141 Mt of sugarcane and 28 Mt of pulses. Amongst cereal crops, wheat, maize, rice, and millet contribute 70 % of crop residues, followed by fibre crops which contribute about 13 %. Agricultural crops generate substantial amounts of excess residues, and increases in food production lead to corresponding to generation of crop residues. These excess residues exhibit not only resource loss but also a missed opportunity to improve a farmer's income. The use of crop residues in numerous areas are being explored by researchers across the globe in areas such as in textile-making processes, electric power generation, biogas production, animal feed, compost and manures. The rising trend in addition of bio-energy co-generation plants, rising demand for animal feedstock and rising trend for organic agriculture indicate a competitive opportunity for crop residue in agriculture. It is noted that the use of crop left-over residue is often not commonly exclusive which makes measurement of its economic value more difficult. For instance, straw can be used as animal bedding and as a crop fertilizer (Saroj Devi, *et al.*, 2017).

UNIVERSITY FOR DEVELOPMENT STUDIES

The total annual residue production varies from community to community, and these depend on the location of one's farm, the types of crops cultivated and the production system of the area. In 1981, North and Central America led in the global production of fibrous crop residues and was followed by Asia, Europe, USSR and Africa, in that order. In terms of crop residue production, North and Central America had an yearly overall production of 6.66 tons of dry matter (DM) for every livestock unit whereas Africa had the production of 2.20 tons DM of crop residues per

www.udsspace.uds.edu.gh

livestock unit (Kossila, 1985). The mean yields of cereal crop residues in the medium altitude highlands of Ethiopia alone were approximately 2 tons of DM ha^{-1} (Mclntire *et al.*, 1988).

Figure 2.11: Crop residues left on the farm after harvest

Figure 2.12: Residues generated after threshing maize

2.6 Burning of Crop Residues

UNIVERSITY FOR DEVELOPMENT STUDIES

Burning of crop residues gives rise to numerous environmental problems. The key effects of burning of crop residues consist of the emission of greenhouse gases which contributes massively to global warming, loss of biodiversity of agricultural lands, increasing level of particulate matter and smoke that cause health risks and decline in soil fertility (Lohan *et al.*, 2018). Burning of crop residues significantly increases the amount of air pollutants (Figure 2.13) such as CO, NH_3, CO_2 and hydrocarbons (Mittal *et al.*, 2009). This mostly accounts for the loss of organic carbon and nitrogen and other nutrients, which would have been retained in the soil. Jain *et al.* (2014) reported that burning of 98.4 Mt of crop residues has resulted in emission of nearly 0.65 Mt NMHC, 8.57 Mt CO, 0.037 Mt SO_2, 0.23 Mt NO_2, 141.15 Mt CO_2, 0.12 Mt NH_3 and 1.46 Mt NMVOC, 1.21 Mt PM during the period of 2008 and 2009 where CO_2 is 91.6 % of the total emissions. The remaining 8.43 % comprises 66 % of CO, 2.2 % of NO, 5 % of NMHC and 11 % of NMVOC (Jain *et al.*, 2014). Gupta *et al.* (2004) predicted that cumulative CO, CO_2, N_2O and NO emissions from the burning of rice and wheat straw are 0.11, 2.306, 0.002 and 0.084 Mt respectively. Street *et al.* (2003) have estimated that roughly 730 Mt of biomass is burnt annually in Asia.

Crop burning increases the particulate matter in the atmosphere and contributes significantly to climate change. One contributor to worldwide climate change is the release of black and brown carbon that contributes to the change in light absorption (Jiang *et al.*, 2019). Lightweight particulate matter can stay on hold in the air for a longer period and can travel to a long distance with the wind (Singh *et al.*, 2011). The effect of particulate matter gets worsened by the weather conditions, as the particles are light in weight and can stay in the air for a longer period and cause smog. The annual contribution of paddy residue in the Patiala area of Punjab was projected to be 60 to 390 mg/m^3. During October 2017, smoke from the burning of crop wastes in Punjab and

UNIVERSITY FOR DEVELOPMENT STUDIES

Haryana blows across northern India and Pakistan. With the onset of cooler weather in November, the smoke, mixed with fog, dust, and industrial pollution, forms a thick haze. Wind usually helps in the dispersion of air pollutants, in the absence of which worsens the problem for several days as was the case during November 2017 (Lohan *et al.*, 2018).

UNIVERSITY FOR DEVELOPMENT STUDIES

Figure 2.13 Burning of crop residues during land preparation for crop farming

2.7 Crop Residue Biomass

Each year, agriculture generates about 140 billion tons of biomass (Figure 2.14) which is equal to about 50 billion tons of oil. The energy produced from agricultural biomass waste can expressively replace fossil fuel, which can reduce the production of greenhouse gases and also provide renewable energy to about 1.6 billion individuals in developing countries across the world, which are still lacking access to electricity. In the same way, green crop residue which has a narrow

www.udsspace.uds.edu.gh

carbon: nitrogen ratio (30:1), facilitates composting and can also serve as an alternative to high energy derived from inorganic fertilizers. This provides a viable option for eco-friendly organic farming (Dia 2005; Weindorf *et al.*, 2008; Dia *et al.*, 2009). Findings from previous studies have suggested that the ligno-cellulose byproducts including sorghum stalks, pineapple and banana leaves, maize stovers, rice and wheat straw and leaves, can be used to extract natural cellulose fibres suitable for textile and other industrial applications (Reddy and Yang 2005).

UNIVERSITY FOR DEVELOPMENT STUDIES

Cellulosic biomass can be obatined from agricultural sources, including crop residues as well as perennial energy grasses, and forest sources, such as woody biomass and forest residues. Crop residues mostly include maize stovers, wheat straw, and rice straw. Because these resources are by-products of crop production, their collection and utilization ensure sustainable practice and do not result in food energy feud and land competition. Thus, the negative impacts of cellulosic biomass making from crop residues on food prices can be projected to be insignificant. Even though cellulosic feedstocks vary significantly in their environmental output (Nurudeen *et al.*, 2018) they can offer appropriate benefit and prospect for many environmental benefits if compared with the coal they will substitute (Brent, 2014).

Agronomic biomass has been set aside to be an important energy resource (Terrapon-Pfaff, 2012). Between the feedstocks available in abundance to the US are the crop residues and the choice of selecting the suitable agronomic biomass and manure for bioenergy production is a measure of some aspects, which may consist of the type and scale of resources in each location. The use of agronomic leftovers and manure to produce bioenergy offers a substantial advantage for local and

www.udsspace.uds.edu.gh

regional economies. At present, 17.0 % of the world population remains without electricity which is estimated to be 1.2 billion people (IEA, 2015).

Figure 2.14: Crop Residue Biomass

UNIVERSITY FOR DEVELOPMENT STUDIES

2.8 Organic Materials Produced Off-Farm

Ghana's agriculture is mainly subsistence in nature of which small-holder farms, representing 82 % of the total land, are used for agricultural activities with 80 % for food production (FAO, 2012). These subsistent farmers used to practice the shifting cultivation method of faming. As population human increased, it became difficult to continue practicing that method of farming due to scarcity of land. These resulted in reduction in crop yields and exhaustion of soil nutrients. The soils became depleted and eventually lost organic matter and nutrients. Mokwunye *et al.* (1996) indicate that soil fertility decline has been associated with small-holder farms as a main biophysical limitation impacting on agriculture, particularly nitrogen (N) and phosphorus (P) deficiencies.

Organic materials are crop residues generated after crops have been harvested or processed. The residues, known as 'field residues' or 'processed residues', based on the nature in which they are generated. Field residues are generally abandoned on the farm as shown in (Figure: 6a).

These include stalks and whiskers (plant stem, plant leaves, and pods). Organic residue can be tilled directly into the soil, or charred first. In contrast, organic reduced till agricultural practices are carried out in order to maximize crop residue cover. proper managing of field residues can increase efficiency of soil fertility, water conservation, soil aeration, irrigation and control of soil erosion in the field (Perucci *et al.*,1997). Simple line transect measurements can be used to estimate residue coverage while processed residues are created in the course of processing harvested crops (Figures 2.15 and 2.16). They are constituents left after the produce is processed into a usable resource. These organic residues include plant husks, seeds, molasses and roots. They can be used as fodder for animals, soil conservation, fertilizers and in manufacturing industries (Richards *et al.*, 1984).

UNIVERSITY FOR DEVELOPMENT STUDIES

Figure 2.15: Field crop residues left on the farm after harvest

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Figure 2.16: Processed residues generated after harvesting of crops

2.9 Crop Residues for Energy Generation

Bioenergy resources are well thought-out to be clean and are also an vital portion of attempts to solve the danger of economic, environmental, climatic, and social security challenges compared with the utilization of fossil fuel, which is at present the main energy source. Bioenergy and biofuel utilizing biomass such as plant materials and manure, biorefinery and waste resources for renewable fuels for transport, ensures sustainability, and power generation and these can serve as low-carbon energy alternatives to fossil fuels (Jekayinfa and Scholz 2007). There are global increases in the utilisation of agricultural residues for energy generation all over the world due to a number of reasons. Karekezi and Kithyoma (2005) indicate that the growth of bagasse-based

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

cogeneration in some African countries reduced the dependence on oil imports, improved local production of electricity and gave rise to an effective energy sector. The accessibility of the production equipment in present-day sugar processing factories has brought about an increase in bagasse-based electricity generation (Deepchand, 2001).

Janssen and Rutz (2011) posited that the use of agricultural residues has the prospect to deliver clean energy to rural African households. Bioenergy is among the major plans to deliberately phase out electricity generation from coal as well a wide-ranging climate plan through carbon capture and other procedures. Biomass assortment advocated over time and reaction pathways are the other areas of stronger efforts for an economical and biologically synthesized process. In addition, the use of agronomic residues and manure to produce bioenergy offers a substantial opportunity for local and regional financial prudence. Crop residues in particular are the globally largest biomass resources and the best choices for use to produce bioenergy. It has been realized that agronomic residues are significant resources for future sustainable biofuel and bioenergy generation (Brent, 2014). Kong (2000) states that uses of rice husk include power generation in Malaysia. It has also been reported that residues generated from maize, oats, wheat, rice, sugarcane and sorghum are used in generating power in Zimbabwe. Cereal crops such as maize, barley, wheat, sorghum, oats, millet, sugarcane and rice have the prospect of generating huge quantities of crop residues (Jingura & Matengaifa, 2008 and Scarlat *et al.*, 2010). Goldemberg (1988) and Lal (2004) indicate that residues of crops are harmless and environmentally-friendly once used as an alternative source of energy. Such resources are plentiful and inexpensive, and their utilization will rake in economic returns.

www.udsspace.uds.edu.gh

The potential of residues from sugarcane over the years has been confirmed and rated high for electricity generation in many developing countries. In Mauritius, almost 30 % of the electricity is produced from crop residues (Karekezi *et al.*, 2008). The use of off-farm crop residues is enormous in developing countries. Crop residues stand a huge chance of becoming a major source of biomass as the agricultural sector is the backbone of these economies. Karekezi and Kithyoma (2005) point out that people in western Kenya utilize crop residues as a fuel in boilers in order to generate steam and electricity. Electricity generation in Kenya utilizes agricultural off-farm materials by a technology via direct burning or gasification; briquetting; biogas production; pyrolytic oil production for automobile fuel whereas conversion of methanol and ethanol is for internal combustion machines.

Valdez-Vazquez *et al.* (2010) state that there is wide range of resources distributed and it is important to have explicit data on location of crop residues for their effective use. As a result, quantifying the potential production capacity of crop residues from this resource is necessary. A study by Gan & Yu (2008) on the evaluation of the geographical spread of crop residues reported the need for the growth of home-grown bio-energy projects for the generation of electric power to supplement the existing energy sources. Scarlat *et al.* (2010) confirm the existence and use of crops residues all over the world in their research in 27 European countries. The study revealed large quantities of crop residues generated in this area with projected energy production of approximately 1530 PJ/year. Countries like France, Spain, Germany, Italy, Romania, Poland and Hungary had huge residues potentials as per their large agricultural sectors.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

2.10 Crop Residues as Biogas and Biofuel

Biogas with high amounts of methane generated via anaerobic breakdown of organic substances offers a multipurpose system capable of producing renewable energy. Once methane can be utilized in place of fossil fuels in heat and power production as well as an automobile fuel, its role in greenhouse gases emission reduction and climate change mitigation is huge (Annimari, 2006)**.** Methane produced through anaerobic digestion is one of the most energy-efficient and has no negative effects on the environment, hence, the best alternative of producing vehicle biofuel (Choudhury *et al.*, 2002). Crop residues might be the greatest alternative for producing local biofuels. Methane produced from crops of high energy and crop residues is projected in the EU agricultural division, to have generated 1500 million tons of biomass; 50 % of this coming from energy crops (Amon *et al.*, 2001). The total amount of energy produced per year from the EU agricultural residues and landfill gas is projected to surpass 80 million Mtoe (tons of oil equivalents). The yearly amounts from biogas production from agricultural residues as well as energy crops are 45Mtoe (European Commission, 1997).

2.11 Crop Residues for Animal Feed

The variations between production schemes in resource projects, feed availability, levels and kinds of livestock production present diverse opportunities for the usage of crop residues as feeds for livestock. According to Mclntire *et al.* (1988), crop wastes are the main sources of ruminant feed, especially in mixed cropping and animal farming systems, for animal grazing areas are limited in such a system. This is as a result of the expansion of cropping land where local grass is available every season and animals graze on degraded lands or might only get green fodder in the rainy season. Crop cultivation and livestock are combined in integrated subsistent farming systems in

www.udsspace.uds.edu.gh

most tropical areas (Thornton and Herrero 2001; Rufino *et al.*, 2011). Crop residues are fed to livestock in the dry season when feed is very scarce while manure is used in crop cultivation when chemical fertilizers are scarce or expensive (Rufino *et al*. 2011; Rusinamhodzi *et al.*, 2013). Crop residues are used as by-products in crop cultivation, nonetheless they are important sources of animal feed in mixed farming systems (Williams *et al.*, 1997).

Throughout the world, it is a common practice to use crop residues to feed animals. Seyoum *et al.* (2001) state that it is an efficient use of resources regardless of the critics on nutrient removal, mostly in areas where manure is not used to enrich soil nutrient. Crop residues are one of the major feed resources in smallholder farms that practise the system of mixed farming. Although there is variability across systems, residues of cereals such as maize, rice, sorghum, teff, millet, barley, wheat and pulse crops like bean, field pea, grass pea, plant weeds are main feed sources for animals in Africa. Although huge amounts of crop residues are used as feed for livestock in several countries, a lot still go waste due to poor storage techniques, termite attack, inefficient feeding and other reasons. Major constraints to successful crop residues as livestock feeding are associated with crop production and their other uses for agricultural households (Mazvimavi *et al.* (2008); Erenstein (2011); Rufino *et al.* (2011); Johansen *et al.* (2012). An improved collection, storage and feeding techniques of crop residues could to sustainable agricultural production, nutrient recycling. However, availability of technology, availability, land tenure system and land fragmentation can be a limitation to substituting crop residues with good quality feed for livestock (Benjamin *et al.*, 2010).

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

2.12 Crop Residues for Soil Nutrients

According to Kone *et al.*, (2008) soil is the most important among natural resources and that soil quality depends on its capacity to function within the ecosystem and sustains biological productivity, maintains environmental sustainability, and promotes plant growth and animal health. Soil fertility is simply the presence of nutrients to support plant growth. Follet *et al.* (1987) defines soil fertility as the soil's ability to provide nutrients for plant growth and development. These qualities or benefits of soil are obtained from organic manure which in turn has certain quantity and quality features emanating from crop residues (Nzuma and Murwira 2000; Lekasi *et al.* 2003; Rufino *et al.*, 2007). Soil productivity is dependent on the natural fertility of the soil and nutrients supplemented as fertilizer, organic residues plus other sources; soil biological and physical characteristics; management in addition to other external influences affecting the production of the crops; and climate (Follet & Wilkinson, 1985). In Ghana and the rest of the West African sub-region, the fertility of the soil plays significant roles in agriculture and any decline in fertility adversely affects food production.

According to Ranamukhaarachchi *et al.* (2005), decline in soil fertility negatively impacts on food production and impoverishes developing countries. Therefore, it is a wake-up call for developing countries to re-enrich the soil with organic manure, most especially in areas where the ordinary farmer would not be able to afford inorganic fertilize in order to increase soil fertility. Manure plus crop residues are important in improving the physical and chemical and physical properties of soils in small-holder farming systems (Harris, 2002). Although in the first ten years of manure application, the rate of soil organic matter buildup is often at the maximum, it subsequently reduces in the years that follow (Sommer-Feldt *et al.*, 1988). Farmers encounter a lot of challenges when

www.udsspace.uds.edu.gh

managing crop residues; as they are torn between using the residues mulch for their crops or as organic manure to increase the fertility of the soil (Naudin *et al.*, 2012; Valbuena *et al.*, 2012; Rusinamhodzi, 2013).

In most developing countries, a lot of people undertake intensive farming near their homes and they improve fertility of their soils by incorporating crop residues, household waste and animal manure into the soil. These have improved the fertility of the soil for continuous farming, and crop harvests from such fields are a lot higher compared to those of distant farms which in some instances still fall under the traditional farming system (NSFMAP, 1998). In Ghana, the key nutrient sources to preserve soil fertility are of biological origin; these are crop residues, cattle dung and poultry manure. Organic manure application is a vital tool for an integrated strategy for managing soil nutrients as per its implementation can at the same time improve levels of soil organic manure and provide nutrients for the growth and development of crops (Magdoff & Weil, 2004).

UNIVERSITY FOR DEVELOPMENT STUDIES

Schlecht and Hiernaux (2004) state that low soil organic manure as well as inadequate supply to crops is the main problem affecting agricultural productivity of the sub-Saharan Africa. The physical, biological and chemical characteristics of soils can be increased by adding organic manure (Waswa *et al.*, 2007). Nevertheless, organic matter content of soils is dependent on how much crop residues are added (Beauchamp & Voroney, 1994). Benjamin *et al.* (2010) opine that crops capable of producing more residues are more capable of improving organic carbon content of soils compared to those that low amounts of crop residues. Crop residues are very vital to soil, as they increase its physical and chemical and physical properties. Crop residues improve soil structure, decrease soil erosion and increase access of water to plants (Latham, 1997; Tittonell *et al.,* 2008).

A substantial amount of retained crop residues improves fertility of the soil and has great impact when other sources of nutrients such as manure or chemical fertilizer are added. Thus, when crop residues and farm yard manure added, it enhances N and P accessibility, availability of soil water, soil organic manure as well as enzyme activities compared to the absence of crop residues. Although the benefits from manure and crop residues in the tropics might not be as apparent compared with those in the temperate countries, due to rapid oxidation processes in the tropics, however, crop residues continue to be the basic components of several agricultural interventions (Aggarwal *et al.,* 1997). Benjamin *et al.* (2010) conclude that farming systems will be sustainable if farmers allot high amounts of manure and crop residues to increase soil fertility.

UNIVERSITY FOR DEVELOPMENT STUDIES

2.13 Crop Residue as a Major sour of Nitrogen (N)

Nitrogen (N) is a major source of fertilizer for agricultural food production. Approximately 67.84 million tons of N are yearly applied to agricultural fields, without which approximately half of the world's population would not survive today (Liu *et al.* 2010). Returning crop residues to the soil is an alternate and sustainable way of N fertilization. Even though impacts of returning crop residues on plants and available N in the soil have been widely studied, there is still no systematic way of reviewing their mechanisms and models. When plant residues are returned to the soil, N undergoes biotic immobilization–remineralization, abiotic immobilization, soil organic N mineralization and plant residue organic N mineralization. Plant residues adjust inorganic N using three mechanisms: mineralization, immobilization–mineralization and immobilization, depending

www.udsspace.uds.edu.gh

on plant residue nature and soil physio-chemical properties. In plant residues C/N ratio is not always effective to forecast the effect of plant residues on crop growth. Instead, soil physio-chemical properties and the forms of carbon and nitrogen should be well thought-out. Mineralization always promotes N uptake by crops and decreases the risk of N loss.

UNIVERSITY FOR DEVELOPMENT STUDIES

Moreover, even though net immobilization is involved in immobilization–mineralization and immobilization, it does not certainly induce lower crop nitrogen uptake. Nitrogen loss during mineralization can be reduced by an immobilizer. Net N immobilization during immobilization–mineralization and immobilization can be reduced by changing the timing of ploughing and fertilizer application (Baoqing *et al.*, 2004).

2.14 Crop Residue as Mulching

In a research by Tindjina (2011), mulch is any system which enables a lot of crop residues to be retained (30% or more) on the soil surface. The soil is prepared in such a way that plant residues or other mulch materials are retained on or near the surface of the farm. The rural farmers often use crop residues such as groundnut leaves, rice husk and others on surfaces of soils to improve activities of earthworms (Mele & Carter, 1999). Mulching is intended to upsurge rates of infiltration, and hence decrease erosion and runoff (Edwards *et al.*, 1988). Crop residues also prevent the formation of surface crusts and insulate surface soil from temperature extremes at times where crop canopy is not available. In effect, sandy and other low-grade soils can be used more effectively and with less erosion risk, even on steeper slopes (Quinton *et al.*, 2001).

www.udsspace.uds.edu.gh

Mulching is very important to smallholder farmers as the decomposition of crop residues is a necessary step for soil organic matter formation and stabilization as it is for recycling of organically bound nutrients (Guggenberger, 2005). Decomposition in general is a process that leads to the transformation of organic materials into increasingly stable forms that can absorb onto mineral surfaces which include physical (fragmentation, dissolution and leaching), chemical (oxidation and condensation) and biological alteration of residues (Berg & McClaugherty, 2008). According to Gregorich (2000), microbes help reactions that are progressively deriving energy and nutrients from organic residues while transforming them into various products. Crop residues are mostly vital to soils apart from being used as animal feed, energy supply and materials for construction. Crop residues increase soil physical and chemical properties because they improve soil structure, increase access of water to plants via mulching and decrease soil erosion (Latham, 1997 and Tittonell *et al.,* 2008). It is therefore prudent that mulching should be done in dry land areas to conserve soil moisture as crop residues are capable of decreasing degradation of soil as well as increase water infiltration. Crop residues are utilized as mulching materials by smallholder farmers as a strategy to increase land use efficiency through efficient water and soil management practices.

UNIVERSITY FOR DEVELOPMENT STUDIES

2.15 Crop Residue potentials

The World Health Organization (WHO) as well as the United Nations Development Programme (UNDP) indicate that approximately 1.5 billion people, that is one-quarter of the world's population, do not have access to electricity. In order to meet the UNDP millennium development goals, approximately 2.0 billion people need energy supplies. Inadequate and continuous supply of electricity and liquid transportation fuels further weakens poor and developing countries, where

www.udsspace.uds.edu.gh

population density is high and access to resources is low. Approximately 2.0 billion people rely on plant biomass or fuelwoods used primarily for cooking and heating purposes. Thus, burning of such plant biomass or fuelwoods results in ecological pollution and health hazards. In the long term, the outcomes are huge costs on human health, where the major victims are children and women owing to the burning of solid fuels in poorly ventilated places (Legros, *et al.*, 2009).

UNIVERSITY FOR DEVELOPMENT STUDIES

On the other hand, developed countries depend on bioenergy to fight the menace of ecological pollution due to CO_2 production and possibly reduce it and provide domestic energy (Tilman, 2009). Energy food crops with the potential of producing high-yielding biomass have been studied (Heaton *et al.*, 2008). Research on special energy crops in developing nations can possibly lead the breeding and production of multi-purpose crops that provide both food and energy (Rajagopal, *et al.*, 2007). Food security and energy provision from these crops, may be ensured when degraded lands are used to grow crops after cutting down of trees, which can result in CO_2 production because of excessive land use (Fargione, *et al.*, 2008). Chances therefore abound in dual cropping systems, which may enhance agricultural productivity by producing bioenergy from agronomic residues or waste while food production is ensured.

2.16 Role of crop Residues in the Field

Crop residues, when left in the field, offer a lot of environmental services, such as playing a role in forming soil organic carbon that stops erosion, improving soil structure, lowering evaporation from soil surface, contributing nutrients to the soil, supporting living things and providing water filtration and retention capacity (Whitmore, 2011). It is prudent to harvest these crop residues for the production of low-carbon biofuel on a sustainable basis without causing adverse effects on the environment. This segment discusses the environmental part of crop residues on the farm,

www.udsspace.uds.edu.gh

concentrating on what is already known about soil organic carbon effects of retaining residues against taking them out. The ensuing sector offers a fresh quantitative valuation of soil organic carbon influences of retaining residues versus removal.

Soil organic carbon is significant for storing carbon to alleviate climate change as well as for contribution to good fertile soils. Soil organic carbon intensifies the water-holding capacity of sandy soils (Rawls *et al.*, 2003) and brings about improvement in soil structure (Smith, 2016), and capable of therefore hypothetically improving crop yields (Nicholson *et al.*, 2014). Organic carbon of soils is made from dead above-ground biomass and plant root biomass. It is different from inorganic carbon of soil, which is found in mineral forms, including limestone, and does not possess similar water holding features nor help biota in similar fashion like soil organic carbon. In yearly cropping systems, the major biomass contributions to the soil are rotting roots and residues of crops. Soils lose organic carbon due decomposition activities of microorganisms and through erosion. Over time, the preservation or variation in soil organic carbon is the overall balance between the outputs and inputs. It is largely recognized that retaining crop residues on the farm contributes to better formation of soil organic carbon and more soil organic carbon when compared to total removal of residues (Nicholson *et al.*, 2014), nevertheless the extent of benefits from soil organic carbon and the quantity of residue needed to deliver soil organic carbon benefits are not clear. In an assessment of long-term series of research from several parts of the world, Powlson *et al.* (2011) noticed that most studies stated more soil organic carbon with use of residue or retention as against complete removal of residues, although the variation was significant statistically in other studies.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

The amount of residue needed to prevent additional soil organic carbon loss is not well understood or agreed upon. Earlier studies in the United States suggested 30% of maize stover could be sustainably removed (Andrews, 2006), while it has generally been believed in the EU that two-thirds of straw could be removed (Joint Research Center, 2009). In a lifecycle assessment of biofuel produced from maize stover, Liska, *et al.*, (2014) concluded that any residue removal would result in soil organic carbon loss compared to complete residue retention in fields, although this study did not specifically evaluate evidence of soil organic carbon impacts with varying levels of residue retention. Some studies have explicitly studied how varying amounts of residue affect soil organic carbon levels. In an experiment in Denmark, Thomsen *et al.*, (2004) found a linear relationship between soil organic carbon and straw input with four varying levels of straw input ranging from zero to 12 ha. Kenney (2011) also found that, increasing soil organic carbon with increasing stover input compared to complete stover removal in an experiment in Illinois, United States, but it is not clear from this study whether this relationship is linear. Overall, there is a relative paucity of studies reporting on soil organic carbon impacts of varying amounts of residue application or retention at the same experimental site, so the relationship between amount of residue applied and soil organic carbon is not clearly understood.

UNIVERSITY FOR DEVELOPMENT STUDIES

Kenney, (2011) and other studies report the amount of stover removed as a percentage of total stover production. However, yields of stover and other crop residues can vary considerably by location, so the percentage removed is not entirely informative. For example, removing 50% of stover from a field yielding 10 t/ha stover leaves twice as much stover on the ground as removing 50% from a field with a 5 t/ha stover yield. The latter depletes soil organic carbon to a much greater extent than the former. Understanding how crop residue removal or retention affects soil carbon

www.udsspace.uds.edu.gh

and quality according to the absolute amount, rather than the percentage, is thus likely to be more meaningful. It may be possible to remove a larger fraction of very high yielding residue crops without adverse environmental impacts.

Other agricultural practices may influence the relationship between residues and soil organic carbon. Soil texture may matter. Clays, which are mineral soils with small particle size, may theoretically support greater soil organic carbon accumulation than soils with larger particle size. Clay allows greater aggregation or bonding in soils, reducing erosion. In addition, clay can encase organic particles and prevent or slow decomposition (Lutzow *et al.*, 2006). The starting soil organic carbon content of soil may also affect further soil organic carbon accumulation if soils begin to reach soil organic carbon saturation (Six *et al.*, 1999).

Tillage practices also may influence the impact of residue retention on soil organic carbon. Tillage mixes air into the soil and reduces soil aggregation, accelerating the decomposition of residues and organic matter (Stubbs,*et al*, 2004). Tillage could thus reduce the effectiveness of residue retention in building soil organic carbon. This effect is apparent in U.S. data on land used to grow continuous maize. Using data from Searle and Malins (2016), we find statistically significantly greater soil organic carbon accumulation in no-till plots compared to conventional-till plots in the United States, with full stover retention on all plots. At least in the United States, practicing no-till does seem to enhance the positive effect of residue retention on soil organic carbon. In the EU, however, no-till is far less common than in the United States (Horowitz, *et al.*, 2010). Evidence is thus lacking on the combined effects of no-till or reduced-till and residue retention in that context.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

There is disagreement in the literature on the extent to which no-till can improve soil organic carbon globally (Powlson *et al.*, 2015).

There may be reason to expect that lower amounts of residue are necessary to achieve any particular level of soil organic carbon benefit in the EU compared to the United States, as conditions and management practices vary. For example, the EU overall tends to have lower erosion rates (Nearing, *et al.*, 2017), which is one factor affecting soil carbon and quality. There is a fair amount of literature in the United States on soil organic carbon impacts of maize stover retention versus removal, but the findings of this body of research may not be fully applicable to the EU. Less research and analysis have been done on this topic in the EU context specifically. In the next section, we conduct a thorough review of relevant experiments that have been conducted in EU countries and present a meta-analysis of findings across these studies.

UNIVERSITY FOR DEVELOPMENT STUDIES

2.17 Importance of Crop Residues

Society is progressively asking for a more sustainable way of managing agro-ecosystems in a framework of climate change as well as an ever-growing worldwide population. The destiny of crop residues is one of the vital management facets under discussion, since it epitomizes an unneglectable amount of organic matter which is capable of being kept in or eliminated from the agro-ecosystem. The issue of residue management is not novel, nonetheless the necessity for universal deduction on the effect of management of crop residues on the agro-ecosystem related to homegrown pedo-climatic conditions has become clear with an growing volume of research displaying a variety of deductions. This research explicitly concentrates on temperate climate and loamy soil using seven-year statistics between 2008 and 2016. Once a crop is harvested, farmers

www.udsspace.uds.edu.gh

must decide what to do with the residual crop residues (biomass that is above ground which is cut and not harvested). Residues are either exported and valorized as co-products (e.g. biogas production and animal fodder), or returned to the soil or following burning. Sending back straw straight to the field has been endorsed as an organic matter source and away to upsurge soil water retention capacity and its general quality. In view of this, it is assumed to help in the maintenance or to a certain degree return, soil fertility (Laletal, 2004).

When residues are sent back to the soil, farmers must decide on how to manage them by means of either conventional way tilling the soil or other possibilities such as low tillage. The exact effect of the compensation of residues and of the decision on the tillage system to adopt to the soil-plant system is still not clear and appears to depend on the pedo-climatic conditions (soil structure, macro fauna, moisture etc.) (Powlson *et al.*, 2011). For example, soil organic carbon mostly appears to some extent rise if residues are sent back to the soil, especially in the long run (Meranteetal.,2017). Nevertheless, the real quantification of straw integration consequence on soil organic carbon stocks demonstrates contradictory outcomes, as indicated by Poeplau *et al.* (2015), with research mentioning soil organic carbon losses, soil organic carbon maintenance or even insignificant or slight effect. The consequence of tillage on soil organic carbon is not so clear. Whereas some research findings show a rise of soil organic carbon with decreased or no-tillage (Arrouays *et al.*, 2002), show in their assessment, the effect of managing crop residues on crop yield is also inconsistent in current studies. The existence of residues appears to be damaging to crop germination as they are capable of forming a physical hindrance for seedlings (Arvidsson, *et al.*, 2014), can make a cold and moist micro-climate around seeds (Soaneetal.,2012) and offer a conducive environment for slugs (Christian &Miller, 1986) as well as plant pathogens (Arvidsson,

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

et al., 2014).Generally, studies show that weather situations are the key factor affecting crop yields (Dam, *et al.*,2005). Relationships between management of crop residues and the soil-water-plant structure are complicated and innately hinge on the pedo-climatic circumstances. Local evaluation and system approach are consequently essential to come to appropriate guiding principles for managing residues under definite pedo-climatic environments. The aim of the research was thus to find out the impacts of distinguishing strategies for managing crop residues on crop production and mechanisms of the soil fertility, for periods of several years on crop production.

UNIVERSITY FOR DEVELOPMENT STUDIES

2.18 Factors Affecting Crop Residue Decomposition

Processes involved in residue breakdown are influenced by three main factors: (a) kind of residues of plants, (b) edaphic/soil factors, and (c) factors associated with managing residues. Many factors affect the rate of crop decomposition and tend to be dependent as a variation in one factor could influence other factors. For instance, high levels of moisture in the soil possibly will end up in superficial residue application reduced aeration in the soil might have effects on soil temperature and moisture respectively. Owing to these strong relationships, it is frequently hard to separate the impacts of explicit environmental influences on residue disintegration.

2.18.1 Crop Residue or Waste Factors

Ground plant material has Frequently been used for suitability in the study of plant residue decomposition because of their uniform substrate. Debate on the consequence of particle size of plant residue on the degree of residue mineralization-immobilization tum over and decomposition of soil nitrogen (Angers and Recous, 1997). Smaller particles could decay quicker than the larger particles as a result of the enlarged surface area and larger dispersion in soil increasing the

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

predisposition to microbial outbreak (Summerell and Burgess, 1989), particularly when residues are not infiltrated readily by bacteria and fungi (Angers and Recous, 1997). Although fauna of the soil is accountable for only a smaller percentage (10 %) of respiration in the soil (Anderson, 1991), they play a significant part in accelerating the degree of decay of the organic matter, rendering it more susceptible to attack be microbes. For example, Curry and Byrne (1992) asserted that a 26 - 47% greater straw decay in net bags allowing earthworms than in bags that excepted earthworms during a period of 8-10 months of decay. Nevertheless, the biomass microbes and formed products in the initial decay of smaller particles could be improved compared to more breakdown as a result of mineral soil being more thoroughly mixed (Skene *et al.*, 1996).

Furthermore, an increased exposure to insoluble carbohydrates elements might result in immobilization of nitrogen and a greater surface area capable of being exposed to additional phenolic materials recognized to prevent decay (1990). Ambus and Jensen (1997) asserted that the greater microbial activities related to the initial decay of plant material in the ground was as a result of greater interaction of soil plant residues, nonetheless in the longer period, grinding of plant residues had no substantial impact on dynamic forces of nitrogen. The influence of particle size of plant residue on mineralization-immobilization tum over may thus be a dealing between secondary metabolic products, silt and clay content, faunal activity and chemical structure of plant residue. The management of residue particle size and the degree of mechanical destruction may thus be important for the conservation of nitrogen in agricultural systems.

a. Age of Residue

www.udsspace.uds.edu.gh

The chemical structure of a lot of crops varies intensely throughout their growth when the crop reaches maturity, its composition of water-soluble protein elements decreases gradually and the quantity of hemicellulose, lignin and cellulose increases. In general, water-soluble segments such as sugars, organic acids, portion of carbohydrates and proteins are broken down foremost, and next are the structural polysaccharides as well as the young plant residues usually decays more easily compared to the mature plants, and therefore leads to more nutrient releases (Luna-Orea *et al.*, 1996).

UNIVERSITY FOR DEVELOPMENT STUDIES

b. Leaf Toughness

Physical leaf toughness affecting residue decomposition has received a drastic attention. Gallardo and Merino (1993) developed a toughness index of residue and projected leaf toughness as an index of substrate quality. Silica content is responsible for leaf toughness and was reportedly said to have an effect on plant material digestibility and their decomposition.

c. Desiccation

The drying of crop residues before incorporation is a common procedure in nitrogen mineralization studies. Heat drying plant materials even at low temperatures between 50 and 60^{0}C can produce critically significant increases in lignin awareness because of the production of artifact lignin through a non-enzymatic charring reaction that involves plant nitrogen. This resulted in a significant reduction in nitrogen mineralization from the residues compared to fresh residues (Breland, 1994).

2.18.2 Crop Residue Quality

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Plants contain cellulose (15 and 60 %), hemicellulose (between 10 and 30 %), lignin (between 5 and 30 %), protein (21.5 %), as well as soluble substances, which include amino acids, sugars and organic acids, that could form part of the dry weight. Plants also contain cutin and silica. The degree of breakdown of organic matter hinges on the relative amounts of these individual elements, for instance cellulose, hemicellulose, soluble sugars and lignin. According to Hagin and Amberger, the half-lives of cellulose, hemicellulose, lignin and sugars were 364.5, 14.0, 6.7 and 0.6 days respectively. It has been known for a long while that with time the fractional loss rate decreases (Bending e' al., 1998), and such a drop mirrors the quality reduction of the residual substrate. The Crop Residue Quality which affect residues quality are as follows:

a. C/N Ratio and Nitrogen Content

Crop residues contains carbon on dry weight basis, but their nitrogen composition changes significantly, instigating the distinction in C/N proportions. It is largely recognized that residues with a varied C/N proportion decay more slothfully compared to those with a slim C/N proportion whereas residues of plants that have high constituent display higher levels of decay and release of nutrients (Douglas and Rickman, 1992). Very substantial relationships amongst nitrogen composition, release of nitrogen and loss of biomass. Findings of other research works have similarly shown the relevance of first nitrogen composition for finding out the decomposition of residues. Higher amounts of nitrogen in residues decreases competition of accessible nitrogen by microbes and thus making it easy for decay by preserving higher microbial activities. Adding nitrogen to reduce the C/N proportion of wheat straw (75: l) meaningfully caused release of additional carbon dioxide compared to control and level of decomposition of crop residues on adding farmyard manure.

www.udsspace.uds.edu.gh

Research findings indicate that that 44 % of straw (0.92 % N) decayed in the first four weeks although just 7% of the straw (comprising 0.4% N) decayed in the four weeks of incubation. It is also known that green foliage and fresh roots of pea plants (3.9% N) decomposed quickly. Decomposition of crop residues on accessible carbon and nitrogen appears to have a correlation with data from the field than composition related to total nitrogen and carbon. Available carbon for microbial decomposition has been estimated for different plant residues, which correlated with decomposition (Mtambanengwe and Kirchmann, 1995).

UNIVERSITY FOR DEVELOPMENT STUDIES

Even though the C/N ratio and N content of crop residues are valuable in envisaging decomposition rates of crop residues, these ought to be utilized with some care as the C/N ratio has limited information on available carbon and nitrogen to micro-organisms. Any factor that increases the rate of decomposition and hence the nitrogen demand, tends to increase the threshold nitrogen concentration (lower the threshold C/N ratio). For example, a more favorable climate and higher rates of residue application with a greater amount of readily available carbon in the substrate would stimulate greater microbial activity, increase nitrogen demand, and increase the threshold of nitrogen concentration (Dendooven *et al.*, 1990).

b. Lignin

The function of lignin in inhibiting the breakdown was explained in numerous research works (Giller and Cadisch, 1997), Lignin is recognized as a recalcitrant material, very resilient to microbial breakdown with just a few micro-organisms capable of degrading lignin and these are entirely aerobic. Various research findings show that increasing concentration of lignin decreases

www.udsspace.uds.edu.gh

the rate of breakdown and release of nutrients from crop residues and similarly increases immobilization of nutrients. Concentration of lignin in substrates was a very good guide for forecasting rates of decomposition and weight losses of forest litter samples. Lignin concentration was useful indicator for predicting the decay rate of residues than the concentration of nitrogen (Giller and Cadisch, 1997).

c. Polyphenols

Polyphenols are attached to protein and constitute complex substances impervious to decay. Polyphenols are as well capable of binding to organic nitrogen substances (amino acids and proteins) in leaves, making nitrogen unavailable, or bind to soluble organic nitrogen released from leaves, forming resistant complexes in the soil (Northup *et al.*, 1995). Polyphenols also inhibit enzyme action. Net mineralization of nitrogen from leaves of tea with high solvable nitrogen as well as good polyphenol amount compared to those with high blew nitrogen but small polyphenol content. Leguminous plat growth formed part of the fastest degrading plant substances because they contained large amounts of protein and small quantity of lignin and some inhibitors such as polyphenol compounds.

The relevance of polyphenols in the decomposition of residues as well as the process mineralization has often been discussed in some studies, ployphenols as well as ployphenoI/N and (lignin + polyphen01)/N relations have been related with the decomposition of residues and release of nutrients, whereas in other studies, nitrogen content. lignin composition, as well as lignin/N proportions were well associated with decomposition of residues and release of nitrogen (Constantinides and Fownes, 1994).

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

d. Combined Chemical Compositions

According to Tlan *et al.* (1995), the rate of decay rate of residues of plants were not projected from organic substances such as C/N proportion, lignin, or carbohydrate materials, nonetheless once put together these properties are capable of precisely predicting comparative decomposition rates for a wide array of residues of plants.

Residue decomposition occurred in two phases. Phase I is relatively rapid and is dependent on the initial residue nitrogen content (Jama and Nair. 1996), whereas phase Il decomposition is relatively slower and is regulated by lignin and polyphenol decomposition (Jama and Nair, 1996), which shows little variations in the rate of decomposition of residues despite initial nitrogen content because soluble, easily decomposable components have already been utilized by microbes or lost by leaching (Douglas el al., 1990). The links among the quantities of a chemical constituent as well as the decomposition rate of straws apart from the greater proportion of water-soluble substance in straws of barley, that could be as a result of the second phase of decay. The distinction between these two phases occurred when the "lignocellulose index" [LCI ratio of lignin (lignin + cellulose)] reached a value of about 0.7 When this lignocellulose index value been reached, the composition of decaying material remained unchanged and the decay was determined by environmental factors. Both carbon and nitrogen dynamics were broadly described by this two-phase model (Palm. 1995). Microbial, particularly fungal, succession on decomposing litter reflects changes in litter composition, as do fauna with recognition of phases in palatability and interaction with microflora (Hammel, 1997). A consequence of this points to the correlations among mineralization rate or loss of nutrients as well as simplified terms of the preliminary

www.udsspace.uds.edu.gh

conformation of litter could possess limits (Heal *et al.*, 1997). These changes are not only restricted to chemistry. For example, Gallardo and Merino (1993) distinguished an initial leaching phase in which the leaf toughness and toughness-to-Phosphorus concentration of the original litter provided the best prediction of mass loss.

UNIVERSITY FOR DEVELOPMENT STUDIES

Problems Associated with Residue Quality Characterization Methodological

In recent years, several attempts have been made to quantify residue quality and its relationships with residue decomposition, mostly in terms of nitrogen mineralization (Bending e' al.,1998). Although general trends have been observed, no unique relationship has been developed (Vanlauwe *et al.*, 1997). This is partly due to different methodologies and approaches used by different workers.

a. Extraction Methods for Lignin and Polyphenols

Different methods are used in extracting polyphenols from plant tissues. Amounts of total ploypheno1s extracted from plant tissues varied from 30 to 90 % according to a method use. Tedious and inaccurate methods of proximate analysis obscured the biochemical composition. The advent of more sophisticated techniques (e.g., variants of mass spectrometry) allows the rapid and sensitive characterization of organic materials, thus enabling their degradation and synthesis to be followed (Heal 1997).

b. Age of Plant Residues and Molecular Size of Polyphenols

Polyphenol concentration is usually more in matured residues compared to those in green leaves, in addition polyphenols have diverse characteristics with regards to binding nitrogen-containing

www.udsspace.uds.edu.gh

substances, and these depend on their molecular weight. These explained why polyphenols correlated with decay as well as release of nitrogen in certain research works although unavailable in other compounds (Vanlauwe *et al*., 1996).

c. Methods of Determining Decomposition Rates

Different particle sizes of crop residues and methods of determining residue decomposition (viz. direct application to soil or application in mesh bags) are known to affect residue decomposition rates (Magid *et al.*, 1997). Variations in residue weight loss determinations using mesh bags, which is the most common method of estimating decomposition.

d. Variation in Composition of Same Plant Species at Different Sites and Different Plant Parts

Study results indicate that there exist variations in decay of residues as a result of variances in N, C/N, lignin/N, and polyphenol/N proportions even in the case of same species. Variation of site, plant part, and environment conditions also affected the litter chemistry of residues from the same plant species. For example, Pinus Sylvesrris needles varied in carbohydrate composition and lignin polymerization in relation to nutrient status and pH of different soils on Which they were grown (Sanger *et al.*, 1996). Likewise, Vitrusek *et al.* (1994) found that the litter of tropical tree Metrosideros polymorpho grown on dry Hawaiian lava flows decomposed twice as rapidly as litter of the same species on wet sites. These workers concluded that superior quality of substrates from dry locations might be as a result of trade-offs in nutrient as well as water use efficiency and absorption of carbon by plants when grown under different climates. An unconventional approach was adopted by Maizeelissen (1996). where the weight loss of more than 100 species of leaf, needles. and shoot litter was measured under standard field

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

conditions. The weight loss was related to a variety of plant characteristics such as growth habits, evergreen vs deciduous, autumn correlations, and evolutionary advancement. There existed a strong signal of the adaptive approach of defense of tissues (gather diverse chemicals in their tissues) (Maizeelissen's, 1996).

UNIVERSITY FOR DEVELOPMENT STUDIES

2.18.3 Edaphic Factors

a. Soil pH

One of the utmost vital issues affecting the decay of residues is soil pH as it impacts on the nature and number of micro-organisms as well as the diversity of enzymes at the microbial level, which afterward impact on decay. Generally, the decay of residues of crops occurs at a faster rate in neutral compared to acid soils. Therefore, liming acid soils quickens the decomposition of tissues of plants, simpler carbonaceous substances, as well as organic materials in soils. Research results indicate that with regards to practical conditions in the United Kingdom, 42% of the ryegrass-derived carbon survived after I year in a soil with a pH of 3.7, while just 31 % persisted in soils with a pH of 4.4 - 6.9. This could be as a result of changes in populations of soil microbes and their activities following changes in pH of the soil. Typically, the population moves from bacteria to actinomycete to fungi with decline in the pH of the soil (Condron *et al.*, 1993)/

b. Soil Temperature

Microbial decay activities are much relevant compared with chemical and physical developments in producing residue losses from the field, resulting in nutrient releases. Temperature impacts on the rates of physiological reaction of organisms as well as activities of microbial cells by thermodynamics laws and thus microbial activities and breakdown of residues (De-Neve *et al.*,

www.udsspace.uds.edu.gh

1996). The influence of temperature on crop residue decomposition has been described quantitatively as the temperature quotient nitrogen mineralization rate of native soil organic matter in the temperature range between 5 and 35^{0}C have been reported to be approximately 2 (Scholes *et al.*, 1994). Higher quotient value values have been reported by other workers between different temperature ranges (Vigil and Kissel. 1995), indicating some interactions between temperature and quality of crop residues.

Micro-organisms perform at supreme growth and activity between 20—40 ^{0}C and displayed highest breakdown within that range of temperature. At the extreme ends of the temperature scale (e.g., O and 40^{0}C). it is generally believed that temperature regulates the activity of microorganisms more than their mass. Under field conditions, marked diurnal and seasonal fluctuations in surface soil temperature are common. Even though it has largely been realized that microbial growth is repressed by changing temperatures. Some studies showed that nitrogen mineralization is almost not affected in the mesophilic (but optimum between 25 and 35^{0}C) temperature range (Kanai, 1995).

UNIVERSITY FOR DEVELOPMENT STUDIES

c. Soil Moisture

Micro-organisms in the soil depend on soil moisture for their growth and activities, and the soil moisture paves the way for the breakdown of plant residues as well as cycling of nutrients to occur. The degree of straw breakdown, quantified in terms of loss in dry weight loss, was greatest at -0.1 MPa and reduced with corresponding decrease in the external soil water potential (Schomberg *et al.*, 1994).

www.udsspace.uds.edu.gh

A study conducted by Das *et al.* (1993) showed that there were greater volumes of nitrogen releases from decaying residues of crops at maximum field capacity compared to 50% of field capacity. According to Thomsen (1993), there was higher amounts of soil microbial biomass on straw addition under moist soil conditions (54— 82%) compared to wet conditions (4-27%), perhaps as a result of restricted aeration for microbial activities under wet conditions. Hence, very dry and very well conditions of soil prevent decay by restraining either moisture content or soil aeration for microbial activities.

d. Freezing and Thawing

The thawing of previously frozen surface detritus resulted in the immediate release of large amounts of soluble materials. This is thought to represent the release of materials previously immobilized in microbial tissue. Such a release of soluble materials contributed to the burst of decomposer activity that occurred at the onset of snow melt, which may lead to a substantial increase in the decomposition rate.

UNIVERSITY FOR DEVELOPMENT STUDIES

e. Drying and Rewetting

The effect of drying and rewetting on the decomposition of plant residues is unclear. It was found that although drying stimulated the subsequent mineralization of carbon and nitrogen from soil humus, it retarded the mineralization of fresh plant materials (van Gestel er al., 1993). The decay rate of biomass increased relatively greater by soil desiccation and remoistening than decay rates of non-biomass. Repeated drying and wetting of the soil appeared to increase the resistance of certain nitrogen compounds of the plant to microbial decomposition. Franzluebbers *et al.* (1994) reported that repeated drying and rewetting did not reduce the carbon mineralization of cowpea

www.udsspace.uds.edu.gh

[Vigna unguiculata (L) Walp.l significantly; nitrogen mineralization from cowpea, however, was reduced significantly. Repeatedly drying and wetting can inhibit microbial growth and/or activity severely. In the field, it could reduce nitrogen mineralization from legume green manure compared to decomposition in continuously moist soil. This may contribute to long-term soil nitrogen fertility by increasing the soil organic nitrogen content.

UNIVERSITY FOR DEVELOPMENT STUDIES

f. Aerobic and Anaerobic Conditions

Decomposition and mineralization are slower and less complete under anaerobic than aerobic conditions (Kretzschmar and Ladd, 1993). When soils become so wet that larger pores are filled With water, the decomposition of organic matter is limited by the rate at which oxygen can diffuse to the site of microbial activity, as the diffusion coefficient of oxygen in water is 10,000 times slower than in air Thus, even a modest oxygen demand cannot be met if larger soil pores are filled with water.

g. Soil Salinity

This is generally attributed to a direct influence of the osmotic potential on microbial activity or through the alteration of pH, soil structure, aeration, and other factors (Nelson *et al.*, 1996). Residue composition, as well as increased salinity, affected the decomposition and C02 surface flux dissolved organic carbon and may be an important factor for carbon storage in saline systems (Olsen e' al., 1996). In the absence of pH and aeration effects, Nelson *et al.* (1996) concluded that sodality increased and salinity decreased the decomposition of finely ground plant residues, with no significant interaction.

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

h. Available Nutrients

Most primary limiting factor in most soils for microbial growth is carbon. An abundance of carbon is added to the soil through crop residues. New cells of microorganisms require not only C, H, O, and N. but also P. K, S, Mg, Ca, and micronutrients. When an organic material is added to the soil, microorganisms decomposing it can obtain the necessary inorganic nutrients (N, P, K, S, Ca, etc.) for growth from two sources: (i) those already present in the soil in plant available forms and (ii) those in the added organic material itself. Apart from nitrogen, other elements have also been shown to influence residue decomposition. For example, Cheshire and Chapman (1996) concluded from adding N and P to 14C-labeled ryegrass that P, whether intrinsic or added, increased the rate of decomposition of organic residues but there was a Strong interaction with N, which had a predominant influence. In addition, Enriquez *et al.* (1993) demonstrated that the decomposition rate increased with both intrinsic N and p. "The effect of N on its form. Increased intrinsic tissue N increased the rate of C loss, whereas added inorganic N decreased the rate of C loss during decomposition (Cheshire and Chapman, 1996).

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Study Area

3.1.1 Location of the Study Area

The research was conducted in the Tamale Metropolis (Figure 3.1). The Tamale Metropolitan Area is located at the centre of Northern Region. It is a fast-growing city with a population of 414,548 as of 2010. This number depicts a rise of 75 % over the 1984 human population of 167,778 and denotes an increase rate of 3.5 % (GSS, 2010). The Metropolis is located between longitudes $0^{0}46'$ W and $0^{0}59'$ W and latitudes $9^{0}15'$ N and $9^{0}32'$ N and covers a total area of 3,688 km^{2} (SARI, 2004).

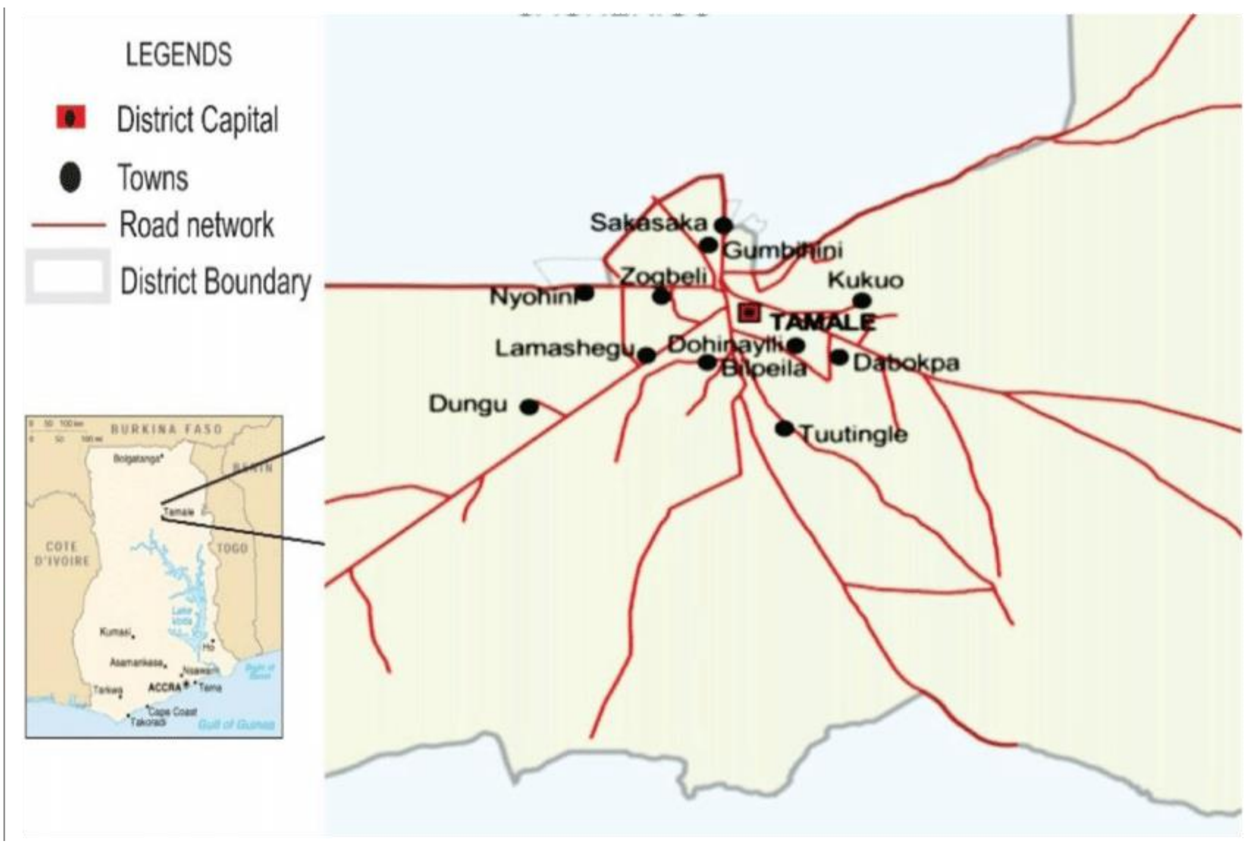

Figure 3.1: Map of Tamale Metropolis

www.udsspace.uds.edu.gh

3.1.2 Climate

The mean annual rainfall is about 1043 mm; with means of 156 mm and 67 mm per month as the maximum and minimum respectively. The average diurnal maximum temperature is between 33 °C and 39 °C whereas the average diurnal minimum temperature is between 20 °C and 22 °C. The diurnal relative humidity between April and October is 96 % at night and 70 % during the afternoon. Daily sunshine period is between 9.45 hours in November and 4.00 hours in the overcast months of August and September. Annual figures of evaporation from free water surface are approximately 1830 mm as against rainfall of about 1100 mm (SARI, 2004).

3.1.3 Soil of the Study Area

The rocks are voltaian sandstone formation. They are mainly shales and mudstone which have developed ferruginous layers. The ferruginous materials are hardened when exposed at the surface to form hard pans. The topography of the land is gently undulating and composed of three low ridges or hills which have been separated into eastern, central and western uplands by two broad and shallow depressions. The soils are generally gravelly and sandy. Top soils are thin above an underlying concretionary layer (FAO-UNESCO, 1988). The main soil types in the Metropolis are sandstone, gravel, mudstone and shale that have weathered into different soil grades. Due to seasonal erosion, soil types emanating from this phenomenon are sand, clay and laterite ochrosols. The availability of these soil types has facilitated real estate development in the area as estate developers have resorted to using these materials in the building industry (GSS, 2010).

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

3.1.4 Population Size, Structure and Composition

The human population of Tamale Metropolis represents 9.4 % of the population of the Northern Region. Males make up 49.7 % while females form 50.3 %. The percentage of the population dwelling in urban parts (80.8 %) is greater than that of rural areas (19.1 %) of the Metropolis. Tamale Metropolis has a relatively youthful population (nearly 36.4 % of the population is under 15 years) showing a wide base population pyramid, tapering off with a small proportion of elderly people (60 years or older) forming 5.1 %. The district has a total age dependency ratio of 69:4, while the rural areas have an age dependency ratio of 86:5, which is higher than that of the urban part (65:7) (GSS, 2010).

3.1.5 Household Size, Composition and Structure

Tamale Metropolis has an overall number of 219,971 households, dwelling in 19,387 houses. The mean household size is 6.3 people per household. Children form the largest segment of the household structure, constituting 40.4 % while household heads form 16.1 % of population of households. Married couples make up approximately 9.4 % while other relatives form 12.9 % of the population. The percentage of households living in extended household structure (head, spouse(s), children as well as head's relatives) form the highest percentage (46.1%) compared to any other kind of household structure. Nuclear households (head, spouse(s) as well as children) form just 19.5 % of households (GSS, 2010).

3.1.6 Economic Activity Status

Approximately 63.3 % of the people living in the Tamale Metropolis are aged 15 years or more in the Metropolis are active economically. Of these, 92.6 % are working whereas 7.4 % have no jobs.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

For the ones that are economically not active, a higher proportion are students (56.0 %), 20.9 % carry out household chores while 12.4 % are very young or old to work. Approximately 52.9 % of jobless people in the Metropolis are looking for jobs for the very first time in their lives(GSS, 2010).

UNIVERSITY FOR DEVELOPMENT STUDIES

3.1.7 Occupation

Of working population in the Metropolis, the largest percentage (33 %) is engaged as sales and service workers. Craft and related trade workers who constitute 21.5 % of the employed population form the second largest occupation. Skilled agricultural, fishery and forestry workers constitute 17.6 % of the working population. People working as professionals form just 8.1 % (GSS, 2010).

3.1.8 Agriculture

Approximately 26.1 % of households in the Tamale Metropolis are working in the agricultural sector. In the rural areas, the percentage of households involved in agriculture (43.3 %) is lower than that of the urban ones (56.7 %). About 84.8 % of households engaged in agriculture are cultivating crops, 52.9 % in urban areas and 47.1 % in rural parts. Fish farming is undertaken by the smallest percentage (less than 0.1%) of households (GSS, 2010).

3.1.9. Drainage and Vegetation

The Metropolis has few water bodies and it has adversely impacted on the regular water supply to households in the Metropolis. The few natural water systems are the seasonal streams which contain water in the rainy season and dry up in the dry season. The Tamale Metropolis is located in the savannah woodland agr0-ecological zone of the country. The trees are short-scattered woodlots. The main tree species are Shea (Vitellaria paradoxa), Dawadawa (Parkia biglobosa), Nim (Azaditachta indica), Acacia (Fadherbia albida), Mahogany (Khaya spp), and Baobab (Adansonia digitata), among others. The area is blessed with tall grasses in the rainy season, and these are used in making the local mats commonly known as, "Zanamat". During the dry season, Zanamat making by most farmers decreases rural-urban drift of young people from rural communities to urban areas. Also, the only economic tree, the Shea tree, has gained global recognition. The picking, processing as well as marketing of sheanuts for the past decades has engaged virtually all households in the Metropolis. Certainly, these shea-related economic activities have created job opportunities for young people, improved household incomes and also decreased poverty. Cashew is cultivated by many people in the Metropolis (GSS, 2010).

UNIVERSITY FOR DEVELOPMENT STUDIES

3.2 Sources and Types of Data, Sample Size and Data Collection Technique

3.2.1 Sources and Types of Data

Both primary and secondary data were obtained from the study. The primary data was obtained by employing quantitative and qualitative methods. The quantitative method involved the weighing of organic residues at rice mills, maize shelling centres, groundnut shelling centres, sheanut processing centres, maize mills, sawmills, food sellers (such as kenkey sellers, rice sellers) in the four demarcated zones of the Tamale Metropolis. The qualitative methods used included direct personal observations and interviews with the ninety randomly-selected people in the Metropolis who generate organic residues at the organic residue generating centres and food selling points. Secondary data were obtained from libraries, books, periodicals and seminar papers, research reports and the internet.

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

3.2.2 Sample Size and Sampling Technique

The Tamale Metropolis is quite large with a heterogeneous population. As a result, and for the purposes of this research, a preliminary study was done and stratified sampling technique was used to divide the area into four strata or zones: Jisonayili Zone (representing Tamale North); Vittin Zone (representing Tamale South); Kalpohin Zone (representing Tamale East); and Nyohini Zone (representing Tamale West). According to the 2010 PHC, the Tamale Metropolis has a human population of 223,252 and covers a total area of 3,688 km^2 (SARI, 2004). This means each of the four zones has approximately 25 % (55,813) of the total population and covers an area of 922 km^2. These zones consisted of various areas where organic residues are generated; rice mills, maize shelling centres, groundnut shelling centres, sheanut processing centres, maize mills, sawmills, food sellers (such as kenkey sellers, rice sellers). Global Position System (GPS) was used to locate organic residue generating centres and points and loaded on to a software for reference and easy identification. Physical measurements of organic residues at these centres and points were done. The residues weighed included maize stovers, rice hulls, rice straw, vines and husk of legumes (such as groundnuts, soya beans), peels of yam and cassava. Thirty per cent of the total number of people who generate organic residues in each zone was selected using simple random sampling technique (Social Cops, 2017). In all, 90 respondents were selected and interviewed using administered semi-structured questionnaires.

3.3 Data Analysis

The collected data was analyzed using both qualitative and quantitative methods. The quantitative data was analyzed using Microsoft Excel and Genstat statistical packages. The qualitative data

www.udsspace.uds.edu.gh

were analyzed using descriptive statistics, from which percentages of responses, frequencies and means were gotten. The results were presented in the form of tables, histograms and pie-charts.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

General Overview

This chapter presents findings of the study on the quantification of spatial and temporal availability of organic materials in the Tamale Metropolis. A total of ninety respondents were randomly selected and interviewed on generation, processing, management and uses of organic materials in the Tamale Metropolis. The first section focuses on the analysis of the demographic characteristics and background information of the respondents. The second section discusses the quantities of organic materials produced in the Metropolis, their current usage, their periods of availability, the costs of at they are obtained as well as constraints associated with their management and usage.

4.1 Demographic Characteristics of Respondents

4.1.1 Age Distribution of the Respondents

The percentage distribution of the respondents according to age, as indicated in Figure 4.1 shows that majority (50 %) of the respondents fall within the age bracket of 31- 40 years, followed by age range 20-30 (23.3 %). The results show that about 15 (16.7 %) of the respondents were aged between 41 and 50 years while only 9 (10 %) were 51 years and above. The average age of the respondents was 29 years. The minimum and maximum ages of the respondents were 21 and 56 years respectively. This implies that middle aged farmers have greater strength to do the labour-intensive work with regards to the collection and utilization of organic materials.

UNIVERSITY FOR DEVELOPMENT STUDIES

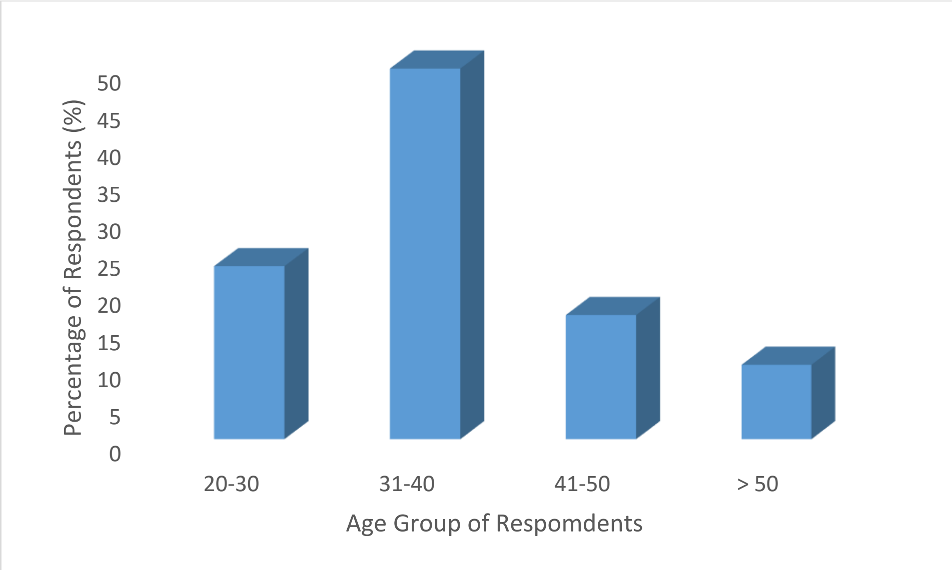

Figure 4.1. Age Groups of Respondents in the Tamale Metropolis

4.1.2 Gender of Respondents

With regards to the gender of the respondents, 67 (74.4 %) of the households are males and the remaining 23 (25.6 %) are females. As can be inferred from Figure 4.2, majority of the respondents are males. This implies male respondents are most likely to engage in generation, processing and utilization of crop residues. These results confirm an assertion by Danso *et al.* (2002) that activities associated with farming and generation, processing, management and utilization of crop residues are largely dominated by men. This could be attributed to the culture in the areas, economic situation and the drudgery nature of those activities.

www.udsspace.uds.edu.gh

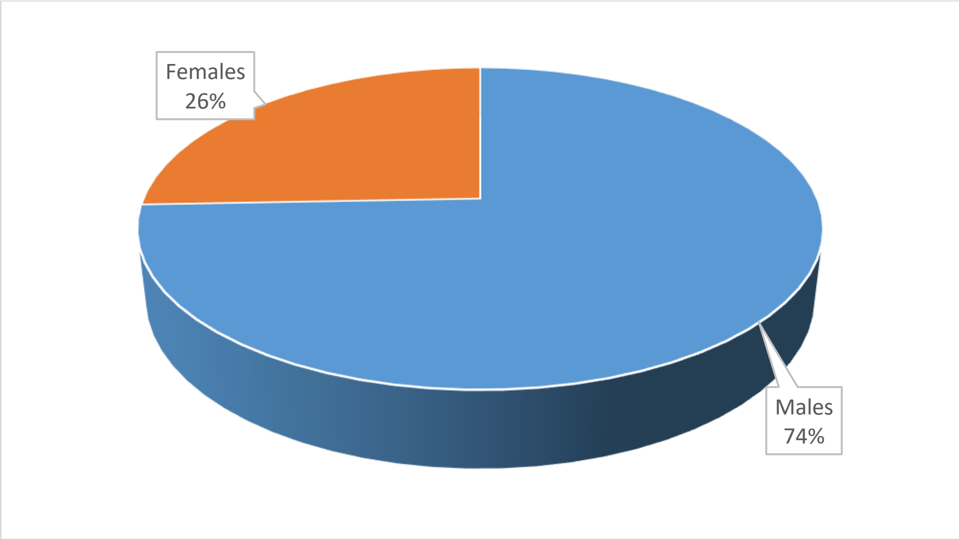

Figure 4.2. Gender of Respondents

4.1.3 Marital Status of Respondents

Findings of the research indicate that all categories of people are involved in the processing and utilization of crop residues in the Tamale Metropolis. An analysis of the gathered data indicates that 78 % of the respondents interviewed are married, while 12 %, 7 % and 3 % are single, divorced and widowed respectively (Figure 4.3).

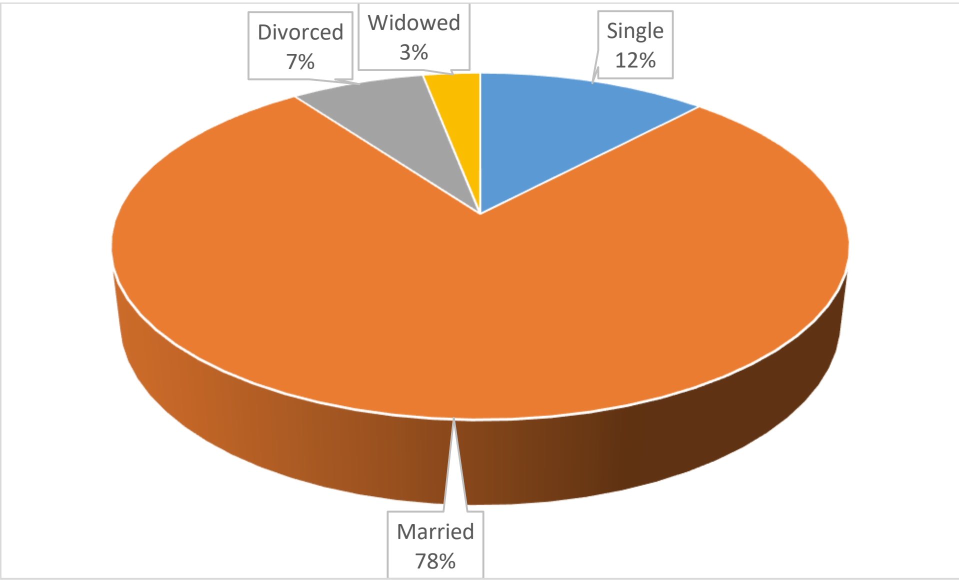

Figure 4.3. Marital Status of Respondents

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

4.1.4 Educational Level of Respondents

Analysis of the gathered research data (Figure 4.4) shows that 57 (about 63 %) of the respondents had no formal education; 8 (9.2%) had basic education; 23 (25.1%) of the respondents had Senior High School (SHS) education while only 2 (representing 2.4 %) of the respondents attained tertiary education. The findings show that a higher proportion of the respondents had no formal education. This is line with findings of Eyasu (2002) who posited that the level of education is one of the demographic features of people involved in farming and processing and management of crop residues, and that these play crucial roles in accessing information on farming activities environmental issues as well as the processing and management of crop residues. Therefore, education or literacy has an impact on the level of participation of people in the processing and management of crop residues.

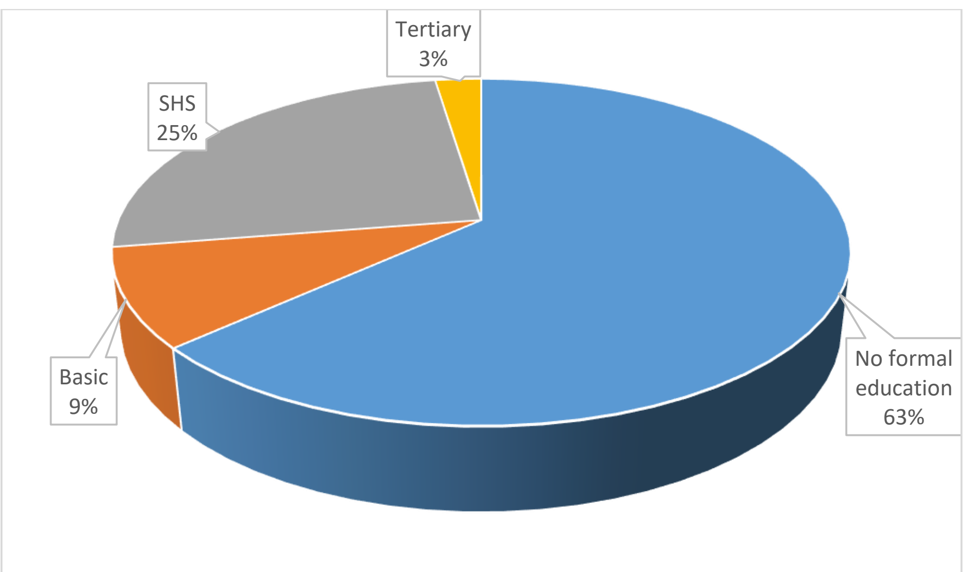

Figure 4.4. Educational Level of Respondents

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

4.1.5 Number of Years of Experience in the Generation and Uses of Crop Residues

The research findings show that 38 (42.2 %) of the respondents had 11-15 years of experience, followed by 21 (representing 23.3 %) who had 16-20 years; 19 (21.1 %) had 6-10 years; 8 (8.9 %) had 21 years and above of experience in generation and/or utilization of crop residues. Only 4 (4.4 %) of the respondents had 1-5 years of experience (Figure 4.5). These were probably young school leavers who have just gone into the business of generation/processing and/or utilization of crop residues.

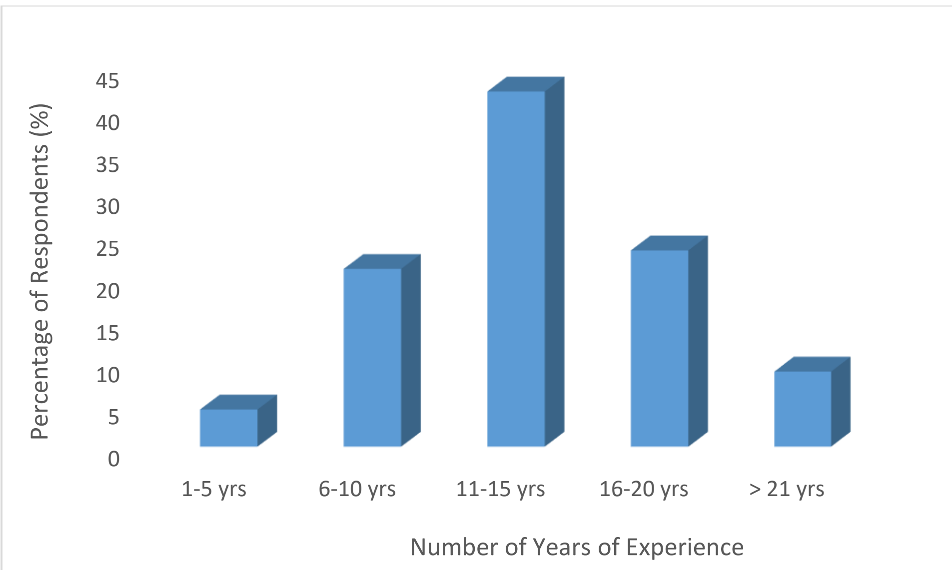

Figure 4.5 Number of Years of Experience of Respondents in Generation and Uses of Crop Residues in the Tamale Metropolis

4.2 Quantities of Crop Residues Produced in the Tamale Metropolis

4.2.1 Quantities of Off-Farm Crop Residues Produced in the Zones

The research basically involved the quantification of organic materials generated in the Tamale Metropolis. In view of this, the various locations and places in the four zones (Jisonayili, Nyohini, Vittin and Kalpohin) where organic residues are generated were visited and data was taken on

www.udsspace.uds.edu.gh

organic materials produced. These locations and centres were rice mills, maize shelling centres, groundnut shelling centres, sheanut processing centres, maize mills, sawmills, food sellers (kenkey sellers, etc.). By weighing the organic residues generated at these centres and other places in each zone in the Tamale Metropolis, the total amount of organic residues produced in all the four zones in the Metropolis was extrapolated to 4932.2 tonnes per annum (Table 4.1). An analysis of the results indicates that the zones significantly differed ($p < 0.05$) in the quantities organic residues produced in the Tamale Metropolis, with Jisonayili Zone producing the largest quantities of the residues (2937.3 ton yr^{-1}), followed by Nyohini Zone (914.4 ton yr^{-1}), with Kalpohin Zone producing the least (269.7 ton yr^{-1}). Nyohini and Vittin zones did not however differ ($p > 0.05$) in the quantities of organic residues produced (Table 4.2).

Table 1. Types and Quantities of Organic Residues Produced in the Tamale Metropolis

		ZONE			
Crop residue	**Jisonayili**	**Nyohini**	**Vitiin**	**Kalpohin**	**Total (tons)**
Maize stalk	2465.0	771.0	636.0	225.0	**4821.0**
Maize cobs	436.0	136.0	112.0	40.0	
Rice hull	5.5	1.1	9.1	-	**102.4**
Rice straw	30.5	6.3	50.0	-	
Soya beans	0.3	-	2.9	4.7	**7.9**
Groundnuts	-	-	0.9		**0.9**
Total (tonnes)	**2937.3**	**914.4**	**810.8**	**269.7**	**4932.2**

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Table 2. Quantities of Organic Residues Produced in the Zones in the Tamale Metropolis

Zone	***Quantity of Organic Residues Produced (ton yr^{-1})***
Jisonayili	2937.3[a]
Nyohini	914.4[b]
Vittin	810.8[b]
Kalpohin	269.7[c]
LSD (0.05)	121.4
CV (%)	23.2

Means with the same superscripts within a column are not significantly different (p>0.05)
Means with different superscripts within a column are significantly different (p<0.05)

4.2.2 Types and Quantities of Off-farm Crop residues

Table 4.6 shows the organic residues generated from each crop at the various zones in the Tamale Metropolis. The quantities of residues generated by the various crops varied widely and differed significantly ($p < 0.05$). There was significant difference ($p < 0.05$) between maize residues and the other crop residues, with maize residues produced at the processing centres and other locations being the highest (4821 tons yr^{-1}), followed by rice residues (102.4 tons yr^{-1}) while the groundnut residues (0.9 tons yr^{-1}) were recorded as the least produced in the zones. Soya beans and groundnuts residues did not however significantly differ in terms of the amounts of residues they generated in the zones in the Metropolis (Table 4.3). These variations were mainly as a result of the different types and amounts of crops processed at the various processing centres and food production units in the zones within the Metropolis. It was also found out that some processing centres were not processing some types of crops. This was due to the unavailability of the required processing machines and/or crops for processing or preparing them into food products. This is in

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

line with an assertion by Tesfaye *et al.* (2006) that the availability of on or off-farm crop residues depends on levels of production of the crops, natural, social and economic factors existing within that locality.

4.2.2.1 Quantification of Maize Residues

The total amount of residues generated per annum from maize was about 4821.0 tons yr^{-1}. Maize stalks contributed the bulk of the residues generated from this crop (Table 4.1). In overall terms, maize residues constituted about 98 % of the total residues generated in the Metropolis. Results of the research show that maize off-farm crop residues are produced in all the four zones of the Metropolis; the Jisonayili, Nyohini, Vittin and Kalpohin zones producing 2937.3, 914.4, 810.8 and 269.7 tons yr^{-1} respectively.

4.2.2.2 Quantification of Rice Residues

There was a total rice residue production of approximately 102.4 tons yr^{-1} in all the zones in the Metropolis, except in the Kalpohin Zone. Rice residues contributed about 2.1 % of the total organic residues generated in the Metropolis. Rice residue production was more concentrated in three zones (Jisonayili, Nyohini and Vittin zones). Vittin and Jisonayili zones were the highest producers of rice residues in the Metropolis with a residue generation of about 59.1 and 36.0 tons yr^{-1} respectively.

4.2.2.3 Quantification of Soya Beans Residues

The amount of organic residues generated from soya beans was about 7.9 tons yr^{-1}. Soya beans contributed only 0.2 % of the total organic crop residues in the Metropolis, and apart from the Nyohini Zone, were produced in all the zones, with the amounts generated in Kalpohin, Vittin and

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Jisonayili as 4.7, 2.9 and 0.3 tons yr^{-1} respectively (Table 4.1). The highest organic residues from soya beans were produced in the Kalpohin Zone. Generally, compared with maize and rice, there was low soya beans residue production in the Metropolis.

4.2.2.4 Quantification of Groundnuts Residues

Groundnuts generated total residues of 0.9 tons yr^{-1}. Groundnuts residues contributed the least to the total organic residues produced in the Metropolis, with only 0.02 % of the total organic residues produced, and this was mainly concentrated in one zone, Vittin Zone (Table 4.1).

Table 3. Types and Quantities of Organic Residues Produced in the Tamale Metropolis

Crop	***Quantity of Crop Residues (ton yr^{-1})***
Maize	4821.0[a]
Rice	102.4[b]
Soya beans	7.9[c]
Groundnuts	0.9[c]
LSD (0.05)	34.1
CV (%)	7.6

Means with the same superscripts within a column are not significantly different (p>0.05)
Means with different superscripts within a column are significantly different (p<0.05)

4.2.3 Quantities of Organic Residues in the Tamale Metropolis

With regards to the quantities of organic residues collected from processing centres and other locations in the zones, organic residues (rice, millet, maize, groundnuts and soya beans residues) in the Metropolis were collected and weighed. Ninety respondents involved in the generation of organic residues were randomly selected in the four zones and their generated organic residues

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

were weighed and recorded. The estimated quantities of residues ranged from less than 1000 kg to over 5000 kg per respondent per year. As indicated in Figure 4.6, majority (56 %) of the respondents produce less than 1000 kg of organic residues per year. Twenty percent produce between 1000 kg and 2000 kg, followed by 2000 kg and 3000 kg (10 %), 3000 - 4000 kg and above 5000 kg constituting 6 % each while only 3% produce 4000 - 5000kg of organic residues. Further analysis reveals that the average quantity of organic residues produced annually is 1469.10 kg while the minimum and maximum are 50 kg and 35,660.00 kg respectively. Although these are quantities of organic residues generated per person per year, they are in sharp contrast with reported quantities of organic residues of about 5.2 million tons per annum in Kenya, as reported by Cooper and Laing (2007), while Senelwa and Hall (1993) reported a figure of about 11 million tons per annum in Kenya. This variation is due to differences in the main approach utilized, the number and combination of crops evaluated and crop residue characteristics, such as residue to product ratios and moisture content utilized as well as size of the study area. Butterworth and Mosi (1985) stated that there could be variation in accuracy of estimation as it is difficult to make precise estimation of residue production due to uncertainty of crop production figures and harvesting indices.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

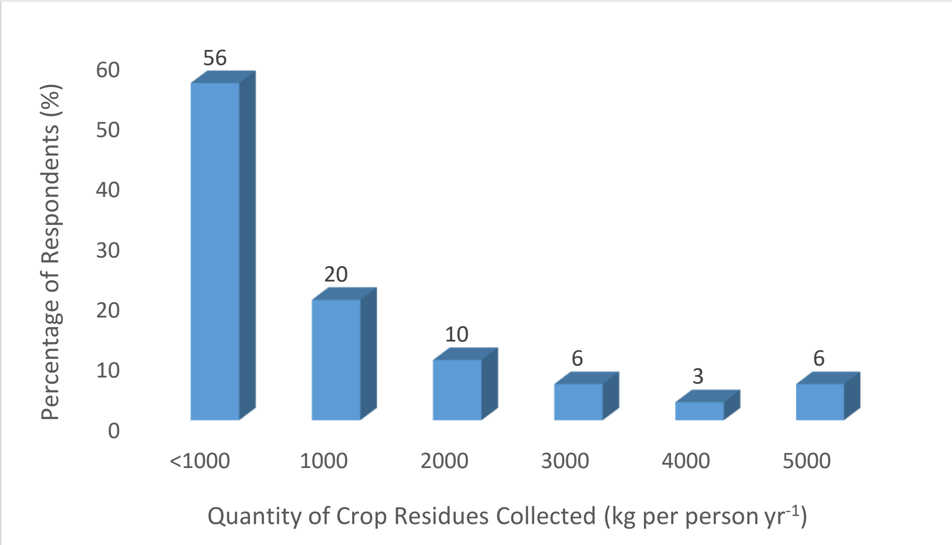

Figure 4.6. Quantities of Organic Residues Collected in the Tamale Metropolis

4.3 Costs of Obtaining Organic Residues in the Tamale Metropolis

Table 4 depicts the various costs incurred in obtaining organic residue in the Tamale Metropolis. The main costs incurred in obtaining organic residues were cost of organic residues (if purchased), cost of packaging and cost of transportation from processing centres and food selling points in the Metropolis. The total cost of organic residues purchased was GhȻ 1.32 kg^{-1} or GhȻ 1317.50 ton^{-1} while the cost of packaging organic residues was GhȻ 0.80 kg^{1} or GhȻ 799.00 ton^{-1}. It was gathered that the cost of transporting organic residues from the residue generation points (processing centres and other places) to the house was GhȻ 0.15 kg^{1} or GhȻ 151.00 ton^{-1}. However, Magnan *et al.* (2012) estimated the average shadow price of crop residue at $198 ton^{-1}.

Statistical analysis indicates that the three different costs involved in obtaining the organic residues in the study area differed significantly ($p < 0.05$), with the cost incurred in buying the organic residues being the highest (GhȻ 1317.50 ton^{-1}), followed by packing cost (GhȻ 799.00 ton^{-1}), with cost of transport (GhȻ 151.50 ton^{-1}) being the least (Table 4).

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Table 4. Costs Incurred in Acquiring Organic Residues in the Tamale Metropolis

Item	*Cost (GhȻ ton^{-1})*
Organic residues	1317.50[a]
Packaging	799.00[b]
Transport	151.00[c]
LSD (0.05)	42.10
CV (%)	15.30

Means with the same superscripts within a column are not significantly different (p>0.05)
Means with different superscripts within a column are significantly different (p<0.05)

4.4 Uses of Organic Residues in the Tamale Metropolis

Findings of the study indicate that organic residues are usually used for various purposes. These include the use of the residues as compost manure to improve soil fertility, animal feed, domestic fuel material, food preparation material, material for electricity power generation, source of income and soil moisture conservation.

Analysis shows that the uses differed significantly ($p < 0.05$), with the crop residues used as animal feed being the highest percentage (96.6 %) of the respondents, followed by residues used for domestic fuel (95.6 %). Organic residues used for the generation of electric power through the production biogas was mentioned by the least percentage of respondents (26.7 %) (Figure 1)

4.4.1 Organic Residues as Compost Manure to Improve Soil Fertility

Findings of the study show that out of the 90 respondents interviewed, 92.2 % of them said they use crop residues as compost manure to improve soil fertility (Figure 4.7). These confirm research

www.udsspace.uds.edu.gh

results obtained by Harris (2002) who posited that organic materials such as crop residues over the years is proven to improve the chemical and physical characteristics of soils and therefore used by many people to improve soil fertility for crop farming. Similarly, Taiwo *et al.* (2006) agree that green manure crops and crop residues improve soil condition and therefore widely used in soil fertility improvement. The findings are also in line with those of Aggarwal *et al.* (1997) who posited that a considerable amount of crop residue retention increases soil fertility, while Ranamukhaarachchi *et al.* (2005) also indicated that soil infertility threatens food security and as a result farmers in developing countries use crop residues as organic manure to improve soil fertility since most of them cannot afford inorganic fertilizers.

UNIVERSITY FOR DEVELOPMENT STUDIES

4.4.2 Organic Residues Used as Animal Feed

According to Mclntire *et al.* (1988), crop residues are the major source of ruminant feed especially among farmers who practise mixed farming systems due to limited grazing field for animals. This was confirmed in this study by 96 % of the respondents who were of the view that organic residues form the main source of feed for animals (Figure 4.7). Results of this study also confirm similar results obtained by McDowell (1987) that crop residues are usually used for animal feed in addition to being used as fuel for cooking. The research results are also in line with findings by Rusinamhodzi *et al. (*2013) that crop residues are used as feed for livestock during the dry season where feed is severely limited. Similar assertions were made by Williams *et al.* (1997) that crop residues are regarded as a vital source of livestock feed in the mixed farming system.

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

4.4.3 Organic Residues Used as Domestic Fuel

Results of this study indicate that 95.6 % of respondents said they use crop residues as domestic fuel. These are in line with findings of Rahman (2006) who asserted that crop residues were used as domestic fuel and building materials as well as to improve the soil in Bangladesh. The results also agree with similar ones obtained by Janssen and Rutz (2011) that the use of crop residues has the potential to provide energy in rural Africa. Research has projected the potential of crop residues for energy generation as the results confirm existence and use of crop residues all over the world. In Scarlat *et al.* (2010) research in 27 nations of the EU, it revealed high amounts of crop residues produced in these regions with estimated energy generation of about 1530 PJ/year.

4.4.4 Organic Residues Used in Food Preparation

As to whether crop residues were used in food preparation, only 51 % of respondents stated that in the preparation of local food such as “Kenkey”, “Waakye” and “Tubaani” some crop residues Such as maize husk and leaves were often used. This buttresses an assertion made by Mensah *et al.* (2012) that crop residues such dried leaves of plantain (Musa paradisiaca), banana (Musa sapientum) and dried husk of maize (Zea mays) are used as packaging material for foods such as ‘kenkey’ in Ghana.

4.4.5 Organic Residues Used in Electricity Power Generation

Findings of the study indicate that 26.6 % of the respondents said crop residues are used to generate electric power through the production biogas from crop residues. This confirms findings of Kong (2000) that crop residues are used for power generation in Malaysia. Scarlat *et al.* (2010) also been

www.udsspace.uds.edu.gh

reported that crop residues from maize, wheat, oats, sorghum, rice and sugarcane are used in generating electric power in Zimbabwe.

4.4.6 Crop Residues Used for Economic Benefits

As illustrated in Figure 4.7, the study results indicate that 27.8 % of the respondents said they sell crop residues and use the income obtained to support their household budgets to cater for the financial needs of their households. The findings confirm an assertion by Timothy *et al.* (1997) that economic gains are gotten from crop residues when the residues are sold to generate income to economically support household budgets.

4.4.7 Organic Residues Used in Soil Moisture Conservation

As depicted in Figure 4.7, 41.1 % of the respondents said they use crop residues as mulch to conserve soil moisture. The respondents' views on mulching confirm postulations by Tittonell *et al.* (2008) that organic/crop residues improve soil chemical and physical characteristics. Crop residues enhance soil structure, reduce soil erosion and improve water availability to plants. Consequently, they are used as mulch material by smallholder farmers to improve soil and water conservation. Even though 41.1 % of the respondents agreed that crop residues are used in mulching, it demonstrates that mulching is done in dryland areas to conserves soil moisture since crop residues have the potential to reduce soil degradation and improve water infiltration (Guggenberger, 2005; Berg & McClaugherty, 2008).

UNIVERSITY FOR DEVELOPMENT STUDIES

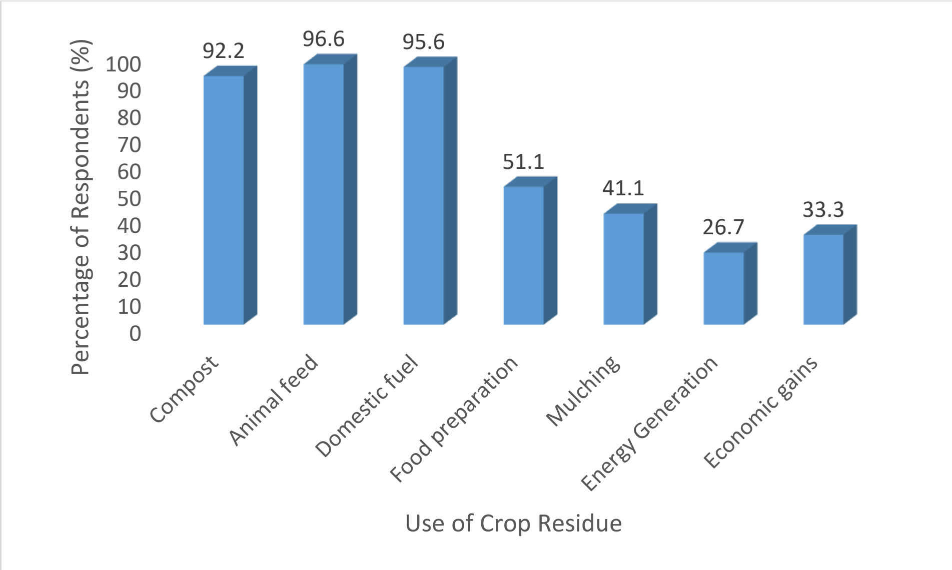

Figure 1. Uses of Crop Residues in the Tamale Metropolis

4.4.8 Types and Most Used Organic Residues in the Tamale Metropolis

Table 4.11 shows that residues of cereals such as millet, rice, sorghum and maize were the most used organic residues in the Metropolis. This reflects in the views of 90 % of respondents who said they use such residues most often. Leguminous crop residues such as vines and husk of groundnuts and soya beans, were also used by 83.4 % of the respondents. Results of the study agree with the assertion by Jingura and Matengaifa (2008) who reported that residues generated from maize, wheat, oats, sorghum, rice and sugarcane were mostly used in power generation in Africa. According to Lal (2004), cereal crops such as maize, wheat, barley, oats, sorghum, millet, rice, and sugarcane are mostly used, because they have the potential to generate large amounts of crop residues.

UNIVERSITY FOR DEVELOPMENT STUDIES

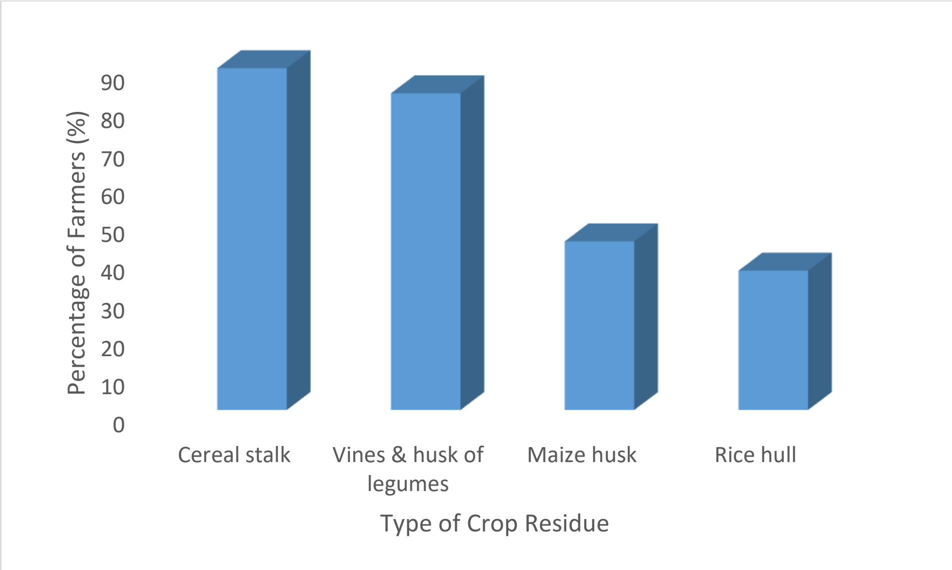

Figure 4.8. Types of Crop Residues Mostly Used by Respondents

4.4.9 Treatment of Crop Residues

About 63 % of the respondents said they treat their crop residues with chemicals and other treatment agents before they were used, whereas 37 % indicated that they do not treat their crop residues before using them (Figure 4.9). This suggests some level of knowledge of the respondents in the use of crop residues. The results show that majority of the respondents still rely on the traditional method of storing and using crop residues and the need to treat them or clean them thoroughly before using them, especially when used in food preparation such as maize husk used in making 'kenkey'.

4.4.10 How Organic Residues are Acquired

About 44 % of the respondents said they purchase organic residues that they use while about 56 % indicated that they do not purchase the residues because they are either their own residues from their farms or from farms of family members or from farms of their friends (Figure 4.10). The

UNIVERSITY FOR DEVELOPMENT STUDIES

findings support those of Timothy *et al.* (1997) who said locally produced residues are acquired in a number of ways including outright purchase and/or from other sources including family and non-family relations.

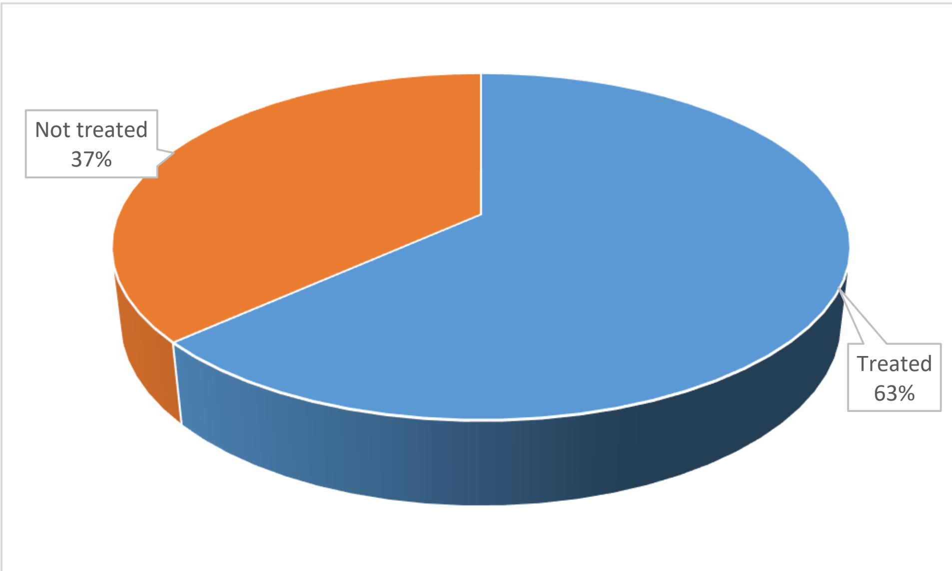

Figure 4.9. Treatment and non-treatment of Crop Residues Before Use

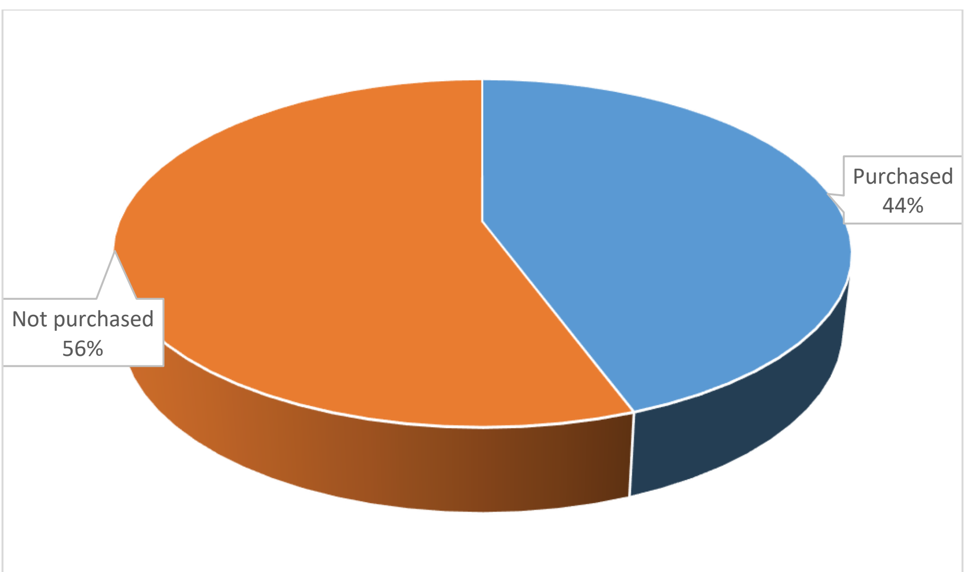

Figure 4.10. How Organic Residues are Acquired

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

4.4.11 Storage and Packing Materials

Figure 4.11 below shows the different methods used by people in the Tamale Metropolis in storing organic residues. About 72.2 % of the respondents interviewed said they usually gather the residues and tie them up in bundles before storing them for subsequent/future use. Twenty percent of the respondents said they store their residues in jute sacks, while 5.6 % indicated that they store them in polythene materials. For the remaining 2.2 % of the respondents, they said they store their organic residues in other materials such as dug-outs, trenches/holes (as in the case of composting the crop residues for use as organic manure), silos, wooden containers, large baskets (as in the case of storing vines and husk of legumes for later use as feed for domestic animals).

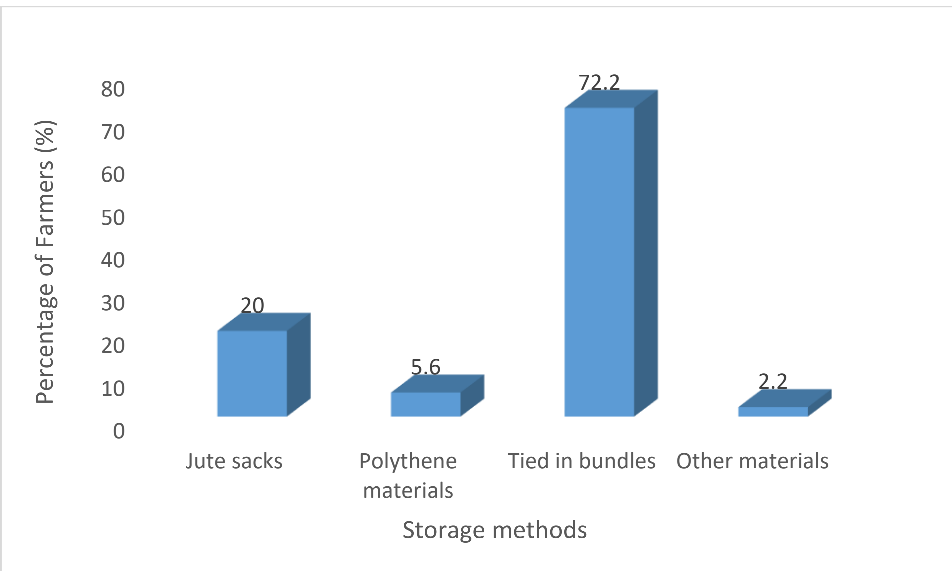

Figure 4.11. Methods of Storing Crop Residues in the Tamale Metropolis

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

4.4.12 Methods of Transporting Organic Residues from Processing Centre to the House

It was gathered from the research that people in the Tamale Metropolis use different methods to transport crop residues from farms to the house. As shown in Figure 4.12 below, about 27 % of the respondents said they use tricycles to convey their crop residues to the house, while 22 %, 19 %, 15 % and 10 % said they do so by using bicycles, trucks, motorcycles and farm tractors respectively. About 7 % said they and their household members carry their crop residues as headloads and walk from the farm to the house.

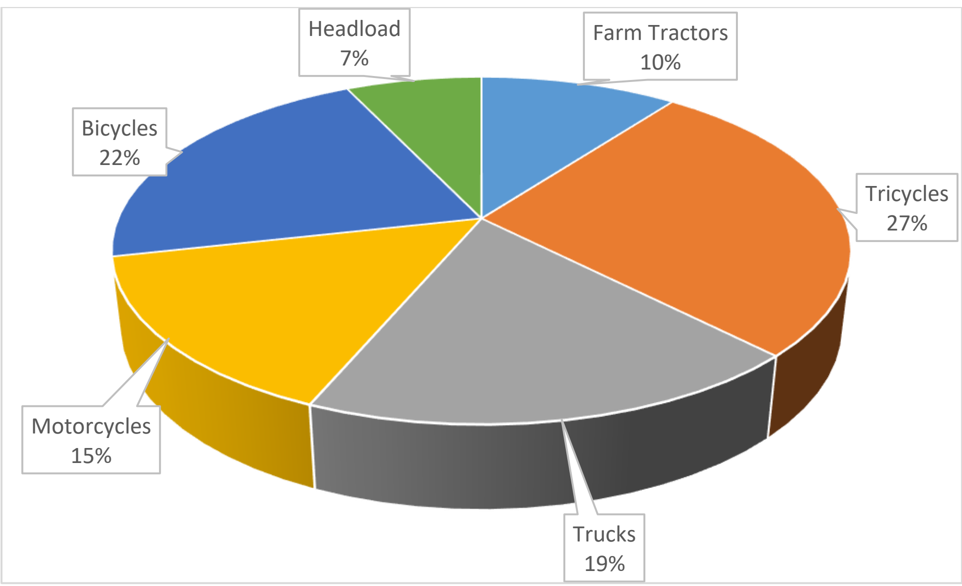

Figure 4.12. Methods of Transporting Organic Residues from Processing Centre to the House

4.5 Assessing Temporal Availability of Crop Residues in the Tamale Metropolis

Spatial and temporal availability of crop residues in the study area were assessed on monthly basis by asking the respondents to classify availability of crop residues as highest, moderate or lowest. Results obtained show that organic residues, particularly from maize, soya beans, groundnuts and

www.udsspace.uds.edu.gh

rice, were mostly available between September and November, as these usually are periods during which crops cultivated in the year would been harvested, thereby making available their residues after processing the crops. The amounts of residues available depend largely on the types of crops and other competing uses for their residues. The results show that temporal availability of organic residues in Tamale Metropolis differed significantly ($p < 0.05$), with the September-November period (ranked first) mentioned by 53.3 % of the respondents as the period in which organic residues in the Metropolis are mostly available. This was followed by the December-February period (ranked second) which was mentioned by 32.2 % of the respondents as the period of availability of organic residues in the Metropolis (Table 4.5). The least likely period of availability of organic residues in the Metropolis was identified by 14.4 % of the respondents being 'throughout the year', which means organic residues are available any time within the year.

Generally, the findings indicate that there are variations with respect to the quantities of organic residues available throughout the year. The highest in abundance was reported to occur towards the beginning of dry season (September-November) and least abundant levels were reported to be at the end of dry season (December-February). This is in line with research findings of Tsopito (2003) who noted that there are variations in availability of organic residues and these variations constitute the major factors constraining the utilization of the residues.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Table 5. Temporal Availability of Organic Residues in Tamale Metropolis

Period of Availability of Crop Residues	***Chances of Being Available (%)***
September - November	53.3[a]
December - February	32.3[b]
All-year-round	14.4[c]
LSD (0.05)	9.7
CV (%)	10.1

Means with the same superscripts within a column are not significantly different (p>0.05)
Means with different superscripts within a column are significantly different (p<0.05)

4.5.1 Types of Organic/Crop Residues Available in the Tamale Metropolis

The major crop residues available in the study areas were identified as from maize stovers (leaves, stalks, husk and cobs), rice (straws and hull), groundnut vines and husk/shells and soya beans vines and husk. The results (Figure 4.13) show that maize stovers constitute about 36 % of the crop residues in the Metropolis while rice, groundnuts and soya beans residues make up 28 %, 18 % and 14 % of the crop residues. Residues of other crops such as yam, cassava, guinea maize, millet and cow pea constitute about 4 % in the Metropolis. These findings are in line with those of Lal (2005) who indicated that the amounts of crop residues generated by various crops vary widely.

www.udsspace.uds.edu.gh

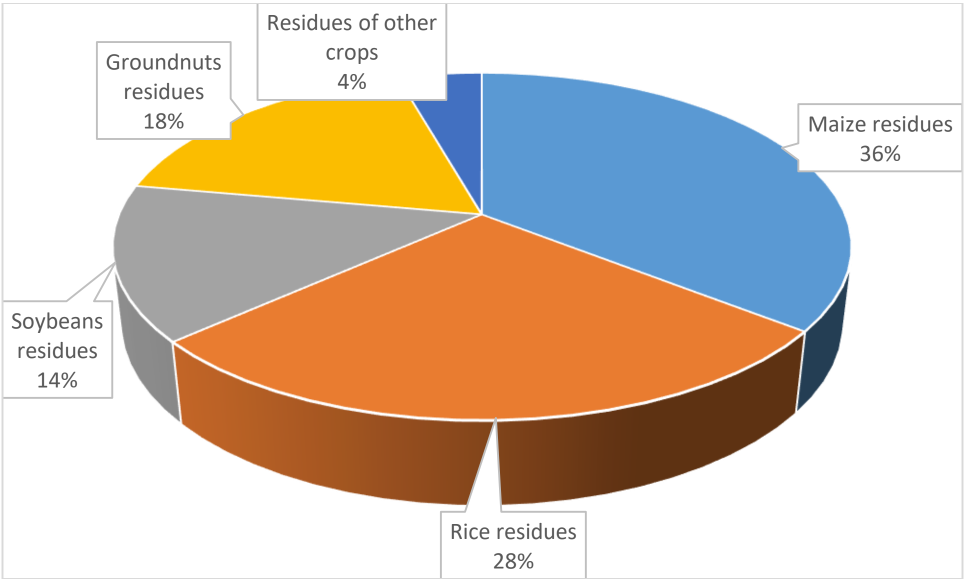

Figure 4.13. Types of Crop Residues Available in the Tamale Metropolis

4.6 Constraints Associated with the Availability, Processing, Management and Utilization of Organic Residues

The study identified constraints related to availability, processing, management and utilization of organic residues in the Metropolis to be transportation, low production of residues due to inadequate supply of crops for processing into residues, inadequate labour, destruction by bad weather, difficult to use, insect and pest infestation. An analysis of the respondents' opinions on the main constraints of the availability, management and usage of crop residues in the Tamale Metropolis show that the constraints differed significantly ($p < 0.05$), with transportation of crop residues from crop residue processing centres and food selling points to the house being the most pressing constraint (41.0 %). This was followed by difficulty in getting some crop residues because of lack of adequate quantities of crops for processing into residues (19 %). Infestation of crop residues by insects and pests (2 %) was the least ranked constraint by the respondents interviewed. These findings are in line with those of Mazvimavi *et al.* (2008), Erenstein (2011), Rufino *et al.* (2011) and Johansen *et al.* (2012) who opined that the constraints associated with the generation

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

and utilization of crop residues in many countries include wastage of residues due to poor storage techniques, termite attack and low crop production from which low amounts of residues are generated.

UNIVERSITY FOR DEVELOPMENT STUDIES

Table 6. Constraints Associated with Generation and Utilization of organic Residues in the Tamale Metropolis

Constraint	***Percentage of occurrence (%)***
Transportation	41.0[a]
Inadequate Crops for processing	19.0[b]
Inadequate labour	16.0[b]
Destruction by bad weather	12.0[c]
Difficult to use	10.0[c]
Insect and pest infestation	2.0[d]
TOTAL	**100.0**
LSD (0.05)	3.9
CV (%)	4.6

Means with the same superscripts within a column are not significantly different (p>0.05)
Means with different superscripts within a column are significantly different (p<0.05)

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter is made up of the summary and conclusions of the research findings, recommendations and suggested areas for further research.

5.2 Summary and Conclusions

The study focused on the quantification of organic materials generated in the Tamale Metropolis. Using stratified sampling technique, the Metropolis was divided into four zones (Jisonayili, Nyohini, Vittin and Kalpohin). The various locations and places in the zones where organic residues are generated were visited and data was taken on organic materials produced. These locations and centres were rice mills, maize shelling centres, groundnut shelling centres, sheanut processing centres, maize mills, sawmills, food sellers (such as kenkey sellers and rice sellers). By weighing the organic residues generated at these centres and other places in each zone in the Tamale Metropolis, the total amount of organic residues produced in all the four zones in the Metropolis was extrapolated to 4932.2 tonnes per annum. An analysis of the results indicates that the zones significantly differed ($p < 0.05$) in the quantities organic residues produced in the Tamale Metropolis, with Jisonayili Zone producing the largest quantities of the residues (2937.3 ton yr^{-1}), followed by Nyohini Zone (914.4 ton yr^{-1}), with Kalpohin Zone producing the least (269.7 ton yr^{-1}). Nyohini and Vittin zones did not however differ ($p > 0.05$) in the quantities of organic residues produced. The quantities of residues generated by the various crops varied widely and differed significantly ($p < 0.05$). There was significant difference ($p < 0.05$) between maize residues and

www.udsspace.uds.edu.gh

the other crop residues, with maize residues produced at the processing centres and other locations being the highest (4821 tons yr^{-1}), followed by rice residues (102.4 tons yr^{-1}) while the groundnut residues (0.9 tons yr^{-1}) were recorded as the least produced in the zones. Soya beans and groundnuts residues did not however significantly differ in terms of the amounts of residues they generated in the zones in the Metropolis.

The main costs incurred in obtaining organic residues were cost of organic residues (if purchased), cost of packaging and cost of transportation from processing centres and food selling points in the Metropolis. These costs differed significantly ($p < 0.05$), with the cost incurred in buying the organic residues being the highest (Gh₵ 1317.50 ton^{-1}), followed by packing cost (Gh₵ 799.00 ton^{-1}), with cost of transport (Gh₵ 151.50 ton^{-1}) being the least.

Findings of the study indicate that organic residues are usually used as compost manure to improve soil fertility, animal feed, domestic fuel material, food preparation material, material for electricity power generation, source of income and soil moisture conservation. Analysis shows that the uses differed significantly ($p < 0.05$), with the crop residues used as animal feed being the highest percentage (96.6 %) of the respondents, followed by residues used for domestic fuel (95.6 %). Organic residues used for the generation of electric power through the production biogas was mentioned by the least percentage of respondents (26.7 %).

Spatial and temporal availability of crop residues in the study area were assessed and the results show that temporal availability of organic residues differed significantly ($p < 0.05$), with the September-November period (ranked first) mentioned by 53.3 % of the respondents as the period in which organic residues in the Metropolis are mostly available. This was followed by the

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

December-February period (ranked second) which was mentioned by 32.2 % of the respondents as the period of availability of organic residues in the Metropolis. The least likely period of availability of organic residues in the Metropolis was identified by 14.4 % of the respondents being ‘throughout the year’, which means organic residues are available any time within the year.

The identified constraints related to availability, processing, management and utilization of organic residues in the Metropolis to be transportation, low production of residues due to inadequate supply of crops for processing into residues, inadequate labour, destruction by bad weather, difficult to use, insect and pest infestation. The constraints differed significantly ($p < 0.05$), with transportation of crop residues from crop residue processing centres and food selling points to the house being the most pressing constraint (41.0 %). This was followed by difficulty in getting some crop residues because of lack of adequate quantities of crops for processing into residues (19 %). Infestation of crop residues by insects and pests (2 %) was the least ranked constraint by the respondents interviewed.

UNIVERSITY FOR DEVELOPMENT STUDIES

5.3 Recommendations

Based on the findings of the study, the following are recommendations;

1. The Government of Ghana, through the Ministry of Food and Agriculture, should organize workshops and skills training programmes for the people in the Metropolis on the treatment and use of crop residues in making compost for improving the fertility of the soil. This will not only help reduce the costs of improving soil fertility and increase crop yields but will also increase their knowledge and interest in agriculture as well as crop residue management.

www.udsspace.uds.edu.gh

2. The Government of Ghana and Non-Governmental Organizations (NGOs) should set up industries that will convert crop residues to generate electric power in the study area. Crop residues used for electric power will help solve the problem of inadequate power supply as it is also the cheaper and environmentally-friendly means of power generation.
3. Majority of the people in the study area could not read nor write. The high illiteracy rate in the study area has a negative effect on their standard of living. The study recommends that policies should be put in place for every person to have access to adult education.
4. The youth are engaged in farming activities and crop residue management. It is, therefore, significant for farmers to have farm machinery and modern equipment to achieve food security.
5. It is observed that crop residue temporal availability and management need to be considered. Therefore, possible areas of future research could cover the mechanism use in the storage of these residues as well as its economic benefits to farmers and the nation at large.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

R EFERENCES

Aggarwal, R. K., Praveen, K., Power J. F., (1997). Use of Crop Residue and Manure to Conserve Water and enhance Nutrient availability and pearl millet yields in an arid tropical region. *Soil & Tillage Research*, *41*(1-2), pp. 43-51.

Ailincâi, C., Jitareanu, G., Bucur, D., & Ailincâi, D. (2012). Long-term effect of fertilizer and crop residue on soil fertility in the Moldavian Plateau. *Cercetari Agronomice in Moldova*, *45*(2), 29-41.

Ambus, P, E. S, (Nitrogen mineralization denitrification as influenced by crop Size Soil 197, 261270. Global (R. J. Kimble, E. Levine, and B. A, Stew163 —l IS CRCFLJ

Amon T., Hackl E., Jeremic D., Amon B. & Boxberger J. (2001). Biogas production from animal wastes, energy plants and organic wastes. In: van Velsen, A. F. M. & Verstraete, W. H. (eds), Proc. 9th World Congress on Anaerobic Digestion: 381–386. Technologisch Institute, Antwerp.

Anderson, B. (1991). Imagined Communities, revised edition. *London and New*

Andrews, S. S. (2006). Crop residue removal for biomass energy production: Effects on soils and recommendations. USDA. Natural Resource Conservation Service. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/ nrcs142p2_053255.pdf.

Angers, A. S. (1997), Of and rye residue as affected by particle Size. 189, 197-203, Angers, D. and A, (1993a), and biochemical Changes induced by rotation and tillage soil Cm. J, S"' Sci. 73,

Annimari L. (2006). Biogas production from energy crops and crop residues. Studies in Biological and Environmental Science 163. Jyväskylä University Printing House, Jyväskylä 2006.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Antle, J., and J. Stoorvogel. 2008. "Agricultural carbon sequestration, poverty, and sustainability." *Environment and Development Economics* 13:327—352.

Arrouays, D., Balesdent, J., Germon, J. C., Jayet, P. A., Soussana, J. F., Stenge., l. P. (2002). Mitigation of the greenhouse effect. Increasing carbon stocks in French agricultural soils? Synthesis of an assessment report by the French Institute for Agricultural Research (INRA) on request of the French Ministry for Ecology and sustainable development. Paris: INRA, 36pp.

Arvidsson, J, Etana, A, Rydberg, T. (2014). Crop yield in Swedish experiments with shallow tillage and no-tillage 1983–2012. European Journal of Agronomy 52: 307–315 DOI10.1016/j.eja.2013.08.002.

Badiane, O. & Delgado, C. (1995). *A 2020 vision for food, agriculture, and the environment in Sub-Saharan Africa*. Food, Agriculture, and the Environment Discussion Paper 4. Washington, DC, International Food Policy Research Institute.

Baoqing, C., Enke L., Qizhuo T., Changrong Y., Yanqing Z. (2014). Soil nitrogen dynamics and crop residues. A review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2014, *34* (2), pp.429-442. 10.1007/s13593-014-0207-8. hal-01234828

Bationo, A., Kihara, J., Vanlauwe, B., Waswa, B. & Kimetu, J. (2006a). Soil organic carbon dynamics, functions and management in West African agro-ecosystems. *Agricultural systems*, 94, pp. 13-25.

Beauchamp, E. G. and Voroney, R. P., (1994). Crop Carbon Contribution to the Soil with different Cropping and Livestock Systems. *Journal of Soil and Water Conservation*, 49(2), pp. 205-209.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Benjamin, J. G., Halvorson, A. D, Nielsen, D.C. and Mikha, M.M., (2010). Crop management Effects on Crop Residue Production and changes in Soil Organic Carbon in the Central Great Plains. *Agronomy Journal*, *102*(3), pp. 990-997.

Berg, B. and C. McClaugherty. (2008). Plant litter: decomposition, humus formation, carbon sequestration. Springer-Verlag, Berlin, Germany.

Biederman, Lor; A; W. Stanley Harpole (2010). Bio char and managed perennial Ecosystems.

Bocchiaro, P., Zimbardo, P. G., & Van Lange, P. A. (2012). To defy or not to defy: An experimental study of the dynamics of disobedience and whistle-blowing. *Social Influence*, *7*(1), 35-50.

Bow, J. R., Muir, J. P., Weindorf, D. C., Rosiere, R. E., & Butler, T. J. (2008). Integration of cool-season annual legumes and dairy manure compost with switchgrass. *Crop science*, *48*(4), 1621-1628.

Breland, T. A. (1994). Enhanced mineralization and denitrification as a result of heterogeneous distribution of clover residues in soil. *Plant and Soil*, *166*(1), 1-12.

Brent, A. (2014). The agricultural sector as a biofuels producer in South Africa. In: Understanding the Food Energy Water Nexus. South Africa: WWF-SA.

Brewer, C.E. (2012). Biochar Characterization and Engineering, Paper 12284, Iowa State University.

Butterworth, M. H. and A. K. Mosi. (1985). Practical evaluation of crop residues and agro-industrial by-products for ruminants in developing countries with emphasis on east Africa. FAO Animal Production and Health Paper 50, FAO, Rome

Cheshire, M. V., & Chapman, S. J. (1996). Influence of the N and P status of plant material and of added N and P on the mineralization of C from 14 C-labelled ryegrass in soil. *Biology and*

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

Fertility of Soils, *21*(3), 166-170.

Choudhury, R., Wurster, R., Weber, T., Schindler, J., Weindorf, W., Miller, M., ... & Kerby, M. (2002). GM Well-to-wheel analysis of energy use and greenhouse gas emissions of advanced fuel/vehicle systems-A European study. *Ottobrunn, September*.

Christian, D. G., Miller, D.P. 1986.Straw in corporation by different tillage system sand the effect on growth and yield of winter oats. Soil andTillageResearch8: 239–252 DOI10.1016/0167-1987(86)90337-5.

Commission of the European Communities (2005). Biomass action plan, communication from the Commission. 47 p., Commission of the European Communities, Brussels.

Condron, L. M., Tiessen, H., Trasar-Cepeda, C., Moir, J. O., & Stewart, J. W. B. (1993). Effects of liming on organic matter decomposition and phosphorus extractability in an acid humic Ranker soil from northwest Spain. *Biology and fertility of soils*, *15*(4), 279-284.

Constantinides, M., & Fownes, J. H. (1994). Nitrogen mineralization from leaves and litter of tropical plants: relationship to nitrogen, lignin and soluble polyphenol concentrations. Soil Biology and Biochemistry, *26*(1), 49-55.

Cooper, C. J., & Laing, C. A. (2007). A macro analysis of crop residue and animal wastes as a potential energy source in Africa. *Journal of Energy in Southern Africa*, *18*(1), 10-19.

Cormack, W. F., Shepherd M. and Wilson D. W. (2003). Legume species and management for stockless organic farming. Biological Agriculture & Horticulture 21:383-398.

Curry. J. p, and D. (1992), The role of euthworms in Straw ckxomposition and nitrogen turnover in land in 24, 1409 - 1412.

Dam, R. F., Mehdi, B. B., Burgess, M. S. E., Madramootoo, C. A., Mehuys, G. R., Callum, I. R. (2005). Soil bulk density and crop yield under eleven consecutive years of maize with

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

different tillage and residue practices in as and loamy soil in Central Canada. Soil and Tillage Research 84: 41–53 DOI10.1016/j.still.2004.08.006.

Danso, G., Drechsel, P., Wiafe-Antwi, T., & Gyiele, L. (2002). Income of farming systems around Kumasi. *Urban Agriculture Magazine*, *7*, 5-6.

Das, B. K., Gentsch, J. R., Hoshino, Y., Ishida, S. I., Nakagomi, O., Bhan, M. K., ... & Glass, R. I. (1993). Characterization of the G serotype and genogroup of New Delhi newborn rotavirus strain 116E. *Virology*, *197*(1), 99-107.

Deepchand, K. (2001). Commercial scale cogeneration of bagasse energy in Mauritius. *Energy for sustainable development*, *5*(1), 15-22.

Dendooven, A. M., Lissens, M., Bruyninckx, F., & Vanhecke, J. (1990). Electrical injuries to peripheral nerves. *Acta Belgica. Medica physica: organe officiel de la Societe royale belge de medecine physique et de rehabilitation*, *13*(4), 161-165.

De Neve, W., De Wagter, C., De Jaeger, K., Thienpont, M., Colle, C., Derycke, S., & Schelfhout, J. (1996). Planning and delivering high doses to targets surrounding the spinal cord at the lower neck and upper mediastinal levels: static beam-segmentation technique executed with a multileaf collimator. *Radiotherapy and oncology*, *40*(3), 271-279.

Diacono, M. & Montemurro, F. (2010). Long-term effects of organic amendments on soil fertility. A review. *Agronomy for Sustainable Development*, 30, pp. 401-422.

Dia, M. (2005). Plant Stand and Nitrogen Management for Maximisation of Yield and Quality of Baby Maize, M.S thesis, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.

Dia M., Weindorf D., Thompson C., Cummings H., Cacovean H., Rusu T., Spatial distribution of heavy metals in the soils of Erath county, Texas. StudiaUniversitatis Babes-Bolyai,

www.udsspace.uds.edu.gh

Geographia, 2009, 2 99-114

Diao, X., Hazell P., Resnick D., and Thurlow J. (2006). The Role of Agriculture in Development: Implications for Sub-Saharan Africa. http://www.ifpri.org/sites/default/files/publications/dsgdp29.pdf Retrieved: October, 2012, pp 8-19

Ebenstein, A., Harrison, A., McMillan, M., & Phillips, S. (2011). *Estimating the impact of trade and offshoring on American workers using the current population surveys*. The World Bank.

Edström, M., Å. Nordberg, and A. Ringmar. 2005. Evaluation of an agricultural biogas plant at Hagavik. Report, in Swedish with English summary, 31, Swedish Institute of Agricultural and Environmental Engineering (Institutet för jordbruks- och miljöteknik, JTI), Uppsala.

Edwards, W. M., Norton, L. D. and Redmond, C. E., (1988), „Characterizing macropores that affect infiltration into non-tilled soil", *Soil Science Society of America Journal*, 52:483-7.

Egyir, I., & Beinpuo, E. (2009). Strategic innovations in urban agriculture, food supply and livelihood support systems performance in Accea, Ghana. *College of Agriculture and Consumer Sciences. University of Ghana*.

Elias, E. (2002). *Farmers' perceptions of oil fertility changes and management*. Institute for Sustainable Development.

Enríquez, S. C. M. D., Duarte, C. M., & Sand-Jensen, K. A. J. (1993). Patterns in decomposition rates among photosynthetic organisms: the importance of detritus C: N: P content. *Oecologia*, *94*(4), 457-471.

EurObserv'ER. (2005). European barometer 2005 of Renewable Energies. 30 p., Systémes Solaires, Paris.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

European Commission. (1997). COM (97) 599 Energy for the future: Renewable sources of Energy. White paper for a Community strategy and action plan. 54 p., European Commission, Brussels

European Parliament (2003). Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Official J. European Union 123: 42–46.

Fara, M. A., Díaz-Mochón, J. J., & Bradley, M. (2006). Microwave-assisted coupling with DIC/HOBt for the synthesis of difficult peptoids and fluorescently labelled peptides—a gentle heat goes a long way. *Tetrahedron Letters*, *47*(6), 1011-1014.

FAO (Food and Agricultural Organization) (1998). Ethiopia: Soil Fertility Initiative, concept Paper, Report No. 98/028 CP-ETH, FAO/World Bank Cooperative Program. FAO, Rome.

FAO (2012) Gender Inequalities in Rural Employment in Ghana: *An Overview*.

Goletti, F. and Wolff, C. 1999. The impact of postharvest research. MSS Discussion Paper No. 29. International Food Policy Research Institute, Washington D.C

Fargione, J., Hill, J., Tilman, D., Polasky, S., Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. Science; 319:1235-1238

Fening, J. O., Adjei-Gyapong, T. Yeboah, E. Ampontuah, E.O. Quansah, G. and Danso, S.K.A. (2005). Soil Fertility Status and Potential Organic Inputs for improving Small holder Crop Production in the interior savanna zone of Ghana. In: Gliessman, S.R. (ed.). Journal of Sustainable Agriculture 25(4):69-91.

Follet, R. F., S.C. Gupta and P.G. Hunt (1987) Conservation practices: Relation to the management of plant nutrients for crop production. In: soil fertility and organic matter as

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

critical component of production systems (Follet, R.F., C.V. Cole, J. W. B. Stewart, J.F. Power). Soil Science Society of American Journal. 19:19-48.

Follet, R. F. and S.R. Wilkinson. (1985). Soil Fertility and Fertilization of Forages. Pp. 304-317. In: M.E. Heath *et al.* (ed.) Forages: the science of grassland agriculture. 4th ed. Iowa State University Press, Ames.

Franzluebbers, A. J., Hons, F. M., & Zuberer, D. A. (1994). Seasonal changes in soil microbial biomass and mineralizable C and N in wheat management systems. *Soil Biology and Biochemistry*, *26*(11), 1469-1475.

Gallard and Merino. (1993). Tolerance to endotoxin-induced expression of the interleukin-1 beta gene in blood neutrophils of humans with the sepsis syndrome. *The Journal of clinical investigation*, *91*(3), 853-861.

Gan, L., & Yu, J. (2008). Bioenergy transition in rural China: Policy options and co-benefits. *Energy Policy, 36*(2), 531-540. doi: 10.1016/j.enpol.2007.10.005

Ghana Districts. (2012). Addressing agriculture production in northern region (online) Available from: http// www.ghanadistrict.comcontent (accessed on 17th March, 2012).

Ghana Statistical Service, (2015). Revised 2014 Annual Gross Domestic Product.

Giller, K. E., & Cadisch, G. (1997). Driven by nature: A sense of arrival or departure? *Driven by nature: Plant litter quality and decomposition*.

Goldemberg, J. (1988). *Energy for a sustainable world*. New York: Wiley.

Gregorich, E. G. and H. H. Janzen (2000) Decomposition. p. C107-C120. In M.E. Sumner (Ed.) Handbook of Soil Science. CRC Press, Boca Raton, FL

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Greenland, D.J. and Nabhan, H. 2001. Soil fertility management in support of food security in Sub-Saharan Africa. FAO of the United Nations, Rome. http://docsdrive.com/pdfs/ academicjournals/ijss/0000/29642-29642.pdf. (Accessed on October 21, 2013).

Guggenberger, G. (2005). Humification and mineralization in soils. pp: 85-106. In: A. Varma and F. Buscot. (eds) Microorganisms in soils: roles in genesis and functions. Springer, Berlin, Germany.

Gul, S., Yanni, S. F., & Whalen, J. K. (2014). Lignin controls on soil ecosystem services: implications for biotechnological advances in biofuel crops. *Biochemistry Research Trends. Nova Science Publishers, New York*, 375-416.

Gunnarsson, A., U. Gertsson, and I. Bohn. 2005. Anaerobically digested crop material for improved nitrogen efficiency in a crop rotation with Beetroot (*Beta vulgaris* var. conditiva Alef.). Acta Horticulturae (in press).

Gupta, P. K.; Sahai, S.; Singh, N.; Dixit, C. K.; Singh, D. P.; Sharma, C. (2004). Residue burning in rice-wheat cropping system: Causes and implications. Curr. Sci. India, 87, 1713–1715.

Hagin, J., & Amberger, A. (1974). Contribution of fertilizer and manures to the N-and P-load of waters-a computer simulation.

Hammel, K. E. (1997). Fungal degradation of lignin. *Driven by nature: plant litter quality and decomposition*, *33*, 45.

Hansson, A., and K. Christensson. 2005. Biogas energises organic farming. Report, in Swedish, Swedish Board of Agriculture (Jordbruksverket), Jönköping, Sweden.

Harris, F. (2002). Review paper: management of manure in farming systems in semi-arid west Africa. *Experimental Agriculture*, 38, pp. 131-148.

Heal, A. (1997). Horror story. Einstein, A., B. Podolsky, and N. Rosen, "Can quantum-mechanical

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

description of physical reality be considered complete?", Phys. Rev. **47**, 777-780.

Heaton, E. A., Dohleman, F. G., & Long, S. P. (2008). Meeting US biofuel goals with less land: the potential of Miscanthus. *Global change biology*, *14*(9), 2000-2014.

Henao, J. and Baanante, C. (1999). Nutrient depletion in the agricultural soils of Africa. International Food Policy Research Institute. Vision 2020 Brief No. 62.

Herland, E. (2005). Energy scenario for the year 2020 (in Swedish). 58 p., Federation of Swedish Farmers, Stockholm.

Herrero, M., P.K. Thornton, A.M. Notenbaert, S. Wood, S. Msangi, H.A. Freeman, D. Bossio, J. Dixon, M. Peters, J. van de Steeg, J. Lynam, P.P. Rao, S. Macmillan, B. Gerard, J. McDermott, C. Ser, and M. Rosegrant. 2010. "Smart Investments in Sustainable Food Production: Revisiting Mixed Crop-Livestock Systems." *Science* 327:822–825.

Horowitz, J., Ebel, R., & Ueda, K. (2010). "No-till" farming is a growing practice. United States Department of Agriculture, Economic Information Bulletin, EIB-70, Washington. Retrieved from https://www.ers.usda.gov/publications/ pub-details/?pubid=44515.

IFPRI (International Food Policy Research Institute). 2010. Fertilizer and soil fertility potential in Ethiopia constraints and opportunities for enhancing the system. Working Paper July, 2010.

Ingram, K., & Frisvold, G. (1994). Productivity in African agriculture: Sources of Growth and Stagnation. *In International Agricultural and Trade Reports, Africa and Middle East Situation and Outlook Series*, 94-3.

International Energy Agency (IEA). (2015). International Energy Agency. World Energy Outlook 2015, Executive Summary. Paris, France: IEA.

Jama, B. A., & Nair, P. K. R. (1996). Decomposition-and nitrogen-mineralization patterns of

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Leucaena leucocephala and *Cassia siamea* mulch under tropical semiarid conditions in Kenya. *Plant and Soil*, *179*(2), 275-285.

Jekayinfa, S., Scholz V. (2007). Assessment of availability and cost of energetically usable crop residues in Nigeria. In: Paper presented at Conference on International Agricultural Research for Development; Tropentag: University of Kassel-Witzenhausen and University of Gottingen; 2007. pp. 9-11.

Johansen, A., Buchhave, L. A., Latham, D. W., Bizzarro, M., Torres, G., Rowe, J. F., ... & Bryson, S. T. (2012). An abundance of small exoplanets around stars with a wide range of metallicities. *Nature*, *486*(7403), 375-377.

Joint Research Center. (2009). Linking soil degradation processes, soil-friendly farming practices and soil-relevant policy measures. Retrieved from https://esdac.jrc.ec.europa.eu/ projects/SOCO/FactSheets/EN%20Fact%20Sheet.pdf Kemp

Kanai, T. (1995). *U.S. Patent No. 5,386,589*. Washington, DC: U.S. Patent and Trademark Office.

Kelly-Hayes, M. (1990). Time intervals, survival, and destination. Three crucial variables in stroke outcome research. *Stroke (1970)*, *21*(9), II-24.

Kretzschmar, A., & Ladd, J. N. (1993). Decomposition of 14C-labelled plant material in soil: the influence of substrate location, soil compaction and earthworm numbers. *Soil Biology and Biochemistry*, *25*(6), 803-809.

Lal, R. (2004). Is crop residue a waste? *Journal of Soil and Water Conservation*, *59*(6), 4+ 136A,137A,138A, 139A.

Lampinen, A. (2003). Potential for producing vehicle biofuel from wastes in Finland (in Finnish). Kuntatekniikka 1/2003: 31–34

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Latham, M., (1997) Crop residues as a strategic resource in mixed farming systems. In: C. Renard, ed. 1997. *Crop residues in sustainable mixed crop/livestock farming system*. UK: CAB International, pp.181-196.

Legros, B., Thivel, P. X., Bultel, Y., Boinet, M., & Nogueira, R. P. (2009). Electrochemical impedance and acoustic emission survey of water desorption in nafion membranes. *Electrochemical and solid-state letters*, *12*(7), B116.

Lehmann, J., & Kleber, M. (2015). The contentious nature of soil organic matter. *Nature*, *528*(7580), 60.

Lekasi, J. K., Tanner, J. C., Kimani, S. K., & Harris, P. J. C. (2003). Cattle manure quality in Maragua District, Central Kenya: effect of management practices and development of simple methods of assessment. *Agriculture, ecosystems & environment*, *94*(3), 289-298.

Jain, N.; Bhatia, A.; Pathak, H. Emission of Air Pollutants from Crop Residue Burning in India. Aerosol Air Qual. Res. 2014, 14, 422–430.

Janssen, R., & Rutz, D. (2011). Bioenergy for Sustainable Development in Africa Retrieved from http://canterbury.eblib.com.au/patron/FullRecord.aspx?p=886035

Jiang, H.; Frie, A.L.; Lavi, A.; Chen, J.; Zhang, H. Brown Carbon Formation from Nighttime Chemistry of Unsaturated Heterocyclic Volatile Organic Compounds. Environ. Sci. Technol. Lett. Artic. ASAP 2019.

Jingura, R. M., & Matengaifa, R. (2008). The potential for energy production from crop residues in Zimbabwe. *Biomass and Bioenergy, 32*(12), 1287-1292. doi: 10.1016/j.biombioe.2008.03.007

UNIVERSITY FOR DEVELOPMENT STUDIES

Karanja, N.K., Ajuke, F.O. and Swift, M.J. (2006). Organic resources quality and soil fauna: their role on the microbial biomass, decomposition and nutrient release patterns in Kenyan soils. Tropical and Subtropical Agroecosystems 6: 73 − 86.

Karekezi, S., Kimani, J., & Onguru, O. (2008). Energy access among the urban poor in Kenya. *Energy for Sustainable Development, 12*(4), 38-48. doi:10.1016/s0973-0826(09)60006-5.

Karekezi, S., & Kithyoma, W. (2005). Sustainable energy in Africa:cogeneration and geothermal in east and horn of Africa-Status and prospects. Nairobi, AFREPREN/FWD and Heinrich Boll Foundation Regional office for East and Horn of Africa (HBF).

Karekezi, S., Kithyoma, W., & Oruta, A. (2008). Scaling-up bioenergy in Africa. Background paper for international conference on scaling-up renewables in Africa, organised by UNIDO from 16-18 April, Dakar

Kayuki, K.C. and Wortmann, C.S. (2001). Plant materials for soil fertility management in sub humid tropical areas. Agronomy Journal 93: 929 − 935.

Kenney, I. T. (2011). Regional assessment of short-term impacts of maize stover removal for bioenergy on soil quality and crop production. Department of Agronomy, College of Agriculture, Kansas State University. Retrieved from http://krex.k-state.edu/ dspace/handle/2097/13186.

Koné, A.W., J.E Tondoh, F. Bernhard-Reversat, G. Loranger-Merciris, D. Brunet, Y. Tano, (2008). *Changes in soil biological quality under legume- and maize-based farming systems in a humid savanna zone of Cote d'Ivoire*. Biotechnology, Agronomy, Society and Environment 12(2): 147-155.

Kong, H. W. (2000). Current status of biomass utilisation in Malaysia.

UNIVERSITY FOR DEVELOPMENT STUDIES

Kossila, V.L. (1985). Global review of the potential of crop residues as animal feed. FAO Animal Production and Health Paper 50, FAO, Rome.

Lal, R., Griffin, M., Apt, J., Lave, L., Morgan, M. G. (2004). Managing soil carbon. Science 304:393–393 DOI10.1126/science.1093079

Langholtz, M., Stokes, B., Eaton, L., (2016). U.S. Department of Energy. editors. Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy. Oak Ridge, TN: Oak Ridge National Laboratory; 2016, 2016. 448p.

Legros G *et al.* The Energy Access Situation in Developing Countries. A Review Focusing on the Least Developed Countries and Sub-Saharan Africa. New York: WHO-UNDP; 2009

Liska, A. J., Yang, H., Milner, M., Goddard, S., & Blanco-Canqui, H. (2014). Biofuels from crop residue can reduce soil carbon and increase CO2 emissions. Adam Liska Papers, 16. Retrieved from: http://digitalcommons.unl.edu/bseliska/16/?utm_source=digital commons.unl.edu%2Fbseliska%2F16&utm_medium=PDF&utm_campaign=PDFCoverPages

Liu, J., You, L., Amini, M., Obersteiner, M., Herrero, M., Zehnder, A. J., Yang, H. (2010). A high-resolution assessment on global nitrogen flows in cropland. Proc Natl Acad Sci U S A 107(17):8035 –8040. doi:10. 1073/pnas.0913658107.

Lohan, S. K., Jat, H. S., Yadav, A. K., Sidhu, H.S.; Jat, M.L., Choudhary, M., Jyotsna Kiran, P., Sharma, P. C. Burning issues of paddy residue management in north-west states of India. Renew. Sustain. Energy Rev., 81, 693–706.

Luna, I., Cromwell, S. L., Russell, C. K., Lim, Y. M., de Ardon, E. T., & Phillips, L. R. (1996). Uncovering the cultural context for quality of family caregiving for elders. *Western Journal of Nursing Research*, *18*(3), 284-298.

Lützow, M. V., Kögel-Knabner, I., Ekschmitt, K., Matzner, E., Guggenberger, G., Marschner, B.,

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

& Flessa, H. (2006). Stabilization of organic matter in temperate soils: mechanisms and their relevance under different soil conditions–a review. *European journal of soil science*, *57*(4), 426-445.

Kuittinen, V., Huttunen, M. J. & Leinonen, S. (2005). Register of biogas plants in Finland VIII (in Finnish). 71 p., Reports of Karelian Institute 3/2005, University of Joensuu. Yliopistopaino, Joensuu.

Magdoff, F. and R.R. Weil. (2004). Soil organic matter in sustainable agriculture. CRC.Pres, Boca Raton, London, New York, pp. 15- 21.

Magid, J., Jensen, L. S., Mueller, T., & Nielsen, N. E. (1997). Temporal variation of C and N mineralization, microbial biomass and extractable organic pools in soil after oilseed rape straw incorporation in the field. *Soil Biology and Biochemistry*, *29*(7), 1043-1055.

Magnan, N., D.M. Larson, and J.E. Taylor. 2012. "Stuck on Stubble? The Non-market Value of Agricultural By-products for Diversified Farmers in Morocco." *American Journal of Agricultural Economics* 94:1055–1069.

Maizeelissen, Jacob, K. N. D., Tonessia, D. C., Seu, J. G., Soko, D. F., & Koutoua, A. (1996). Influence du décalage de semis du maïs (Zea mays L.) et du bambara groundnut (*Vigna subterranea* L.) Verdc. sur leur production en zone savanicole de la Côte d'Ivoire. *Journal of Applied Biosciences*, *102*, 9745-9755.

Marenya, P., and C. Barrett. 2007. "Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya." *Food Policy* 32:515–536.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Masciandaro, G., B. Ceccanti and C. Garcia. (1997). Changes in soil biochemical and cracking properties induced by 'living mulch systems'. *Canadian Journal of Soil Science* 77:579-587.

Mazvimavi, K. and Twomlow, S. (2009). Socio-economic and Institutional Factors influencing Adoption of Conservation Farming by Vulnerable Households in Zimbabwe. *Agricultural Systems* 10: 20 – 29.

Mclntire, J., J. D. Reed, A. Fedla, S. Jutzi and Y. Kebede. (1988). Evaluating sorghum cultivars for grain and straw yield, pp 283-304. *In* J.D. Reed, B.S. Capper and P.J.H. Neate (eds.). Plant breeding and the nutritive value of crop residues. Proceedings of a workshop held at ILCA, Addis Ababa, 7-10 Dec. 1987. ILCA, Addis Ababa,

McDowel, I., & Newel, C. (1987). Measuring health. *A guide to rating scales and questionnaires. NY*.

Mele, P. M. and Carter, M. R., (1999), „Impact of crop management factors in conservation tillage farming on earthworm density, age structure and species abundance in south-eastern Australia", *Soil and Tillage Research*, 50: 1-10.

Mensah, J. K., Adei, E., Adei, D., & Ashie, M. D. (2012). Perceptions of the use of indigenous leaves as packaging materials in the ready-to-eat maize meals, 6(June), 1051–1068. Ethiopia.

Merante, P., Dibari., C.,Ferrise, R, Sánchez, B, Iglesias, A, Lesschen, J.P, Kuikman, P, Yeluripati, J., Smith, P., Bindi, M. (2017). Adopting soil organic carbon management practices in soils of vary ingquality: implications and perspectives in Europe. Soil and TillageResearch165:95–106 DOI10.1016/j.still.2016.08.001.

Meylan, P. R., Richman, D. D., & Kornbluth, R. S. (1992). Reduced intracellular growth of

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

mycobacteria in human macrophages cultivated at physiologic oxygen pressure. *American Journal of Respiratory and Critical Care Medicine*, *145*(4), 947-953.

Ministry of Food and Agriculture (2011). Agricultural Extension Approaches Being Implemented in Ghana: http://mofa.gov.gh/site/wp- content/uploads/2011/03 /Extension-approaches-in-Ghana-.pdf. Retrieved: April 2013. p.4.

Mittal, S.K.; Susheel, K.; Singh, N.; Agarwal, R.; Awasthi, A.; Gupta, P.K. Ambient air quality during wheat and rice crop stubble burning episodes in Patiala. Atmos. Environ. 2009, 43, 238–244.

Mofa, N. N., Chervyakova, O. V., Ketegenov, T. A., & Mansurov, Z. A. (2003). Magnetic sorbents obtained by mechanochemical treatment of quartz-containing mixtures. *Chemistry in the interests of stable development*, *11*, 755-761.

Mokwunye, A. U., De Jager, A., & Smaling, E. M. A. (1996). Restoring and maintaining the productivity of West African soils: Key to sustainable development (Miscellaneous Fertilizer Studies No. 14). *International Fertilizer Development Center, Muscle Shoals, AL*.

Mosier, A., Kroeze, C., Nevison, C., Oenema, O., Seitzinger, S., & Van Cleemput, O. (1998). Closing the global N 2 O budget: nitrous oxide emissions through the agricultural nitrogen cycle. *Nutrient cycling in Agroecosystems*, *52*(2-3), 225-248.

Mtambanengwe, F., & Kirchmann, H. (1995). Litter from a tropical savanna woodland (Miombo): chemical composition and C and N mineralization. *Soil Biology and Biochemistry*, *27*(12), 1639-1651.

Nandin, Sharma, A., Gokulchandran, N., Chopra, G., Kulkarni, P., Lohia, M., Badhe, P., & Jacob, V. C. (2012). Administration of autologous bone marrow-derived mononuclear cells in

www.udsspace.uds.edu.gh

children with incurable neurological disorders and injury is safe and improves their quality of life. *Cell transplantation*, *21*(1_suppl), 79-90.

Nearing, M. A., Xie, Y., Liu, B., & Ye, Y. (2017). Natural and anthropogenic rates of soil erosion. International Soil and Water Conservation Research, 5(2), 77-84. doi:10.1016/j. iswcr.2017.04.001.

Nelson, A. R., Jennings, A. E., & Kashima, K. (1996). An earthquake history derived from stratigraphic and microfossil evidence of relative sea-level change at Coos Bay, southern coastal Oregon. *Geological Society of America Bulletin*, *108*(2), 141-154.

Nguyen, M. L. & Goh, K. M. (1992). Nutrient cycling and losses based on a mass-balance model in grazed pastures receiving long-term superphosphate applications in New Zealand. 1. Phosphorus. *Journal of Agricultural Science*, *Cambridge* 119, 89–106

Nicholson, F., Kindred, D., Bhogal, A., Roques, S., Kerley, J., Twining, S. Ellis, S. (2014). Straw incorporation review (Research Review 81). Home-Grown Cereals Authority. Retrieved from https://cereals.ahdb.org.uk/publications/2014/ july/30/straw-incorporation-review.aspx.

NSFMAP- National Soil Fertility Management Action Plan. (1998). Gov. of Ghana-Ministry of ‘ Food and Agriculture. Pp 32-35.

Nordberg, Å., A. Lindberg, C. Gruvberger, T. Lilja, and M. Edström. 1998. Biogas potential and future biogas plants in Sweden. Report, in Swedish with English summary, 17, Swedish I nstitute of Agricultural Engineering, (Jordbrukstekniska institutet (JTI)) in co-operation with VBB Viak, a SWECO company, Uppsala.

Northup, R. R., Yu, Z., Dahlgren, R. A., & Vogt, K. A. (1995). Polyphenol control of nitrogen release from pine litter. *Nature*, *377*(6546), 227-229.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Nurudeen, I.M., Nassereldeen, K. and Abass A. (2018). Significance of Agricultural Residues in Sustainable Biofuel Development http://dx.doi.org/10.5772/intechopen.78374.

Nzuma, J. K., & Murwira, H. K. (2000). Improving the management of manure in Zimbabwe. *Improving the management of manure in Zimbabwe.*, (15).

OECD (Organisation for Economic Co-operation and Development). 2001. Available online: https://stats. oecd.org/glossary/detail.asp?ID=77 (accessed on 10 November 2018).

OECD/IEA. (2010). Sustainable Production of Second—Generation Biofuels, Potential and Perspectives in Major Economies and Developing Countries, Information Paper. Paris: IEA;

Olsen, Reith, J., Jørgensen, H. S., Pedersen, P. M., Nakamaya, H., Jeppesen, L. L., & Raaschou, H. O. (1996). Body temperature in acute stroke: relation to stroke severity, infarct size, mortality, and outcome. *The Lancet*, *347*(8999), 422-425.

Olson-Rutz, K., Jones, C., & Pariera, C. (2011). *Enhanced efficiency fertilizers*, (Ed M. S. University).

Palm, C. A. (1995). Contribution of agroforestry trees to nutrient requirements of intercropped plants. *Agroforestry systems*, *30*(1-2), 105-124.

Parr, M. B., Tung, H. N., & Parr, E. L. (1986). The ultrastructure of the rat primary decidual zone. *American journal of anatomy*, *176*(4), 423-436.

Perucci P, Bonciarelli U, Santilocchi R, Bianchi A (1997) Effect of rotation, nitrogen fertilization and management of crop residues on some chemical, microbiological and biochemical properties of soil. Biol Fert Soils 24:311–316. doi:10.1007/s003740050249.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Place, F., C.B. Barrett, H. Freeman, J.J. Ramisch, and B. Vanlauwe. 2003. "Prospects for integrated soil fertility management using organic and inorganic inputs: evidence from smallholder African agricultural systems." *Food Policy* 28:365–378.

Pittelkow, C. M., Liang, X., Linquist, B. A., Van Groenigen, K. J., Lee, J., Lundy, M. E., Van Gestel, N., Six, J., Venterea, R. T., Van Kessel, C. (2014). Productivity limits and potentials of the principles of conservation agriculture. Nature advance online publication DOI10.1038/nature13809.

Poeplau, C., Kätterer, T., Bolinder, M. A., Börjesson, G., Berti A., Lugato, E. (2015). Low stabilization of above ground crop residue carbon in sandy soils of Swedish long-term experiments. Geoderma237:246–255DOI10.1016/j.geoderma.2014.09.010.

Power. J, E, Papendick. R. (1985), Organic Of nutrients. Technology and Use" (O. Eagelsham. ed.). 3rd pp. 503—520. Soil Sci. Sac. Am.,WI.

Powlson, D. S., Glendining, M. J., Coleman, K., & Whitmore, A. P. (2011). Implications for soil properties of removing cereal straw: Results from long-term studies. Agronomy Journal, 103, 1, 279-287. doi:10.2134/agronj2010.0146s

Powlson, D. S., Stirling, C. M., Jat, M. L., Gerard, B. G., Palm, C. A., Sanchez, P. A., & Cassman, K. G. (2015). Limited potential of no-till agriculture for climate change mitigation. Nature climate change, 4, 678–683. doi:10.1038/NCLIMATE2292 Rawls.

Quinton, J. N., Catt, J. A. and Hess, T. M., (2001), „The selective removal of phosphorus from soil: is event size important‟, *Journal of Environmental Quality*, 30:538-45.

Rahman, I., & Adcock, I. M. (2006). Oxidative stress and redox regulation of lung inflammation in COPD. *European respiratory journal*, *28*(1), 219-242.

Rajagopal, D., Sexton, S., Roland-Holst, D., Zilberman, D. (2007). Challenge of biofuel: Filling

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

the tank without emptying the stomach? Environmental Research Letters.;2:044004

Ranamukhaarachchi, S.L., M.D. Mizanur- Rahman and S.H. Begum. (2005). Soil fertility and land productivity under different cropping systems in highlands and medium highlands of Chandina sub- district, Bangladesh. Asia- Pacific Journal of Rural Development *15*(1): 63- 76.

Rawls, W. J., Pachepsky, Y. A., Ritchie, J. C., Sobecki, T. M., & Bloodworth, H. (2003). Effect of soil organic carbon on soil water retention. Geoderma 116 (2003), 61-76. doi:10.1016/ S0016-7061(03)00094-6 Schjønning

Reddy N., Yang Y., Biofibers from agricultural byproducts for industrial applications. USA TRENDS in Biotechnology, 2005, 23(1), 22-27. Rengel, Z., & Singh, B. (2010). *The role of crop residues in improving soil fertility*, In Nutrient cycling in Terrestrial Ecosystems, 10 (Eds P. Marschner and Z. Rengel) Springer-Verlag Berlin Heidelberg.

RegamNd. J. Elliott, L E, and Unger. Y L (1987). Of organic and conventional farming on soil erosion. 330, 370—372.

Rengel, W., Singh, B. (2010). Relationships between mineralogical properties and carbon and nitrogen retention in upland soils of Thailand. In *19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia* (pp. 1-6).

Richards, B. K.; Muck, R. E.; Walter, M. F. (1984). "Variation in line transect measurements of crop residue cover". Journal of Soil and Water Conservation. *39*(1): 60–61. ISSN 0022-4561

Robinson, J. P., & Martin, S. (2010). IT use and declining social capital? More cold water from the General Social Survey (GSS) and the American Time-Use Survey (ATUS). *Social Science Computer Review*, *28*(1), 45-63.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Roy, R., Misra, R., Lesscheen, P. and Smaling, M. 2003. Assessment of soil nutrient balance, approaches and methodologies. Fertilizer and Plant Nutrition Bulletin No. 14. FAO United Nations, Rome.

Rufino, M. C., Tittonell, P., van Wijk M. T., Castellanos-Navarrete, A., Delve, R. J., de Ridder, N. and Giller, K. E. (2007). Manure as a key resource within smallholder farming systems: Analysing farm-scale nutrient cycling efficiencies with the NUANCES framework. Livestock Science 112: 273–287.

Rusinamhodzi, L., Corbeels, M., Zingore, S., Nyamangara, J., & Giller, K. E. (2013). Pushing the envelope? Maize production intensification and the role of cattle manure in recovery of degraded soils in smallholder farming areas of Zimbabwe. *Field Crops Research*, *147*, 40-53.

Sanger, J. M., Chang, R., Ashton, F., Kaper, J. B., & Sanger, J. W. (1996). Novel form of actin-based motility transports bacteria on the surfaces of infected cells. *Cell motility and the cytoskeleton*, *34*(4), 279-287.

Sanchez, P.A., and Leakey, R.R.B. (1997). Land use transformation in Africa. Three determinants for balancing food security with natural resource utilization. European Journal of Agronomy 7: 1 – 9.

Sanchez, P.A., Sheperd, K.D. Soule, M.J. Place, F.M. Buresh, R.J. Izac, A.M.N. Mokwunye, A.U. Kwesiga, F.R. Ndiritu, C.G. and Woomer, P.L. (1997). Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh, R.J., Sanchez, P. A. and Calhoun, F. (eds.). Replenishing soil fertility in Africa. Soil Science Society of America Special Publication Number 51, Madison, Wisconsin USA. pp. 1 − 46.

Sanchez, P. 2002. “Soil Fertility and Hunger in Africa.” *Science* 295:2019 –2020.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Saroj, D., Charu, G., Shankar, L.J, Parmar, M.S. (2007). Crop residue recycling for economic and environmental sustainability: The case of India. https://doi.org/10.1515/opag-2017-0053.

Schlecht, E. and Hiernaux, P., (2004). Beyond adding up Inputs and Outputs: Process Assessment and up Scaling in Modelling Nutrient Flows. *Nutrient Cycling in Agroecosystems*, 70, pp.303-319

Scarlat, N., Martinov, M., & Dallemand, J. (2010). Assessment of the availability of agricultural crop residues in the European Union: Potential and limitations for bioenergy use. *Waste Management*, *30*(10), 1889-1897.

Scholes, J. D., Lee, P. J., Horton, P., & Lewis, D. H. (1994). Invertase: understanding changes in the photosynthetic and carbohydrate metabolism of barley leaves infected with powdery mildew. *New Phytologist*, *126*(2), 213-222.

Schomberg, H. H., Ford, P. B., & Hargrove, W. L. (1994). Influence of crop residues on nutrient cycling and soil chemical properties. *Managing agricultural residues. Lewis Publishers, Inc., Boca Raton, Florida, USA*, 99-122.

Schwab, G. J., & Murdock, L. W. (2005). *Nitrogen transformation inhibitors and controlled release Urea* extension report. Lexington, KY: University of Kentucky College of Agriculture.

Searle, S., & Malins, C. (2016). A critique of soil carbon assumptions used in ILUC modeling (Working paper 201613). Retrieved from the International Council on Clean Transportation, http://www.theicct.org/sites/default/files/publications/ICCT_soil-carbon-assumptions-ILUC_20160613.pdf

Senelwa, K. A., & Hall, D. O. (1993). A Biomass Energy flow chart for Kenya. *Biomass and Bioenergy*, *4*(1), 35-48.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Seyoum B., Getnet A.., Abate T., and Dereje F. (2001). Present status and future direction in feed resources and nutrition research targeted for wheat-based crop livestock production system in Ethiopia. Pp 207-226., In: P.C. Wall (ed.). Wheat and Weed: Food and Feed. Proceedings of two-stakeholder workshop. CYMMYT, Mexico City. Improving the productivity of crop livestock production in wheat-based farming systems in Ethiopia, Addis Ababa. 10-11 October 2000.

Shiferaw, B., and H. Freeman, eds. 2003. *Methods for Assessing the Impacts of Natural Resource Management Research*. A summary of the proceedings of an International Workshop, 6-7 Dec 2002, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, India., ICRISAT International Crops Research Institute for the Semi-Arid Tropics Patancheru 502 324, Andhra Pradesh, India.

Skene, W. G., Scaiano, J. C., & Cozens, F. L. (1996). Fluorescence from samarium (II) iodide and its electron transfer quenching: dynamics of the reaction of benzyl radicals with Sm (II). *The Journal of organic chemistry*, *61*(22), 7918-7921.

Simonyan, K., Fasina, O. (2013). Biomass resources and bioenergy potentials in Nigeria. African Journal of Agricultural Research. 2013; *8*(40): 4975-4989.

Singh, J., Mishra, N. S., Banerjee, S., & Sharma, Y. C. (2011). Comparative studies of physical characteristics of raw and modified sawdust for their use as adsorbents for removal of acid dye. *bioresources*, *6*(3), 2732-2743.

Singh, C.P.; Panigrahy, S. Characterization of residue burning from agricultural system in India using space-based observations. J. Indian Soc. Remote Sens. 2011, 39, 423–429.

Six, J., Elliott, E. T., & Paustian, K. (1999). Aggregate and soil organic matter dynamics under

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

conventional and no-tillage systems. Soil Science Society of America Journal, 63(5), 13501358. doi:10.2136/sssaj1999.6351350x.

Smil, V. (1999). "Crop Residues: Agriculture's Largest Harvest." *BioScience* 49:299–308.

Smith, C. W., (2016). Effects of implementation of soil health management practices on infiltration, saturated hydraulic conductivity (Ksat), and runoff. United States Department of Agriculture. Natural Resource Conservation Centre. Retrieved from: https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/ download?cid...ext=pdf.

Smith, O. B. (1989). Utilization of crops residues in the nutrition of sheep and goats in the humid tropics of West Africa. In: Atta Krah AN, Reyholds L, editors. Sheep and Goat Meat Production in the Humid Tropics of West Africa; Yamoussoukro; 21-25 September, 1987. FAO Animal Production and Health Paper;

Soane, B. D,, Ball, B.C. ,Arvidsson,J. Basch, G., Moreno, F., Roger EstradeJ.2012.Notillin northern, western and south-western Europe: areview of problem sand opportunities for crop production and the environment. Soil and Tillage Research 118:66–87 DOI10.1016/j.still.2011.10.015.

Social Cops. (2017). Quick Guide to Sampling. https://blog.socialcops.com/academy/resources/6-sampling-techniques-choose representative-subset/

Sommer-feldt, T. G., Chang C. and Entz. T. (1988). Long-term annual manure application increase soil organic matter and nitrogen and decrease carbon to nitrogen ratio. Soil Sci. Am. J. 52: 1668- 1672.

Streets, D.G.; Yarber, K.F.; Woo, J.H.; Carmichael, G.R. An Inventory of Gaseous and Primary Aerosol Emissions in Asia in the Year 2000. J. Geophys. Res. 2003, 108, 8809–8823.

Stubbs, T. L., Kennedy, A. C., & Schillinger, W. (2004). Soil ecosystem changes during the

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

transition to no-till cropping. Journal of Crop Improvement, 11(1), 105–135. doi: 10.1300/J411v11n01_06.

Sri Widada, J., Durand, S., Cambournac, I., Qian, D., Shi, Z., Dejonghe, E., ... & Bonami, J. R. (2003). Genome-based detection methods of Macrobrachium rosenbergii nodavirus, a pathogen of the giant freshwater prawn, Macrobrachium rosenbergii: dot-blot, in situ hybridization and RT-PCR. *Journal of Fish Diseases*, *26*(10), 583-590.

Summerell, B. A., & Burgess, L. W. (1989). Decomposition and chemical composition of cereal straw. *Soil Biology and Biochemistry*, *21*(4), 551-559.

Syers, J.K., Powlson, D.S. Rappaport, I. Sanchez, P.A. Lal, R. Greenland, D.J. and Ingram, J. (1997). Managing Soils for long term productivity [and Discussion] Philosophical Transactions: Biological Sciences 352(1356): 1011 − 1021.

Taiwo, L. B., Akande, M. O. and J. A. Adedria (2006). Recycling of Farm Workers for Sustainable Organic Farming in Nigeria. Agriculture, proceedings of the 2nd National Conference on Organic Agriculture, University of Ibadan, Ibadan, Nigeria.

Terrapon-Pfaff J.C. (2012). Linking energy- and land-use systems: Energy potentials and environmental risks of using agricultural residues in Tanzania. Sustainability; 4:278293. DOI: 10.3390/su4030278.

Tesfaye Alemu, Pornsri Chairatanayuth, Pravee Vijchulata and Sayan Tudsri (2006). Production and Utilization of Crop Residues in Three Agro Ecological Zones of Eastern Shoa Zone, Ethiopia, Kasetsart J. (Nat. Sci.) 40 : 643 - 651

Tetteh, F.M.K. (2004). Synchronizing nutrient release from decomposing organic materials with crop nutrient demand in the semi-deciduous forest zone of Ghana. Ph.D thesis. Faculty of Agriculture, KNUST, Kumasi. 185pp.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Thomsen, G. H., & Melton, D. A. (1993). Processed Vg1 protein is an axial mesoderm inducer in Xenopus. *Cell*, *74*(3), 433-441.

Thornton, P. K., & Herrero, M. (2001). Integrated crop–livestock simulation models for scenario analysis and impact assessment. *Agricultural systems*, *70*(2-3), 581-602.

TlAN-SHAN, L. I., Yang, C. Y., Lam, H. C., Lee, H. C., Wei, Y. H., Lu, C. C., Han, T. M., ... & Lee, J. K. (1995). MELAS syndrome associated with diabetes mellitus and hyperthyroidism: a case report from Taiwan. *Clinical endocrinology*, *43*(2), 235-239.

Tilman D *et al.* Energy. Beneficial biofuels—The food, energy, and environment trilemma. Science. 2009; 325 270-271.

Timothy, O.W., S. Fernandez-Rivera and G.K. Timothy (1997). The Influence of Socioeconomic factors on the availability and utilization of crop residues as animal feeds.

Tindjina I. (2011) Effect of Tillage Practices on Soil Fertility. Msc. Degree in Environmental Science, Kwame Nkrumah University of Science and Technology, Kumasi

Tittonell, P., Corbeels, M., van Wijk, M.T., Vanlauwe, B., and Giller, K.E., (2008). Combining organic and mineral fertilizers for integrated soil fertility management in smallholder farming systems of Kenya: explorations using the crop-soil model FIELD. *Agronomy Journal*, 100 (5), pp.1511-1526.

Torstensson, G. 2003. Organic farming: Leaching risks and nitrogen turnover. Organic farming systems with and without livestock on clay soil in Southwestern Sweden. Results from 1997-2002. Report, in Swedish, 73, Division of Water Quality Management, Swedish University of Agricultural Sciences, Uppsala.

Tsopito, C.M. (2003) Crop Residues as a Feed Source for Ruminants. *UNISWA Journal of Agriculture*, 12, 29-34.

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

Union of Concerned Scientists (UCS). The Promise of Biomass: Clean Power and Fuel— If Handled Right. Cambridge, MA: Department of Energy (DoE); 2012.

United States Department of Agriculture USDA. (2006). Crop residue removal for biomass energy production: Effects on soils and recommendations. Soil Quality-Agronomy Technical Note. 2006; 19:1-7

Valdez-Vazquez, I., Acevedo-Benítez, J. A., & Hernández-Santiago, C. (2010). Distribution and potential of bioenergy resources from agricultural activities in Mexico. *Renewable and Sustainable Energy Reviews*, *14*(7), 2147-2153.

Vanlauwe, B., Diels, J., Sanginga, N., & Merckx, R. (1997). Residue quality and decomposition: an unsteady relationship.

Vanlauwe, B., and K. Giller. (2006). "Popular myths around soil fertility management in sub-Saharan Africa." *Agriculture, Ecosystems & Environment* 116:34–46.

Van Gestel, M., Merckx, R., & Vlassak, K. (1993). Soil drying and rewetting and the turnover of ^{14}C-labelled plant residues: first order decay rates of biomass and non-biomass 14C. *Soil Biology and Biochemistry*, *25*(1), 125-134.

Verhulst, N., Govaerts, B., Verachtert, E., Castellanos-Navarrete, A., Mezzalama, M., Wall, P.C., Chocobar, A., Deckers, J. & Sayre, K.D. (2010). Conservation Agriculture, Improving Soil Quality for Sustainable Production Systems? In R. Lal & B.A. Stewart (Red.), *Food Security and Soil Quality*, pp. 2-38. Boca Raton: CRC Press.

Vigil, M. F., & Kissel, D. E. (1995). Rate of nitrogen mineralized from incorporated crop residues as influenced by temperature. *Soil Science Society of America Journal*, *59*(6), 1636-1644.

Virmond E, Rocha JD, Moreira RFPM, José HJ. (2013). Valorization of agro-industrial solid residues and residues from biofuel production chains by thermochemical conversion: A

UNIVERSITY FOR DEVELOPMENT STUDIES

review, citing Brazil as a case study. Brazilian Journal of Chemical Engineering. 2013; *30*(02):197-229

Vitousek, P. M., Turner, D. R., Parton, W. J., & Sanford, R. L. (1994). Litter decomposition on the Mauna Loa environmental matrix, Hawai'i: patterns, mechanisms, and models. *Ecology*, *75*(2), 418-429.

Wakene Negasa. (2001). Assessment of important physico-chemical properties of District Udalf (District Nitosols) Under Different Management Systems in Bako Area, Western Ethiopia. MSc Thesis, Alemaya University, Haramaya, Ethiopia.

Wall, P. C. (2009). *Strategies to overcome the competition for crop residues in southern Africa,* Some light at the end of the tunnel, in: 4th world congress of conservation agriculture. Presented at the innovations for improving efficiency, equity and environment, New Delhi, India.

Waswa, B.S., Mugendi, D.N., Vanlauwe, B., and Kung's, J., (2007). Changes in soil organic matter as influenced by organic residue management regimes in selected experiments in Kenya.In: A. Bationo, B. Waswa, J. Kihara, and J. Kimetu, eds. 2007. *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: challenges and opportunities.* Dordrecht, The Netherlands: Springer, pp.457-469.

Weindorf D.C., Sarkar R., Dia M., Wang H., Chang Q., Haggard B., McWhirt A., Wooten A. (2008). Correlation of X-ray fluorescence spectrometry and inductively coupled plasma atomic emission spectroscopy for elemental determination in composted products. Compost Sci. Utilization, 16(2), 79-82

Accessed at: http:// dx.doi.org/10.1080/1065657X.2008.10702361.

Whiteside, M. D., Garcia, M. O., and Treseder, K. K. (2012). Amino acid uptake in arbuscular

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

mycorrhizal plants. *PLoS One*, *7*(10), e47643.

Whitmore, J. (2010). *Coaching for performance: growing human potential and purpose: the principles and practice of coaching and leadership*. Hachette UK.

Wiggins, D., Singer, J., Moore, K., Lamkey K. (2012). Response of continuous maize with Stover removal to living mulches. Agronomy Journal.;104:917 925

Williams, T. O., Salvador, F.R., Timothy, G.K., (1997). Influence of socioeconomic factors on the availability and utilization of crop residues as animal feeds. In: C. Renard, ed. 1997. *Crop residues in sustainable mixed crop/livestock farming system*. UK: CAB International, pp 25-39.

Yang, W., Thordarson, P., Gooding, J. J., Ringer, S. P., & Braet, F. (2007). Carbon nanotubes for biological and biomedical applications. *Nanotechnology*, *18*(41), 412001.

Yuliani, H., Siswanto, D., & Susetyorini, P. (1998). Perlindungan hukum terhadap dampak pe laksanaan program kali bersih (prokasih) bagi kualitas air sungai di propinsi dati i jawa tengah (The Legal Protection on The Impact of The Cleaner Rivers Program Execution for The Water Rivers Quality in the Central Java Province).

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

UNIVERSITY FOR DEVELOPMENT STUDIES

APPENDICES

APPENDIX 1. ANALYSIS OF VARIANCE (ANOVA) OF RESEARCH RESULTS

Appendix 1a. Analysis of Variance for Quantities of Organic Residues Produced in the Zones in the Tamale Metropolis.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16449377	3	5483126	82246.88	0.0038	3.490295
Within Groups	800	89	66.66667			
Total	16450177	92				

Coefficient of variation = 23.2 %

Appendix 1b. Analysis of Variance for Types and Quantities of Organic Residues Produced in the Tamale Metropolis

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	68755541	3	22918514	406224.6	0.0267	3.490295
Within Groups	677.02	89	56.41833			
Total	68756218	92				

Coefficient of variation = 7.6 %

Appendix 1c. Analysis of Variance for Costs Incurred in Acquiring Organic Residues in the Tamale Metropolis

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2732625	2	1366312	20494.69	0.00344	4.256495
Within Groups	600	89	66.66667			
Total	2733225	91				

Coefficient of variation = 15.3 %

www.udsspace.uds.edu.gh

Appendix 1d. Analysis of Variance for Uses of Crop Residues in the Tamale Metropolis

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24011.75	6	4001.958	96.59899	0.00284	2.572712
Within Groups	870	89	41.42857			
Total	24881.75	95				

Coefficient of variation = 19.7 %

Appendix 1e. Analysis of Variance for Temporal Availability of Organic Residues in Tamale Metropolis

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3032.827	2	1516.413	22.7462	0.000302	4.256495
Within Groups	600	89	66.66667			
Total	3632.827	91				

Coefficient of variation = 10.1 %

Appendix 1f. Analysis of Variance for Constraints Associated with Generation and Utilization of Organic Residues in the Tamale Metropolis

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3517.333	5	703.4667	14.86197	0.00753	2.772853
Within Groups	852	89	47.33333			
Total	4369.333	94				

Coefficient of variation = 4.6 %

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

APPENDIX 2. QUESTIONNAIRE FOR DATA COLLECTION ON 'ASSESSMENT OF SPATIAL AND TEMPORAL AVAILABILITY AND QUANTITIES OF ORGANIC RESIDUES IN THE TAMALE METROPOLIS OF NORTHERN REGION OF GHANA'

UNIVERSITY FOR DEVELOPMENT STUDIES
FABULTY OF AGRICULTURE
DEPARTMENT OF HORTICUTURE
NYANKPALA CAMPUS

UNIVERSITY FOR DEVELOPMENT STUDIES

Consent form

Thank you for the opportunity to speak with you. My name is Amidu Chinnia Issahaku. I am a student of the University for Development Studies, Nyankpala Campus. We are conducting a research on the off-farm usage of organic residue of maize (stalks and husk), rice husk, groundnut (shells, stock), soybean (shells, stock) in the Tamale Metropolis. You were not selected for any reason but we think you are one of the generators/users of at least one of the above residues. The Interview may take 20 to 30 minutes. Your participation is entirely voluntary and shall be used for only academic purposes.

USER PROFILE INFORMATION:	
1.0 Name of Farmer:	
1.1 Sample ID:	
1.2 Community:	
1.3 Contact (Optional):	
1.4 House Number:	
1.5 GPS CODE	
1.6 GPS Latitude	
1.7 GPS Longitude	
1.8 GPS Point Number	

DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

1. Gender of respondent 1 = Male [ ] 2 = Female [ ]
2. Age of respondents
   1 = 20-30 yrs [ ]
   2 = 31-40 [ ]
   3 = 41-50 [ ]
   4 = >50 [ ]
3. Marital status of respondents
   1 = single [ ]

www.udsspace.uds.edu.gh

2 = married [ ]
3 = divorced [ ]
4 = widow/widower [ ]

4. Educational level of respondents
   1 = no formal education
   2 = Basic
   3 = SHS
   4 = Tertiary
5. Farmer years of experience
   1 = 1-5 [ ]
   2 = 6-10 [ ]
   3 = 11-15 [ ]
   4 = 16-20 [ ]
   5 = 21+ [ ]

UNIVERSITY FOR DEVELOPMENT STUDIES

CROPS RESIDUE INFORMATION

6. What type of Residue do you use?	1 = Yes 2 = No	7. Who supplies you the residue?	8. In which period in a year are you able to obtain this residue?
		1 = owned/Family 2 = Purchase	1 = throughout the yr, 2 = Sep-Nov 3 = Dec-Jan
1 Maize stalk			
2 Maize husk			
3 Rice husk			
4 Groundnut shells			
5 Groundnut stock			
6 Soybean Shells			
7 Soybean stock			
8 Others (specify……………………….)			

Quantity of Residue and Packaging Material

4. What type of packaging material do you normally put this residue?	5. What quantity of this residue are you able to obtain in a day?	6. In a year, how much of this residue are you able to get??	7. What is the average weight of each package?
1. Sacks			
2. Polythene			

www.udsspace.uds.edu.gh

3. Bundles/Tired			
4. Others(Specify………………)			

1. What challenge(s) do you face in trying to get this residue?..
....
2. By what means are you able to bring this residue to the place where it is used?
   1 = Farm Tractor [ ] 2 = Tricycle [ ] 3 = Kia Truck [ ]
   4 = Motor cycle [ ] 5 Others (specify…………) [ ]
3. What is the cost of transporting each package to where you keep the residues from where you buy them ....
4. Do you normally buy this residue? 1 = Yes [ ] 2 = No [ ]
5. If you buy, what is the cost of each package?...
6. What are the quantities (kg) of produce obtained per hectare?
7. If you obtain the residues free, why do you think the farmers give them to you free?..
8. What do you think is the reason(s) why some farmers leave their residues on the farm?..
....
....
9. Do you treat the residues before keeping it? 1 = Yes [ ] 2 = No [ ]
10. If yes, what kind of treatment do you used?..
11. How long do you keep your residue in a year?
    1 = 1 – 2 months [ ] 2 = 3-4 months [ ]
    3 = 5-6 months [ ] 4 = A week [ ]
    5 = Less than a week [ ] 6 = More than six months [ ]
    7 = All year round [ ] 8. Others, specify ……… [ ]

UNIVERSITY FOR DEVELOPMENT STUDIES

www.udsspace.uds.edu.gh

18. What do you use this residue for currently when they are obtained from the farm?	19. What other way(s) can we use this residue apart from your current use(s)?
1 As animal feed	1 As animal feed
2 As Fuel in the house	2 As Fuel in the house
3 Kenkey Production	3 Kenkey Production
4 Others (Specify)…………………………	4 Others (Specify) ………………………………

UNIVERSITY FOR DEVELOPMENT STUDIES

20. The source(s) from whom you take this residue, are you aware whether or not they also use these residues for some other purposes?

1 = Yes [ ]
2 = No [ ]

21. If yes, what do they use it for?

1 = Animal feed [ ] 2 = Energy and fuel [ ]

3 = Food preparation [ ] 4 = As organic manure [ ]

5 = Others ………… [ ]

22. Do you know other category of people who also compete with you in obtaining these residues from the farm(s)?

1 = Yes [ ]
2 = No [ ]

23. If yes, who are they?

1 = Colleague Farmers [ ] 2 = Retailers [ ]

3 = Cattle Herdsmen [ ] 4 = Others (specify) -------------- [ ]

24. What exactly do they also use this residue for?

1 = as animal feed [ ]

2 = Fuel Material [ ]

3 = Kenkey production [ ]

4 = Sales [ ]

5 = Others (specify---------------- [ ]

25. In your opinion, are we making good use of these residues?

www.udsspace.uds.edu.gh

1 = Yes [ ]
2 = No [ ]

26. What do you honestly think farmers can best use this residue for on their farms to aid the production process?..
……

27. Interviewer observes the available package(s) with the farmer/user

28. Interviewer samples 2 packages and weighs them

29. Interviewer records the two separate weights down
……………………………………………………………………………………………………

UNIVERSITY FOR DEVELOPMENT STUDIES