UNIVERSITY FOR DEVELOPMENT STUDIES

ASSESSMENT OF THE QUALITY AND EFFECTS OF COMPOSTED MUNICIPAL SOLID WASTE ON SOIL PROPERTIES, GROWTH AND YIELD OF HORTICULTURAL CROPS IN TAMALE - ALEFU (*Amaranthus cruentus*)

SIMON KOFI AMUZU

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BY

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(UDS/MSWC/0001/18)

THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL MECHANIZATION AND IRRIGATION TECHNOLOGY, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES UNIVERSITY FOR DEVELOPMENT STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR TH AWARD OF MASTERS OF PHILOSOPHY DEGREE IN SOIL AND WATER CONSERVATION AND MANAGEMENT

APRIL, 2022

DECLERATION

Student

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere:

Candidate:

Signature: ………………………… Date: 27/04/2022

Name: Simon Kofi Amuzu

Supervisor

I hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on the supervision of thesis laid down by the University for Development Studies.

Principal Supervisor's

Signature: ……………………………… Date: 27/04/2022

Name: Gordana Kranjac-Berisavljevic

ABSTRACT

The management of soil nutrient is necessary in order to maintain the constant productivity of the plant system as well as good soil quality. This study documented the sources and quality of feedstock for the production of compost in the Tamale Metropolis and the effect of the application of the resulting compost on soil properties, the growth and yield of *Amaranthus cruentus.* Quality compost was produced from selected feedstock in Nyankpala and a field experiment setup to study the effect of different rates of the compost and inorganic fertiliser the development of *Amaranthus cruentus*. The experiment was arranged in a completely randomized block design, with two factors (compost and inorganic fertiliser) at four levels each (0kg/ha, 10kg/ha, 20kg/ha, and 30kg/ha) Growth characteristics, plant height, number of leaves, fresh biomass and dry matter content of *Amaranthus cruentus* were assessed during 2019 cultivation season. The soil properties and nutrient content were measured before and after planting of *Amaranthus cruentus* and compared. The results from the laboratory on the compost analysis shows that, the compost was rich and high in Nitrogen (5.75% of N in a 5g of the compost sample taking to the laboratory). The treatments with compost amendment saw changes in the concentration of soil pH from (5.89-6.65), nitrogen from (0.10-1.73) % and organic carbon from (1.17-4.58) %. Also, available phosphorus, potassium, calcium and magnesium increased significantly with organic manure treatment. Whilst the NPK chemical fertiliser reduced soil pH from (5.89-5.75) and exchangeable calcium concentrations and increased the available phosphorus and exchangeable potassium concentrations. These findings indicate that organic manure (compost) derived from urban degradable waste, shea butter slurry and crop by-products can be used in the cultivation of vegetable crops.

Keywords: organic manure (compost); growth performance; nutrient treatment; vegetable production.

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DEDICATION

I dedicate this work to my parents, Mr. and Mrs. Amuzu, and to my competent supervisor Ing. Prof. Gordana Kranjac-Berisavljevic, for inspiring me to stay strong and pursue this degree.

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CHAPTER ONE

1.0 Introduction

1.1 Background

Humans have always produced waste and, as human society develops, the amount of waste has increased. Countries today face a major challenge in sustainable waste collection, treatment and disposal. Waste management differs widely between industrial and developing countries, urban and rural areas (Guerrero *et al.*, 2013; Abdel-Shafy and Mansour, 2018).

The unsustainable management of solid or liquid waste poses a great environmental threat. Landfills contribute to global warming by releasing greenhouse gasses (GHG) as well as polluting soil and water. Five percent of global total (GHG) emissions come from landfill sites. (Lee, 20007; Aliyu *et al.*, 2019). Unsustainable waste management is also a threat to human health and is aesthetically unpleasant (Adeyemi and Adeyemo, 2007). Waste, however, does not have to be an issue, it can also be a potential resource and a rich opportunity for urban agriculture to use organic material.

A typical example of a developing country with unsustainable waste management is Ghana (Arthur *et al.*, 2011; McDougall *et al.*, 2019). Ghana also aims to become a middle-income nation and more waste comes with greater wealth (Ackun, 2015; Donkor, 2015; Adorus-Djentuh, 2018).

In order to maintain soil fertility and reduce nutrient losses, the presence of organic matter in the soil is crucial (Bot and Benites, 2005). Compost contains nutrients as well as organic matter, which is a good source of organic fertiliser for the soil. Organic matter, both in terms of physical structure and as a medium for biological activity, plays an important role in soils (Bot and Benites, 2005; Adugna, 2016). Furthermore, organic matter is strongly involved in soil productivity. It provides the soil with nutrients, improves its water holding capacity and helps the soil to maintain good tilth and thus improve aeration for seed germination and plant root growth. (Wolf and Snyder, 2003; Bot and Benites, 2005; Edwards and Hailu, 2011).

Compost is made up of the comparatively unchanging decomposed organic materials resulting from the accelerated biological degradation of organic materials under controlled, aerobic conditions (Paulin *et al.*, 2008).

One of the most significant factors contributing to increased production and sustainable agriculture is the use of compost (Bernal *et al.*, 2009; Pergoal *et al.*, 2018). In addition, compost can solve the problem facing farmers with a decrease in their soil fertility (Giller *et al.*, 2011; Watson, 2002). Due to problems with soil fertility, crops are more vulnerable to pests and diseases, resulting in low crop yields (Adugna, 2016; Chagnon *et al.*, 2015).

With the goal of recycling plant and animal residues for crop production, compost fertiliser is prepared from plant and animal residues (Arthurson, 2009; Devi *et al.*, 2017). The decomposition process alters organic matter, into a stabilized state that can enhance soil for plant growth (Kallenbach and Grandy, 2011; Kleber and Johnson, 2010). Other beneficial effects of composted organic material include the diverting of landfill waste to alternative uses, the removal of pathogenic inoculates or weed seeds and the decomposition of petroleum, herbicide and pesticide residues, erosion control and ecological revegetation of degraded soils as a nutrient source (Wagas *et al.*, 2018). The use of compost helps produce safe "clean green" horticultural products and enhances the potential for large-scale organic food production (Paulin *et al.*, 2008).

Compost can greatly enhance the physical structure of soil. The addition of compost will reduce bulk density, improve workability and porosity, and increase its gas and water permeability, thus reducing erosion. The addition of compost has both an immediate and long-term beneficial effect on the soil structure when used in appropriate amounts. In fine textured soils, it resists compaction and increases the holding capacity of water and improves soil aggregation in coarse-textured (sandy) soils. Due to its humus content, the soil-binding properties of compost are (Wehba, 2007). The addition of compost may provide greater drought resistance and more efficient water utilization for agricultural crops (Bot and Benites, 2005). Therefore, the frequency and intensity of irrigation may be reduced. Recent research suggests that the addition of compost to sandy soils can facilitate moisture dispersion by allowing water to more readily move laterally from its point of application (Haouvang *et al.*, 2017; Rousset *et al.*, 2019). Compost is capable of binding heavy metals and other contaminants, reducing both their ability to leach and plant absorption. Therefore, sites contaminated with different pollutants can often be improved by composting the soil (Farrell *et al.*, 2010). The same binding effect enables compost to be used as a filter medium for the treatment of storm water and has been shown to reduce pesticide leaching in soils (Beesley *et al.*, 2010).

1.2 Problem statement and justification

Soil fertility is linked to the mineralisation of nutrients contained in organic matter and their release into the soil solution in plant-accessible form (Stockdale *et al.,* 2002; Palm *et al.,* 1997). Mineralisation is the result of normal soil biological cycles and can be stimulated by the addition of adequate quality compost and culture (Fontaine *et al.,* 2003). Because mineralisation takes place over extended periods, it can make a significant contribution to plant growth and minimize the effect of rainfall-related leaching and excess irrigation, (Adugna, 2016; Thierfelder *et al.,* 2017; Simmons *et al.,* 2010). Compost from organic waste is a good source of organic fertiliser, because it contains nutrients as well as organic matter.

The cost of chemical fertiliser and the potential environmental risk posed by its overuse have increased interest in organic materials such as plant residues, manures and composts (Urra *et al.,* 2019; Awasthi *et al.,* 2019). It is not enough to add artificial fertiliser alone to retain a sufficient level of soil fertility. In heavily degraded soils, organic matter is required to maintain water and nutrients, otherwise yield response is limited, even if artificial fertiliser is used (Agromisa *et al.,* 2005). Therefore, farmers need to be careful about the content of organic matter in the soil. An integrated approach, combing application of compost and with or without an application of artificial fertiliser is a good strategy for sustainable crop production (Gete *et al.,* 2010).

This study aims to provide more information on opportunities composting and compost use in Tamale and impact of such practices on municipal waste management. It also analyses the ways to make best use of locally available organic materials in agriculture and horticulture. This will help improve, or at least maintain, the productivity of soils for food production.

1.3 Main Objective:

The objective of this study was to ascertain the possibility of compost production from municipal waste in Tamale for cultivation of horticultural crops and compare its effect to chemical fertiliser effect on soil nutrient status and physical characteristics of soil.

1.4 Specific Objectives:

1. To identify waste sites in Tamale Metropolitan assembly (TaMA) and amount of organic material available for compost production.
2. To compare physical and chemical properties of the soil before and after adding compost, compared to NPK fertilizer input and their combination.
3. To determine the impact of compost and NPK and their combination on growth, and yield of Alefu (*Amaranthus Cruentus*).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Solid Waste

Unwanted materials and substances that originate from industrial waste comprise solid waste, domestic and business activities, which are normally disposed of in landfills, but does not include industrialised harmful wastes (Polprasert and Liyanage, 1996; Singh *et al.*, 2011). Kaseva and Mbuligwe, (2005) and Sntime (2011) also defines solid waste as all the waste arising from human and animal activities that are normally solid and are discarded as useless or unwanted. However, in another definition, solid waste is considered as all unwanted or discarded materials arising from both human and animal activities that have insufficient liquid to be free flowing (Otu, 2011; Adjei, 2013*).*

2.2 Management of solid waste in developing countries

The generation of waste in most developing countries keeps increasing in capacity, diversity and complexity due to population upsurge, growth and progress in these countries (Blaikie, 2016). Changing the standard of living has introduced items such as use of mobile phones, canned soft drinks, bottled water and disposable diapers, which pose unusual waste controlling challenges, as waste management systems in developing countries are not capable of regular adjustment to match changed standard of living (Khatib, 2011).

In most developing countries, waste management comprises collection and disposal, but there is more to waste management (Khatib, 2011; Wilson *et al.*, 2013). Solid waste managing is defined as the mechanism of generation, collection, storing, transporting, treating or processing, and discarding of solid waste in a way that is in accord with the best principles of public health, industrial, economics, managements, and that is also receptive to community approaches (Beede and Bloom, 1995).

Inappropriate solid waste management leads to a significant negative ecological impacts such as contamination of soil, water and air, and generation of greenhouse gases from landfills, and health and safety problems such as diseases spread by insects and rodents attracted by garbage heaps, and diseases associated with different forms of pollution (Abdulai, 2011). The waste management in Ghana is in poor state and there is currently minimal recycling carried out (Oteng-Ababio, 2010, Oteng-Ababio *et al.*, 2013). Problems are encountered at all levels of waste management: sorting, collection, transportation, disposal and evaluation of impact to environment and public health (Yoada *et al.*, 2014). Since waste management and disposal is a problem, it can be a deterrent to economic development.

2.3 Integration of solid waste management

Integration of solid waste management refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects, that is, from generation, separation, transfer, sorting, treatment, recovery and disposal, with an emphasis on maximizing resource use efficiency (Memon, 2010; Shekdar, 2009). It involves the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals (Tchobanoglous, 2009; Badgie *et al.*, 2012; Zia and Devadas, 2008).

2.3.1 Pyramid of integrated solid waste management

A hierarchy pyramid in waste management can be used to rank actions to implement programs in the community. On the waste pyramid, disposal is the least favoured option (Agunwamba *et al.*, 1998; Otu, 2011).

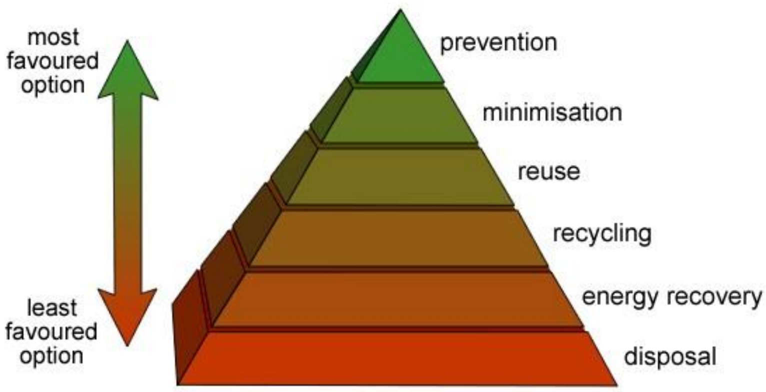

Figure 2.1: waste pyramid

(Source: *https://en.wikipedia.org/wiki/Waste_hierarchy*, downloaded 19th May 2020).

Presently, about 90% of waste is being sent to landfills, so there is a need to reduce this amount. This will help to conserve more space in our landfills and thereby avoiding the need to build more or expand landfills which takes up valuable space. Up from disposal on the pyramid is energy recovery, or waste to energy process. It involves the combustion of waste material into heat, gas, steam and ash inside a specially engineered and purposed-built incinerator (Osei-Mensah, 2008)

The next step on the pyramid is recycling and it involves the separation and collection of waste materials; the preparations of waste materials for reuse, reprocessing and remanufacture (Tchobanoglous *et al.*, 1993). This report is concerned recycling using composting of the organic material. The most favoured steps on the pyramid focus on reducing the amount of waste that is produced in the first place. The top 3 steps, reuse, minimization and prevention can only be encouraged by government and local policy, regulation, education and most importantly, public participation.

Most of the municipal solid waste in developing countries is dumped on land in a more or less uncontrolled manner. These dumps make very uneconomical use of the available space, allow free access to waste pickers, animals and flies and often produce unpleasant and hazardous smoke from slow-burning fires (Oyeku and Eludoyin, 2010; Haileslassie and Gebrement, 2015).

2.4.2 Composting

Composting is a low temperature bio-oxidative process, with a stage of the organic matter degradation and the mineralization of labile organic compounds (readily available for the microorganisms) and belongs to important trends in recycling organic and mineral components of wastes (Xu *et al.,* 2019; Toledo *et al.,* 2020). It is a method for preparing organic fertilisers and amendments economically and ecologically soundly and may well represent an acceptable solution for disposing of municipal solid waste, at the same time increasing its value (Ludwig *et al.*, 2012 and Chandler *et al.*, 1997).

The application of compost from municipal solid waste as fertiliser maintains the sustainability of agro-ecosystems land because it can recover the nutrients contained in them, minimising the negative impact on the environment (Scotti *et al.*, 2015; Diacono and Montemurro, 2011). Composting provides a valuable material improving physical and chemical properties of soil. For example, the agroindustry waste compost application in soil showed a significant increase in the nitrogen, phosphorus, potassium and organic matter content in amended plots (Courtney and Mullen, 2008).

The quality of the compost obtained depends on a great extent the kind of material subjected to stabilisation (Gomez-Brandon *et al.,* 2008; Lazcno *et al.,* 2008). In the case of municipal waste, this method is extremely advantageous, since it eliminates their sanitary epidemiological hazard, bacteria and fungi with high temperature; and reduces the organic content of landfills, source of the development of undesirable microorganisms and the high risk to the proliferation of infections (Hoornwey *et al.,* 1999; Atalia *et al.,* 2015). Compost is the product resulting from the controlled biological decomposition of organic material that has been sanitised through the generation of heat and stabilised to the point that it is beneficial to plant growth (Bernal *et al.,* 2009; Li *et al.,* 2010). Compost is an organic matter resource that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media (Raviv, 2005; Ozores-Hampton *et al.,* 2011). It contains plant nutrients but is typically not characterized as a fertiliser (Noguera, *et al.,* 2001; Chen, 2006; Qiao *et al., 2016*).

A large proportion of municipal waste is not properly disposed of in many countries, posing a potential environmental threat because of the presence of pathogens and toxic pollutants (Okoh *et al.,* 2007; Sobsery *et al.,* 2006; Darby *et al.,* 2006).

2.5 Effects of compost on growing and developing of the plant (*Amaranthus*)

Maximum nutrient availability in soils occurs at slightly acidic to neutral pH. Addition of compost increases the pH of acidic soils and therefore making nutrient more available for plant growth (Sheoran *et al.*, 2010; Fageria and Baligar, 2008). Compost addition in soil or growth media may also correct imbalances in salt content. Addition of compost is reported to have tripled the N content of sandy soils (Bunoan-Olegario, 1991; Reeve and Drost, 2012).

Schulz *et al*. (2014) showed that compost increases both N and total organic content (TOC) in soils, but the effect is more pronounced in sandy than in loamy soils. Moreover, P, K, Ca, and Mg levels are reported to be elevated in soils with increasing addition of compost, whilst the levels of Al and Na decreases (Schulz *et al*., 2014). Presence of salts can lead to chlorosis and root injury which may cause root diseases and interfere with nutrient uptake. Excess salts are also implicated in poor germination and seedling development (Alam, 1999; Hageman, 1984; Pahlsson, 1989).

The N effect in the first year of compost application is reported to be 5-15 % and 2-8 % per annum, subsequently (Abubakari, 2016). Application of 15 tonnes of compost/ha of land increased the soil humus load by 0.4-0.5 in 20 years, whilst the application of inorganic fertilisers decreased the humus load by 0.5 % in the same period (Amlinger *et al*., 2003). This implies that, compost adds on humus whilst inorganic fertilisers reduces humus content in the soil. Compost has wide application in agriculture, forestry and horticulture for crop production, land remediation and restoration (Zhang *et al*., 2012).

2.5.1 Benefits of using compost

Compost improves the soil structure, porosity, and density, thus creating a better plant root environment, gradually releasing nutrients and supporting healthy root growth (Barbanti *et al.,* 2010). Compost improves soil tilth and increases water holding capacity of substrates, thus reducing water loss and leaching in sandy soils (Agegnehu *et al.,* 2015; Aggelides, 2000).

It increases microbial diversity and provide buffering effect on soils, can regulator or destroy certain soil-borne plant pathogens (Xu *et al.,* 2012; Kowalijow and Mazzarino, 2007), as well as increases infiltration and permeability of heavy soils, thus reducing erosion and runoff.

Compost supplies a variation of micro and macronutrients in substantial amounts of organic matter.

2.6.4 Opportunities for organic farming in Ghana

A study by Charnley (2012) on organic production systems by small scale farmers in Ghana, indicated that organic farming helps to provide a safer and healthier environment by not polluting our groundwater, rivers, lakes, and oceans with synthetic pesticides and chemical fertilisers; it reduces soil erosion, improves soil quality, increases diversity of wildlife on and near farms without exposing farm workers to synthetic pesticides.

Economically, the local and international market for organic products has significant prospects for growth (Scott, 2004; UNEP, 2011). This could lead to increased income and improved living conditions for the producers and exporters of organic produce. Charnley (2012) suggests that Ghana's investment in organic farming has the potential to drastically revolutionize the country's agriculture sector and economy by introducing healthier, more robust food, supporting the sustainable use of land, and generating more nutritional goods with better market value.

According to Osei-Asare (2009), there is a huge potential for the organic sector in Ghana for both export and domestic consumption. The prospects for producers are high as most consumers were willing to pay a maximum of 20% premium on organic products.

Also, CAOF (2011) suggests that consumers are often willing to pay extra if the produce is certified as organic. On the other hand, the certification costs are very high because certification is often done by foreign organisations. As a result, because the produce is not recognised as organic (according to international standards), they do not attract premium prices (Yiridoe *et al.*, 2005). Since most of the organic products in Ghana are uncertified and will continue to remain so in the short term, it is important to develop and sustain a local market within neighbouring African countries for these uncertified organic products, and also, to establish alternative form of standards and certification within the local context (Willer *et al*., 2008).

2.7 Compost use in Ghana

Vegetables production in Ghana is mostly under organic or inorganic farming systems or both (Worthington, 2001; Lavison, 2013). Recently advocating of organic foods has led to an upsurge in the land that has been reserved for organic agriculture from a projected 5,453 hectares in 2003, 19,132hectares in 2006 to 26,000 hectares in 2010 (IFOAM & FiBL, 2010). Despite these periodic increases, only 0.13 % of arable land in Ghana is used for organic (vegetable) farming (IFOAM & FiBL, 2010). Organic agriculture is considered a momentous farming system worldwide; it is inexpensive to operate and relies mostly on natural and human resources (Dabbert, 2006; and Hole *et al.*, 2005). Mohammed *et al.* (2014) observed that Ghana has a market potential for organic vegetables to about GH¢ 1,991,224 ($1,640, 083) per annum. This means that if organic vegetable farmers can be efficient in producing organic vegetables they stand the chance of raising their farm income and consequently their welfare.

Organic vegetable production does not only benefit the farmer, it also benefits the consumer. For instance, organic vegetables have recently been promulgated as more wholesome than conventional produce as a result of the latter's tendency of being contaminated by the disproportionate use of agrochemicals (Probst *et al.*, 2012; and Nouhoheflin *et al.*, 2004). For instance, a study conducted to compare organic vegetables with conventional vegetables (Carrington and Arnett, 2014) found much higher levels of cadmium, a toxic metal, in conventional vegetables and pesticide residues that were four times more often than on organic vegetables. Although the higher levels of cadmium and pesticide residue found in the conventional produce were well below regulatory limits, the researchers explained that cadmium accumulates over time in the body and some consumers may wish to avoid this (Gomiero, 2018).

2.8 Compost use in Tamale

In Tamale, the use faecal sludge and organic solid waste has a long history mainly in peri-urban areas (Appiah-Effah *et al.,* 2015; Bellwood-Howard *et al.*, 2015). Traditional reuse practices of organic solid waste are strong in the Metropolis where population density is high and the cost of inorganic fertilisers is increasing (Masak, 2012 and Ofosu-Budu *et al.*, 2015).

With the growth of peri-urban areas, management of municipal solid waste to avoid environmental degradation and public health risks has not gained in significance (Seng *et al.*, 2011; Troschinetz and Mihelcic, 2009).

Agricultural by-products such as rice straw, groundnut vines, shea butter slurry etc. are abundant in the municipality (Ajila *et al*., 2012; Poppe, 2000). Although informal faecal sludge mixed agricultural waste materials use is wide spread in the Metropolis, the treatment and use of the biodegradable organic fraction is still fairly limited (Mujere *et al.,* 2019). The authorities of Tamale Metropolitan Assembly (TAMA), Ministry of Agriculture (MoFA), Environmental Protection Agency and other Non-Governmental Organisations (NGOs) concerned, are finding ways to manage and re-use organic solid waste (Gyasi *et al.*, 2014).

In Ghana, the rising usage of agrochemicals has resulted from the need to meet the food demand of a growing population, despite the health concerns about consumers and the environment (Adolwa *et al.*, 2017 and 2019; Rigby and Caceres, 2001: Lee, 2005; Jennings *et al.*, 2016). However, organic farms in northern Ghana (especially Tamale) despite the fact that they are on small scale, play significant roles in economic activities contributing to the farmers' livelihoods (Tsikata, and Yaro, 2014). Most of the farmers in northern Ghana are poor and would need an effective agricultural strategy to thrive.

Organic farming is confronted with several challenges including the non-availability of exclusive market for organic produce, the absence of premium price in the local market, not creating national recognition for organic produce, and a vague policy direction of the organic farming sub-sector Boateng *et al.*, (2018). To redress these challenges, there is the need to have a strong organic Producer and Consumers Network or a coalition that will champion the course of organic agriculture (Driscoll and Ichikawa, 2017).

In 2007, the Coalition for the Advancement of Organic Farming (CAOF) was formed by a number of Civil Society Organisations (NGOs) and individual organic farmers from the Northern and Upper East Regions of Ghana. The coalition‘s aim was to advocate the identification, development, and promotion of best organic/conservation practices as alternatives to agrochemicals in agricultural production (CAOF, 2011). CAOF is made up of fifteen (15) organisations, namely, the Zuuri Organic Vegetable Farmers‘ Association (ZOVFA) in the Bawku Municipality, Community Self-Reliance Centre (CSRC), Youth Harvest Foundation-Ghana (YHF-G), Trade Aid Integrated and TRAX (all working within the Bolgatanga Municipality), Presbyterian Agricultural Stations (PAS) of Sandema, Garu, Langbensi and Mile 7 in the

Builsa, Garu-Tempani, East Mamprusi and the Tamale Metropolis respectively, Zagslaari Ecological Farms Project (ZEFP) and Chiira Bisi Farms Project (CBFP) in the West Mamprusi District, PEDIC in the Garu-Tempani District, Gia Nabio Agro-forestry Development Organisation (GNADO) in the Kassena Nankana East and the ITF – company (Integrated Tamale Fruit Company) in the Northern Region of Ghana (Boateng, 2018).

These fifteen (15) organisations have been promoting organic/ecological agriculture among smallholder farmers in their respective operational areas (Rice, 2001). Some members of CAOF have collaborated with the Northern Presbytery Development Services (NPDS) to embark on an advocacy campaign against the misuse of chemical pesticides in the two (2) regions of Ghana (Northern and Upper East) Boateng, 2018. Though all the NPDS Stations are CAOF members, there are other CAOF members who are not involved in the campaign. In addition to this, a work plan for CAOF was developed and taken to MoFA and other relevant state sector organisations including the District/Municipal Assemblies (where coalition members operate) to lobby them to integrate this plan into their Annual and Medium-Term Development Plans (MTDPs) for implementation (Boateng, 2018).

2.8.1 Availability of biodegradable materials in Tamale Metropolitan assembly

The study examined the potential of Tamale Metro and its sub-metro to produce high-volume compost manufacturing materials to help address sanitation issues and improve the fertility of the soils in the study area. Production and profitability will be significantly improved by this. Converting all the waste at this different site to compost will assist in the city's waste management situation and also help reduce the amount of waste that is carried to the site of the landfill, thereby reducing the pressure on the landfill to help expand its life span. High volume organic materials from rice straw, rice husk, shea butter slurry, faecal sludge and degradable municipal waste were identified in over fifteen locations.

2.9 The chemical properties of the soil

Treatments with NPK fertilisers significantly reduced soil pH from 6.89 to 5.95, whilst treatments with organic compost increased soil pH significantly from 5.25 to 6.75 El-Nagar *et al.*, 2020; Abedel-Mouty and El-Greadly. 2008). Soil nitrogen was increased after organic compotation, whilst soil nitrogen content was untreated or controlled by NPK fertiliser therapy with the same types of soil. Phosphorus has been increased to about 60% in the soil in both treatments (Margenat *et al.*, 2020; Singh and Agrawal, 2008).

Although both treatments showed a significant increase in concentrations, similar to the phosphorus available, it was more apparent when organic compost was treated. The calcium exchangeable was reduced after the treatment with NPK fertiliser, with no changes in magnesium concentration observed Compost therapy significantly increased the concentration of calcium and magnesium in the soil (Schulz and Glaser, 2012; Subedi *et al.*, 2016; Agegnehu *et al.*, 2016).

Dropping the soil's pH as a result of NPK engraving can be caused by the leaching of basic cations like potassium, calcium and magnesium out of the soil because the soil is without any binding agents, such as compost, to treat it with bio-fertilisers (Olobode *et al.*, 2018). Organic compost (manure) usually increases the pH of the soil with animal by products, but the effects can vary according to the composition of organic matter, its rate of treatment, and the properties of the soil. The soil was acidified by the NPK fertiliser treatment, like in other studies (Usman *et al.*, 2012; Diacono and Montemrro, 2011). Long-term use of NPK fertiliser eventually results in shortcomings in other vital nutrients, which can affect the physical, chemical and biological properties of a soil (Gu *et al.*, 2009; Masto *et al.*, 2006; Diacono and Montemrro, 2011).

2.9.1 Organic matter content

The high composition of organic matter in organic compost has a positive effect on the soil nitrogen, phosphorus, potassium and main cations. Because of the slow decomposition of organic compost, plants are allowed to use nutrients for a long time and reduce the loss of what is not used by plants (Hunang *et al.*, 2007; Han *et al.*, 2016). Compost and chemical fertiliser do increase the phosphorous content in the soil, and the plant has failed to use all phosphorus supplied by treatments which has led, like the results reported by Song *et al.*, 2017, to phosphorus accumulated on the surface of the soil. The treatment of compost increased major cations, including potassium, nitrogen, and phosphorus.

2.10 Soil conditions for the growth of Amaranthus

Amaranth can be grown on a wide range of soil Liu and Stutzel (2002). However, leafy types require fertile soil of sandy loam in nature with well drained and slightly acidic. It does not do well on heavy, poorly drained or on sandy soils, which is very poor in water holding capacity and poor in fertility. It grows well only on the soil, which is thoroughly cultivated up to good tilth. The soil should be pulverized (Gupta *et al.,* 2020; Sharma *et al.*, 2013; Kishor *et al.*, 2010).

2.10.1 Nutritional requirements and management

According to Meena *et al.*, 2019 and Nayak *et al.*, 2012, for good yield application of 20 - 30 t / ha farm yard manure is advisable during ploughing into the soil. Besides 30 to 40 kg / ha nitrogen, 40 to 50 / ha each phosphorous and potassium is applied in 3 or 4 splits. Largely nitrogen is used as top dressing after each cutting Singh *et al.*, 2015. The quantity of phosphorous and potassium needed is applied as based just before sowing or two weeks after planting (Bar-Tal *et al.*, 2004).

2.10.2Manure and fertilisers

Largely, the crop is grown under residual fertility of the previous crop. However, applying 35 – 40 t / ha of well-rotted farmyard manure at the time of preparation of land Prasa Datta *et al.*, (2010). Forty kg / ha of nitrogen is top dressed between rows just before irrigation (Jat *et al.*, 2005).

Despite the fact that *Amaranthus* is a low-maintenance crop that thrives on poor soils, research has shown that fertiliser increases productivity (Ayodele and Sittu, 2013; Palada and Chang, 2003). Myers (1998) and Schippers (2000) reported that Good soil fertility and organic matter are beneficial to *Amaranthus*. Although Mhlontlo *et al.*, (2007) reported that Although modest rates of sheep kraal manure (2.5 t/ha) resulted in considerable improvements in mono-cropped Amaranthus fresh and dry matter yields, information on the fertility needs of both grain and vegetable *Amaranthus* is limited. Elbehri *et al.*, (1993) noted that Using N-P-K fertiliser and irrigation during Amaranthus growing might boost grain output from 700 kg/ha to 3000 kg/ha. Fertiliser application resulted in higher yields were observed by Spreeth *et al.*, (2004) at the University of Zululand, South Africa who applied 250 kg / ha of 2 : 3 : 2 compound fertiliser. Studies conducted by Schippers, (2000) indicated that the crop requires high potassium levels, and the best results were obtained with 400 kg/ha of compound fertiliser 10 – 10 – 20. (NPK). When compared to kraal manure, plants cultivated with poultry manure produced higher yields. (Spreeth *et al.*, 2004). According to Walters *et al.*, (1988); Elbehri *et al.*, (1990); Makus, (1990 b); Putnam, (1990) fertility studies result in Arkansas, Minnesota, Montana, and Tennessee have been quite variable, for both vegetable and grain Amaranth types. A generally suggested fertility guide for Amaranth would be 112 to 135 kg / ha of total available N, with a soil test of 15 to 30 ppm P and 80 to 120 ppm K. Fertility needs will vary significantly, depending upon soil type, prior cropping, and fertiliser history. Higher applications of nitrogen would be applied in the high rainfall areas of the Midwest and under irrigated management as compared to the low rainfall production areas in the Great Plains Dinnes *et al.*, 2002. As the interest in Amaranth production increases, additional fertility studies will be needed for economic production practices (Alemayehu *et al.*, 2015; Cavigelli *et al.*, 2013; Manlay *et al.*, 2007).

2.10.3 Compost as potential source of nutrients for Amaranthus

Manure is often made up of a combination of faecal material, urine, and plant matter (Mohammed, 2015; Mhlontlo, 2008). It includes all of the nutrients essential for plant growth, but in inequitable quantities, therefore it's critical to apply enough manure to meet crop needs. (Van Averbeke and Yoganathan, 2003; Okorogbona and Adebisi, 2012). According to Mkile (2001), Cattle, sheep, and goat manure all have different nutritional levels. The highest levels of N, P, and K were found in goat manure, which was followed by sheep and cattle manure. According to Schippers (2000), When enough manure is put to Amaranthus, it improves its growth and production dramatically, just as it does to most other crops. Farmers in the Eastern Cape (South Africa) practice mixed farming, which includes raising cattle, goats, and sheep on communally owned rangelands, as well as growing maize, beans, and pumpkins on individual holdings of 1 to 3 hectares and vegetable production of cabbage, spinach, onions, peas, and carrots in gardens of 0.1 to 0.3 hectares next to their homesteads (Mandiringana *et al.* 2005, Reij *et al.*, 2013; Mati, 2006). Cattle, sheep, and goats are typically housed in kraals at night for security reasons (Kumalo, 2014; Van Ayerbeke *et al.*, 2008; Bembridge *et al.*, 1992). Animal faeces, usually mixed with fodder, accumulates over time in layers that are locally referred to as kraal manure (Solontsi, 2013 and Seeiso, 2014). Each year, around 1.6 million tonnes of dry manure are produced in the Eastern Cape (South Africa) (Mohammed, 2015; Solontsi, 2013). Mohammed, 2015 and Solontsi, 2013 reported that to combat deteriorating soil fertility, farmers in the Eastern Cape utilize kraal manure in their maize-based cropping systems.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study is focused on different waste materials from the Tamale Metropolitan Assembly using selected waste collection points (Central market, Aboabo market, Choggu, Old Cinema, Jisonaayili, Zoomlion land field site etc.). University for Development Studies (UDS) Nyankpala Campus was used as field experimental site for compost production and crop performance evaluation.

3.2 Tamale Metropolitan Assembly

The Tamale Metropolitan Assembly (TaMA) has been described by Ziem (2013) as the largest urban centre in the north of Ghana, with an estimated current population of 371,351 (GSS, 2013). Geographically, the Metropolis lies between latitude 9°.16' and 9°.34' North and longitudes 00°.36' and 00°.57' West and located approximately 180 metres above sea level and with a total estimated land size of 750 km^2. The Metropolis experiences one rainy season starting from April/May to September/October with a peak season in July/August (Munin, 2019; Osei *et al.,* 2015; Abubakari, 2015). This work focused on composting of waste materials from different locations (Central market, Aboabo market, Choggu, Old Cinema, Jisonaayili, Zoomlion land field site etc.), within the municipality where such degradable waste can be located for compost production. In Tamale, agricultural by-products such as rice straw, groundnut vines, shea butter slurry etc. and other municipal waste are in abundance (Awini, 2017; Ansah, 2015). The actual compost preparation experiment was conducted on-farm at UDS Nyankpala Campus, about 18km from TAMA, March – April, 2019.

3.3 Field survey

3.3.1 Identification and Collection of Composting Materials

Locations with abundance of high degradable materials in Tamale were identified for collection of waste materials and points marked using GIS. Map of these locations is presented as below; **(Plate 1).**

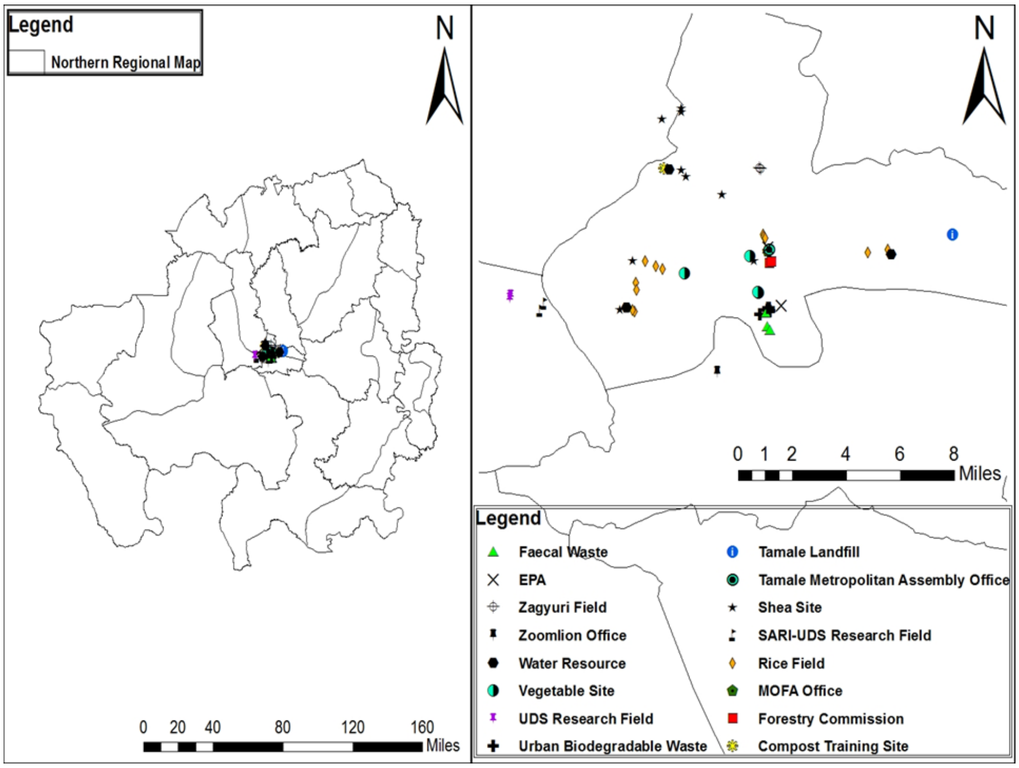

Plate 1: The map shows available areas of waste site, vegetable farming sites and sources of water for dry season farming.

(Source: Field survey, 2018/2019)

Criteria used for sites selection included the following: proximity of the materials to the composting site to reduce the cost of transportation, availability of the materials at the selected sites and the ability to manage the waste properly. Most of these sites were identified with the help of the following institutions: Ministry of Food and Agriculture (MoFA), Tamale Metropolitan Assembly (TaMA), Environmental Protection Agency (EPA), Decentralized Composting for Sustainable Farming and Development (DeCO) and Forestry Commission. In total, six main sites were identified during the field work, as shown on map above **(Plate 1).**

3.3.2 Composting Materials in Tamale

From the mapping and identification of site with available waste for compost production, it was observed that most of the materials suitable for composting in the TaMA were found in fifteen agricultural processing centers and three market areas which have been presented in map and tables. In addition, shea butter slurry from the numerous small-scale butter extraction plants, faecal sludge from public and private toilets, rice straw and husk, as well as groundnut husk were also considered for composting.

Thus, materials used for the preparation of the compost during the study included:

1. Organic municipal waste,
2. Agricultural by-products, such as rice straw & husk, groundnut husk,
3. Shea butter slurry and
4. Fecal sludge.

To mix compost materials was an important part of the study. The material composition of composting pile has a major impact on how well the composting process works and the quality of the final product. Good composting is to have a variety of materials and a balanced carbon to nitrogen ratio. Variety increases the types of microorganisms at work in the pile and the chances of obtaining nutrient rich compost.

Plate 2: Rice husk – Nyankpala rice mill

(Source: Field survey, 2018/2019)

Plate 3: Sorted municipal waste – Zoomlion landfill site

(Source: Field survey, 2018/2019)

3.4 The compost production process at UDS Nyankpala field site

The organic municipal waste was collected and sorted into degradable and undegradable materials. The agricultural by-products were all gotten form the processing centers as waste generated at the processing centers.

The feedstock and organic waste from the market and agricultural processing centers in selected areas of TaMA were composted in circular cross section windrows, over a 10-week period April – May, 2019. The materials were composted in three piles, to accelerate the decomposing process. The open composting system was used, in which the mixed material was piled into long heaps called windrows and left to decompose. The three piles were in a range of 0.6, to 1m high, insulated with soil to promote an even distribution of heat inside each pile. Piles were covered with jute sacks to prevent excess evaporation and to ensure protection from rain.

The windrows were turned using a loading shovel once a week for the first 8 weeks and then, the material was allowed to mature for a period of 2 weeks with no turning when the temperature was stabilized on the 10th week of the production period. There was also periodic measuring of moisture content to monitor the compost pile using the simple hand squeezing test. This was measured by squeezing firmly a sample in the palm. If water come out then the pile is too moist, if there was no drop and the sample is unable to hold together then it was too dry. If it is able to hold together and there were drops of water, then the moisture content of the pile is ideal (Harwood *et al.,* 2009). The compost was then packaged into a 50kg bags. Compost was sampled using the stratified sampling method, thus taking samples at the top, middle and bottom for analysis.

Plate 4: Compost preparation

(Source: Field work at UDS experimental site, 2019).

3.5.0 Compost and Soil analysis

The quality of the compost produced was assessed based on the nitrogen content which was determined by using the Kjeldhal procedure, in three steps: digestion, distillation and titration (Bremner, 1965).

Ten grams of sieved organic was weighed into a 500ml Kjeldahl flask moistened with distilled water. Kjeldahl tablet made up of Selenium and copper sulphate was added as a catalyst and 30ml of concentrated sulphuric acid was also added and then digested for 2hours using the Bunsen burner flame. The solution was then cooled and decanted into a 100ml volumetric flask and made up to the mark.

An aliquot of 10ml of the digested sample was taken into a distillation unit and 20ml of 40% NaOH and 10ml of 4% boric acid were added to it resulting in a pink colour, the distillate was then collected over NaOH solution and boric acid for about 5minutes.The presence of nitrogen gave a blue colour. The solution was then titrated with 0.1MHCL until the blue colour changed to pink signifying the end point.

Using the recorded titer value and the relation below the % of nitrogen was then calculated.

% Total Nitrogen = $\frac{14x(A-B)xNx100}{1000x1}$ ………………eqn 1

Where;

A is the volume of standard acid used in the sample titration.

B is the volume of the standard acid used in the blank titration.

N is the normality of standard acid

14 is atomic weight of nitrogen

3.5.1 Soil Sampling

The tools used included: auger (0-30 cm depth), bucket and cutlass. The 400 m^2 land area was demarcated into four uniform size portions, each of which was sampled separately. The sampling was done in a crisscross manner and five samples were taken from each area separately. The soil was then mixed thoroughly and divided it into four parts. Two parts were rejected and the rest of the soil was mixed again. The process was repeated until it was left with about 0.5 kg of the soil and this was collected and put in a clean paper bag as a single sample. The sample was allowed to air dry at room temperature. The compost was not oven dried, because oven drying can cause changes in the sample.

Determination of soil physical properties

3.5.2 Texture (The Hydrometer Method)

Particle size distribution is a stable soil characteristic that has influence on the physical and chemical properties. In the estimation of soil texture, particles of less than 2 mm in diameter are determined separately and characterized as: coarse sand (2.0–0.2 mm), fine sand (0.2–0.02 mm), silt (0.02–0.002 mm) and clay (< 0.002 mm) Hassink *et al.*, (1993).

3.5.2.1 Procedure

50 g of air-dried fine-textured soil was weighed into a 250 ml beaker. The beaker was filled with 100 ml of distilled water and 20 ml of 30 percent of H2O2 was added to help destroy soil organic matter and thus free the individual soil classes. 50 ml of 5 percent sodium hexametaphosphate solution has been added (Gee and Or, 2002; Bashour and Sayegh, 2007; Mohan and Prasadini).

The beaker was placed on the stirrer and stirred until the soil aggregates were broken down. It was then placed on a hot plate and heated until the first sign of boiling was observed (Day, 1965; Bowan and Hutka, 2002). The contents of the beaker were washed in a shaking cup and then shake vigorously for 5 minutes. The sample was sieved through a sieve mesh of 50 microns in a cylinder of 1000 ml (Day, 1965; Haluschak, 2006; Wilke, 2005). This method separated the portion of sand while the silt and the clay went through the sieve into the cylinder. The portion of sand was dried and further separated by a graded sieve of varying sizes into rough, medium and fine sand. They were weighed and their weights were taken away.

The 1000 ml cylinder containing the dispersed sample was placed on a lower vibration bench and then filled to the mark. It was covered with a glass watch and allowed to stand overnight. The hydrometer method was used to determine the contents of silt and clay. The cylinder with its contents was agitated to the particles to be in suspension, then placed on the beach and the readings of the hydrometer were taken at 20, 40 seconds and 2 hour intervals. The temperature was also taken at each hydrometer reading. After using the percentage of sand, silt and clay calculated on the data sheet, the textural triangle was then used to determine the soil texture class.

3.5.3 Bulk Density

Procedure

Cylindrical metal samplers (core samplers) of volume of 98.13 cm^3 were used to sample soil from the field for bulk density analysis (Black, 1965; Klute, 1987; Singh and Hadda, 2018). The sampler is driven into the soil using a hammer and it is done carefully so that the soil is not disturbed and compressed. The sampler and its content are removed carefully and dried in oven at 105 ^oC for 24 hours. After drying, the dry weight of the sampler and its content is taken. The empty weight of the sampler is also taken and the bulk density is calculated from equation.

Bulk density (Pb) $= \frac{mass\ of\ dry\ soil\ and\ core\ sample - mass\ of\ empty\ sample}{volume\ of\ core\ sampler}$ (gcm^{-3}) Equation 2

3.5.4 Porosity

The total porosity was calculated from equation 2

$f = 1 - \frac{Pb}{Ps}$ ………………………………………………… Equation 3

Where; f – total porosity

Pb – bulk density

Ps – particle density (which is usually 2.65 gcm^{-3}) (Sugimae, 1984; Rocha-Santos and Duarte, 2015).

3.6 Determination of soil chemical properties

Samples were taken from the field to analyze for the relevant chemical properties (pH, O.C, N, P, K before the addition of fertilizer and compost (Meena *et al.,* 2019 and Alburquerque *et al.*, 2012).

3.6.1 pH

The soil pH is the negative logarithm of the active hydrogen ion (H^+) concentration in the soil solution. It is the measure of soil sodicity, acidity or neutrality. The pH meter was calibrated using two buffer solutions, pH (4.0 and 7.0). The electrode was alternately inserted into the beakers containing the two buffer solutions, and the pH was adjusted. The instrument indicated pH as per the buffers read, which shows it is ready to test the samples. 10.0 g of soil sample was weighed and placed into a 100 ml beaker, add 25 ml of distilled water was added, where water was used as a suspension medium. The soil was allowed to absorb the water without stirring at first, and then stirred thoroughly for 2 minutes using a glass rod. The suspension was stirred for 30 minutes.

The pH values were recorded by immersing the electrode of the calibrated pH meter into the suspended solution Coleman and Mehlich, (1957) and Lofts *et al.,* (2004).

3.6.2 Organic Carbon and Organic Matter

The Walkley – Black method was used, as described by Nelson and Sommers (1982). 2.0 g of air-dried soil sample was weighed and transferred to 500 ml of Erlenmeyer flask. 10 ml of dichromate solution was added using a pipette, followed by 20 ml of H2SO4 concentration. The flask was gently swirled to ensure that the solution came into contact with the soil particles. Once again, the contents of the flask were swirled vigorously and allowed to stand on the asbestos for 30 minutes. 200 ml of distilled water was added. Finally, 2.0 ml (of 10 ml) of diphenylamine of indicators were added in that order and titrated with one 10 ml ferrous sulphate solution until the colour changed to blue then to green at the end. The organic carbon was obtained from the relation:

% Organic C in soil =

$(m.e.K2CrO7 - m.e.FeSO4\ )\ X\ 0.003\ X\ 100\ X\ f)/(wt.of\ \ soil)\ldots$ eqn.4

m.e. = Normality of solution x ml of solution used

Correction factor (f) = 1.33, note: the factor 1.33 is a compensation factor for the incomplete combustion of the organic matter in this is procedure. Conversion of % organic carbon to % organic matter was done by multiplication with the empirical factor 2. Therefore, % organic matter = 2 x % organic carbon.

3.6.3 Total Nitrogen

The total nitrogen, as described by Bremner, 1965, was determined by the Kjeldahl digestion and distillation procedure. Approximately 0.2g of soil was weighed into the digestion flask of Kjeldahl and added 5ml of distilled water. A tablet of selenium and 5ml of concentrated H2SO4 were added to the soil after 30 minutes and the flask was placed on the Kjeldahl digestion apparatus and heated for at least 3 hours, initially gently and then vigorously. After obtaining a clear mixture, the flask was removed and then transferred to a 100 ml distillation tube. The solution was also added to 20ml of 40 percent NaOH and then distilled using the Tecator Kjeltec distiller.

The digested material was distilled and transferred to a flask containing 20% boric acid (H3BO3) of approximately 75 ml of distillate. After distillation, the colour change was from pink to green, after which the flask content was titrated from a desktop with 0.02M HCl. The volume of 0.02M HCl used was recorded at the end point, when the solution changed from weak green to pink, and percent N was calculated. To take care of traces of nitrogen in the reagents as well as the water used, a blank distillation and titration was conducted.

Calculation: the percentage nitrogen in the sample was expressed as:

14 g of N contained in one equivalent weight of NH_3

Therefore; weight of N in soil = $\frac{14x(A-B)xNx100}{1000}$ ………………equation5

Where:

A is the volume of standard HCl used in the sample titration.

B is the volume of the standard HCl solution used in the blank titration.

N is the normality of standard HCL

14 is atomic weight of nitrogen

3.6.4 Determination of Available Phosphorus – P

The readily acid-soluble forms of phosphorus were extracted with HCl: a mixture of NH4F called Bray's No.1 extract as described by Bray and Kurtz (1945) and Olsen and Sommers (1982). Phosphorus in the extract was determined on a blue ammonium molybdate spectrophotometer using ascorbic acid as a reducing agent. Approximately 5g of soil was weighed into a 100ml extraction bottle and 35ml of Bray's No.1 extracting solution (0.03M NH4F in

0.02M HCl) was added. The bottle was placed in a reciprocating shaker and shaken for 10 minutes, after which the contents were 38 filtered through Whatman No.42 filter paper.

The resulting clear solution was collected in a 100 ml volumetric flask. An aliquot of about 5ml of clear supernatant solution was pipetted into a 25ml test tube and 10ml coloring reagent (ammonium paramolbdate) was added as well as a pinch of ascorbic acid and then mixed very well. The mixture was allowed to stand for a maximum of 15 minutes to develop a blue colour. The color was photometrically measured using a spectronic 21D spectrophotometer with a wavelength of 660nm. The available phosphorus was extrapolated from the reading of the absorbance.

The standard 0, 1.2, 2.4, 3.6, 4.8 and 6 mg P/l series were prepared from a stock solution of 12 mg/l by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/l in a 100 ml volumetric flask with distilled water. Aliquots of 0, 1, 2, 4, 5 and 6 ml of mg P/l of the standard solution were placed in 100 ml volumetric flasks and 100 ml of distilled water were added to the mark. Available phosphorus was determined by comparing the results with a standard curve, that's

P (ppm) = (a-b) x 2 …………………………eqn 6

a = ppm P in soil extract

b= ppm P in blank

3.6.5 Determination of Available Potassium – K

Potassium determination was performed by atomic absorption spectrometry (Thomas, 1982). 5g of soil sample was weighed to 50ml of 1N and ammonium acetate solution was added and shaken for 5 minutes. The solution was filtered and the filtrate was put into a 50 ml volumetric flask. The distilled water was then used to make the mark and mixed thoroughly with the inversion. The extract was then used to determine K. The photometer was used to obtain an extract reading. Finally, the reading of the meter and the standard curve were used to determine the actual concentration of available K in the soil.

3.6.6 Determination of Available Nitrogen – N

Nitrogen was determined using the Kjeldahl method described by the soil science society of Ghana. Nitrogen was measured according to the micro Kjeldahl method as described by Bremmer and Mulvaney (1982). Sieved soil of ten (10g) was measured into 300ml long-necked Kjeldahl flask, 10ml distilled water was added and let to stand for 10 minutes, catalyst made of 1 selenium tablet +2Na_2SO_4 + $CuSO_4$ tablets were added and followed by concentrated H_2SO_4.

The total solution was digested until a clear solution was produced after approximately 1:30 minutes. It was further diluted in 30-45 minutes. The bottle was then allowed to cool down. The contents were further diluted with about 100ml of distilled water and the solution was filtered into a 100ml volumetric flask.

Later, the soil was washed with 120 ml of distilled water. Using pipette, an aliquot of 10ml of filtrate was added to the Kjeldahl apparatus and 15ml of NaOH was added to the appropriate aliquot and distilled in a 500ml conical flask by steam for about 10 minutes into 10ml of Boric acid. 8 drops of the mixed indicator have been added. The solution was then titrated at 0.1NHCl.

The rate of application of compost to soil varies greatly, but generally ranges from 25-100 t/ha, although higher application rates are not unusual (Johston *et al.*, 2009; Marlander *et al.*, 2003). These rates provide for the optimum nitrogen requirements of growing crops without causing adverse environmental impacts (Tester, 1990; Ehrig and Stahr, 1989).

There was a change of color to gray and it flashed to pink. A blank determination was also made without soil. Total nitrogen was determined using the relationship:

Soil nitrogen weight = 14x (A-B) x N/1000.................. Eqn 7

Where to:

A is the volume of the standard acid used in the titration of the sample.

B is the volume of the standard acid used in the empty titration.

N is the normality of the normal acid (Bremer, 1983).

3.7 Field experimentation, agronomic practices and data collection

3.7.1 Land Preparation

The land was cleared of weeds and debris manually using cutlass and hoe. Shovel and rake were used for land preparation and gathering the weeds on the field. A wheel burrow was used for conveying the weeds from the field. The hoes were also used for turning the soil.

Plate 5: Land preparation

(Source: Field work at UDS experimental site, 2019)

3.7.2 Design and Plot Layout

The layout of the field was done using lines and pegs. A 60 m x 18 m (1080 m^2) plot was demarcated on the field. Four blocks/replications were demarcated with plot size of 1.2x5m. The experiment was designed as a 2x4 factorial experiment in a Randomized Complete Block Design (RCBD). The plot size was 1.2x5 (6 m^2) with 1m border between plots and 2m between replications or blocks. The treatments were in the order of:

Organic compost at four levels.

+ 0 kg organic compost per trial unit (equal to 0 t / ha)

+ 10 kg organic compost per trial unit (equal to 17 t / ha)

+ 20 kg organic compost per trial unit (equal to 34 t / ha)

+ 30 kg organic compost per trial unit (equal to 51 t / ha)

N P K (15-15-15) fertilizer levels

+ 0 g N P K fertilizer per plot (equal to 0 kg/ha)

+ 0.04 kg N P K fertilizer per plot (equal to 67 kg/ha)

+ 0.08 kg N P K fertilizer per plot (equal to 133 k/ha)

+ 0.12 kg N P K fertilizer per plot (equal to 200 kg/ha)

3.7.3 Application of Soil Amendments

The rate of application of compost to soil varies greatly, but generally ranges from 25-100 t/ha, although higher application rates are not unusual (Johston *et al.,* 2009; Marlander *et al.,* 2003). These rates provide for the optimum nitrogen requirements of growing crops without causing adverse environmental impacts (Tester, 1990; Ehrig and Stahr, 1989).

Compost fertilizer was applied at three different rates (18, 34 & 50) t/ha and 0 t/ha as a control. Calculations were based on the nitrogen present in the compost material produce for the research. This was done by spreading both of the amendment on their respective field before planting was done.

Plate 6: Compost application

(Source: Field work at UDS experimental site, 2019).

3.7.4 Planting Material and Weed Control

Amaranthus cruentus L., seeds were obtained from the Council for Scientific and Industrial Research – Savanna Agriculture Research Institute (CSIR-SARI). Amaranthus needs 4-8 weeks to attain maturity, depending on the purpose of cultivation. The expected yield ranges from 30-40 t/ha depending on the geographical location, agronomic practices and fertility of the soil.

The soil amendment Organic (compost) at a rate of (18, 34 and 50) t/ha and Inorganic (NPK) fertilizer was applied at (10, 20 & 30) kg/ha. According to (Tester, 1990; Ehrig and Stahr, 1989), for optimum nitrogen needs and crop growth, rate can be between 25-100 t/ha.

Olufolaji, 1996; Babajide and Olayiwola, (2014) found that well cured poultry manure or compost at 20 t/ha was adequate for high leaf yield in *A. cruentus* in the tropics and subtropics.

After applying the compost to the field, direct seeding of *Amaranthus cruentus L.* (Alefu) was done using a dibbling stick for creating planting holes.

A week after planting, thinning out was done, leaving two plants per hill. Weed control was also carried during the cultivation phase at 2, 3, 4, 5, and 6 weeks after planting, once a week, until harvesting in the 7th week. Weeding was done manually with hoe or by pulling out the weeds.

3.7.6 Data on Vegetative Growth

Data collected on the plant performance at 3 and 6th weeks after planting were as follows: plant height, number of leaves, leaf area (cm^2), and canopy spread (cm), fresh biomass weight (kg), dry matter weight (kg), residual fresh biomass weight (kg), residual dry matter weight (kg)..

Plate 7: Data collection **Plate 8: Data collection**

(Source: Field work; 2019)

Procedure

- Five plants were randomly selected and tagged for data collection.
- Plant height was recorded at 3 and 6 weeks after planting using a graduated ruler in measuring the five plants and recorded.
- Number of leaves; this was done by counting the number of leaves at 3 and 6 weeks after planting of the five tagged plants and the mean recorded.
- Leaf area index; leaf area = L x W x A ………………………eq 9

Where; L – leaf length

W – leaf width

A – constant (0.75) (Montgomery, 1911; Dwyer and Stewart, 1986).

- Canopy spread = L x B, (cm^2) this was done by measuring the length and breadth of the entire plant.
- Fresh weight; this was done by cutting the five tagged plants and weighing.
- Dry matter weight; the five tagged plants cut were put in an oven at temperature of 60 ^{0}C for 72 hours, after which they were removed and weighed.
- Residual fresh weight, the residual yield which sprouted six weeks after the yield was harvested and weighed.
- Residual dry matter weight, the residual harvested yield was oven dry for 72 hours at temperature of 60 ^{0}C.

3.8 Data analysis

Data was analysed with analysis of variance (ANOVA) using GENSTAT (12.0). Differences in means were compared using Least Significant Difference (LSD) at P<0.05 with Duncan range test.

CHAPTER FOUR

4.0 Results

4.1 Waste Sites, Materials and Quantities

4.1.1 Material Available for Compost Production

The waste at various sites identified in the Table 4.1a below was divided into categories. The available waste was classified as easily biodegradable, not easily degradable and not degradable by composting.

Table: 4.1a: Categories of Ease of Decomposition1

Component	Weight (tons)	Percentage (%)
Easily biodegradable	3201.26	60
Not easily biodegradable	106.71	2
Not degradable	2027.47	38
Total	5335.44	100.00

(Source: field work; 2019)

In addition, Zoomlion Ghana Tamale (major waste collecting company) and TaMA also revealed that approximately 810 tons of waste are generated daily in the Metropolis and only 216 tons are transported to the landfill site, with a backlog of 594 tons uncollected (Zoomlion, 2015). Increased commercial and light industrial activities in the residential areas have also resulted in an increase in plastics, metals and organic waste in commercial centres within TaMA.

The survey further showed that the sorted municipal waste from Tamale comprises approximately of 59% easily biodegradable materials and can therefore be composted using the windrow method. However, the non-degradable waste amounted to 41%. Such waste, including metals, glass and plastics of different density, is stored either in the landfill or in the waste containers for recycling or re-use.

Table: 4.1b: Categories of Ease of Decomposition2

Component	Weight (tons)	Percentage (%)
Easily biodegradable	4046.8	59.25
Not easily biodegradable	36.2	0.52
Not degradable	2747.9	40.23
Total	6830.9	100.00

(Source: TaMA and Zoomlion; 2015)

Table: 4.1c: Waste sites, materials and quantities in Tamale

Waste site	Type of material available	Quantity (tonnes)/per Annum
Tiyumtaba Women Shea Butter Processing Site	Shea slurry	506.35
Gob Danda Shea Butter Processing Site	Shea slurry	344.5
Yumzaa SheaButter Processing Site	Shea slurry	333.95
Kpane Shea Butter extraction	Shea slurry	363.97
SEKAF Shea Butter processing centre	Shea slurry	434.22
Aboabo market	Municipal waste	619.75
Central market	Municipal waste	474.7
Kaladan Public Toilet	Faecal waste	450
Old Cinema Public Toilet	Faecal waste	490
Zongo Public Toilet	Faecal waste	515
Jisonaayili Rice fields	Rice straw/husk	200
Sagnarigu Rice fields	Rice straw/husk	175
SARI-UDS Rice Research Fields	Rice straw/husk	235
UDS Research field	Groundnut/Soybean vine/husk	150
Kasalgu rice fields	Rice straw/husk	210
Zagyuri fields	Maize/Groundnut/cowpea	220
Kpane rice fields	Rice straw/husk	223

(Source: field survey, 2018/2019)

4.2 Physio-Chemical Properties of the Soil and Compost

The results of the physical and chemical properties of the soil and compost revealed that the compost was rich in both macro and micro nutrients. The total N (5.75%), available P (24300 mg/kg), K (56000 mg/kg), O.C (63.68%), in the compost were higher than those in the in the soil and ideal for the production of Amaranth. The mineral constituents N (0.1%), available P (6.11 mg/kg), K (62 mg/kg), O.C (1.17%) in the soil were below the critical limit for growing *Amaranthus Cruentus* and this may be due to low soil organic matter.

Table 4.2a: Properties of the soil used during the study

Soil Properties	Values
pH	5.89 ± 0.577
% O.C	1.17 ± 0.092
%N	0.1 ± 0.01
P (mg kg^{-1})	6.11 ± 0.551
K (mg kg^{-1})	62 ± 2.309
Ca (Cmol kg^{-1})	1.72 ± 0.167
Mg (Cmol kg^{-1})	0.60 ± 0.173
Particle size distribution	
% Sand	61.2 ± 1.674
% Clay	8.2 ± 0.635
% Silt	29.5 ± 3.179
Textural class	Sandy loam

(Source: Field studies, 2019)

Table 4.2b: Nutrient composition of the compost used for the study

Nutrients	Composition
pH	7.53 ± 0.02
% O.C	63.68 ± 1.99
% N	5.75 ± 1.01
P (mg kg^{-1})	24300 ± 3000
K (mg kg^{-1})	56000 ± 5000
Ca (Cmol kg^{-1})	2.84 ± 0.61
Mg (Cmol kg^{-1})	1.08 ± 0.05

(Source: Field studies, 2019)

4.3 The composition of the chemical fertilizer used for the study

The chemical fertilizer used for the studies was NPK 15: 15: 15 + TE compound fertilizer or complex fertilizer which contained nitrogen (N) 15%, phosphorus (P_2O_5) 15% and potassium (K_2O) 15% of macro elements. It was observed that, the compound fertilizer contains in itself some micro nutrients which are manganese (Mn), zinc (Zn), iron (Fe), molybdenum (Mo), copper (Cu), magnesium (Mg), boron (B), sulphur (S) and calcium (Ca).

The NPK 15: 15: 15 + TE granular complex fertilizers can be used on all types of soil under all crops. It is used as the basic fertilizer to feed the plants and it is an important fertilizer for plant growth in the early stages.

Table 4.3: The nutrient status of the soil before and after planting

Parameters	Before planting	After planting (Compost)	After planting (NPK-15-15-15)
pH	5.89	6.65	5.75
% O.C	1.17	4.582	0.195
% N	0.1	1.729	0.017
mg/kg P	6.11	10.12	7.95
mg/kg K	62	78	69
Cmol+/kg Ca	1.72	1.87	1.12
Cmol+/kg mg	0.62	0.97	0.62
Sand %	61.4	60	61.2
Silt %	29.5	29	29.7
Clay %	9.1	11	9.1
Mean	17.761	20.3921	18.4652

(Source: Field studies, 2019)

Both treatments that's, compost and NPK fertilizer improved the nutrient status of the soil compared to pre-trial analysis of the soil. Higher values however, were observed from plots treated with compost, compared with plots treated with NPK fertilizer.

4.1 Growth and yield parameters of *Amarathus cruentus*

4.1.1 Height

Height of Amaranthus was influenced by the various rates of the types of soil amendments applied (Figures 1 & 2). Plots treated with 30kg NPK fertilizer produced the tallest plant at WAP (39.9 cm) respectively, while shortest plants (6.49 and 25.32) were observed in plots treated as control 0kg NKP. Although there was no significant difference in the response of the crop to different types of amendments with respect to height but there was significant difference among treatment with (P<.001) both at 3 and 6 WAP (Figures 1 and 2)

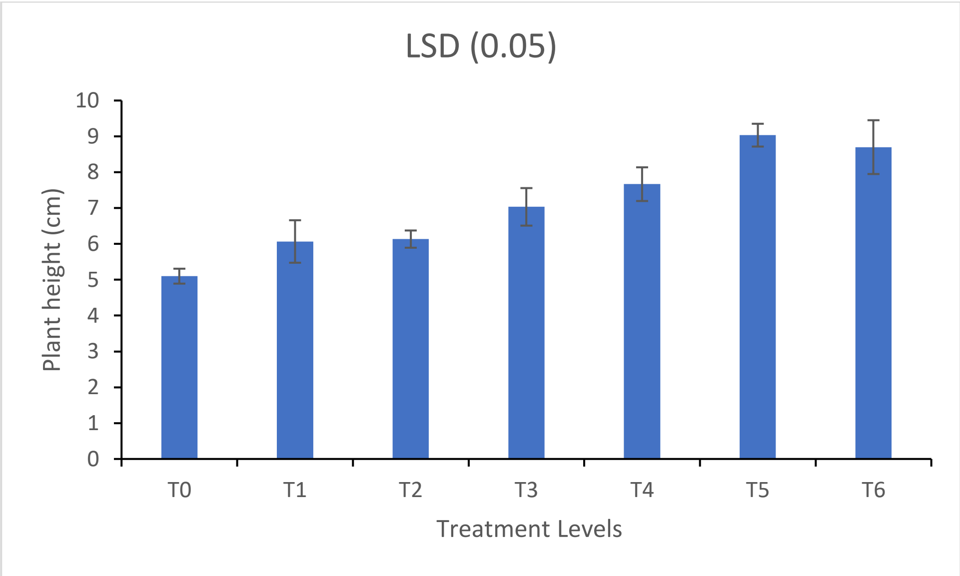

Figure 1: The effect of different soil amendments on plant height 3 weeks after planting (WAP)

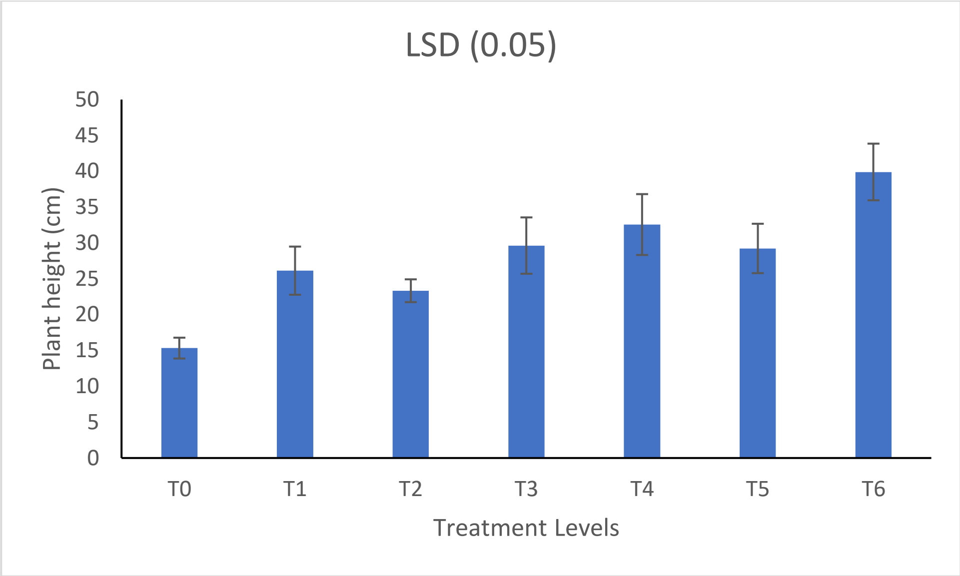

Figure 2: Influence of different rates of soil amendment on plant height 6 weeks after planting.

4.2 Number of leaves

Number of leaves produced by *A. cruentus* improved with various soil amendments, as shown in Figures 3 and 4 at 3 and 6 WAP. The results showed that there was significant (P<.001) difference in number of leaves of Amaranthus grown on nutrient poor soil treated with different soil amendments at various rate. Plot treated with compost had highest number of leaves at 6 WAP (55.7).

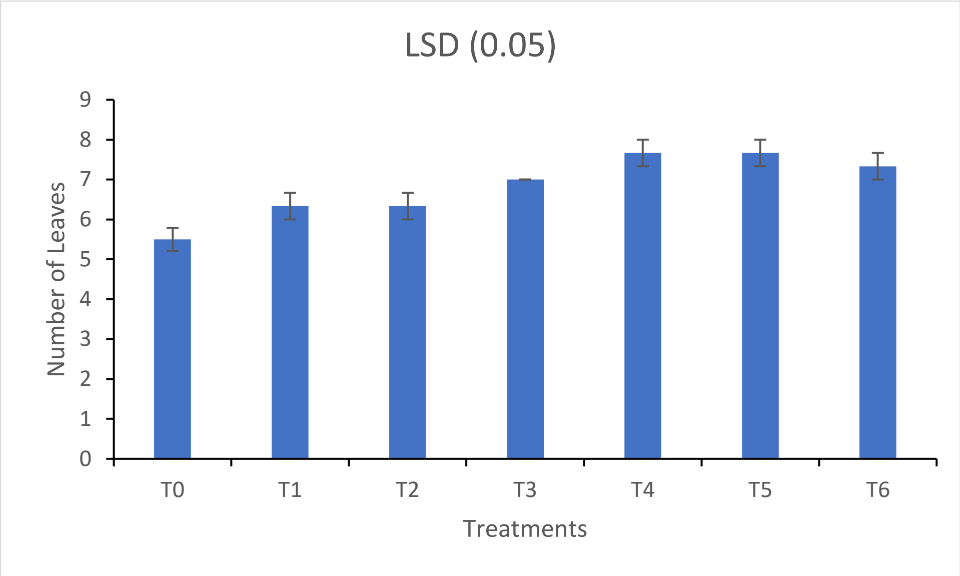

Figure 3: Influence of different rates of soil amendments on number of leaves 3 weeks after planting

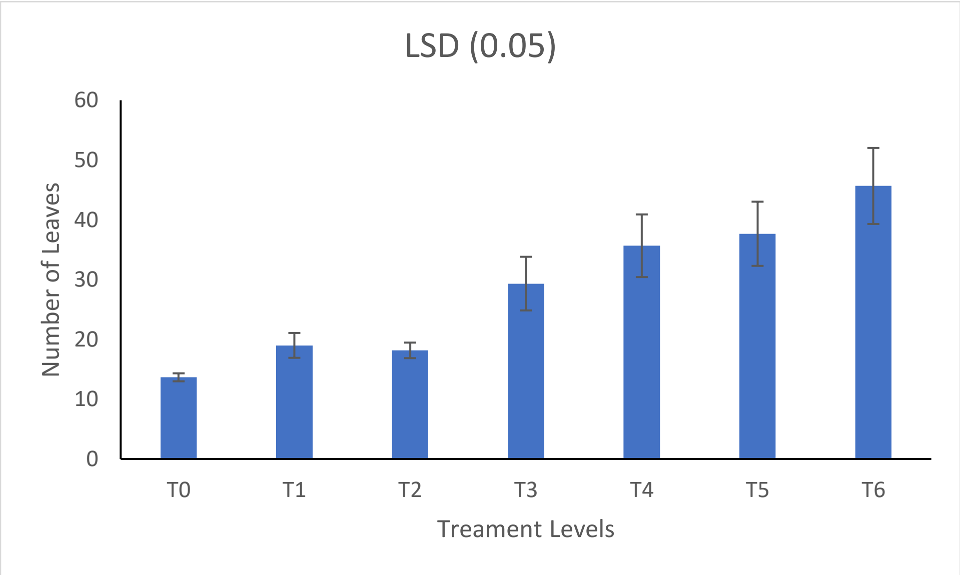

Figure 4: Influence of different rates of soil amendment on number of leaves 6 weeks after planting

4.3 Leaf area (cm^2)

Leaf area was significantly influenced by the various treatment rates of the soil amendments (P<.001) but there was no significant difference among the two amendments on the leaf area of Amaranthus.

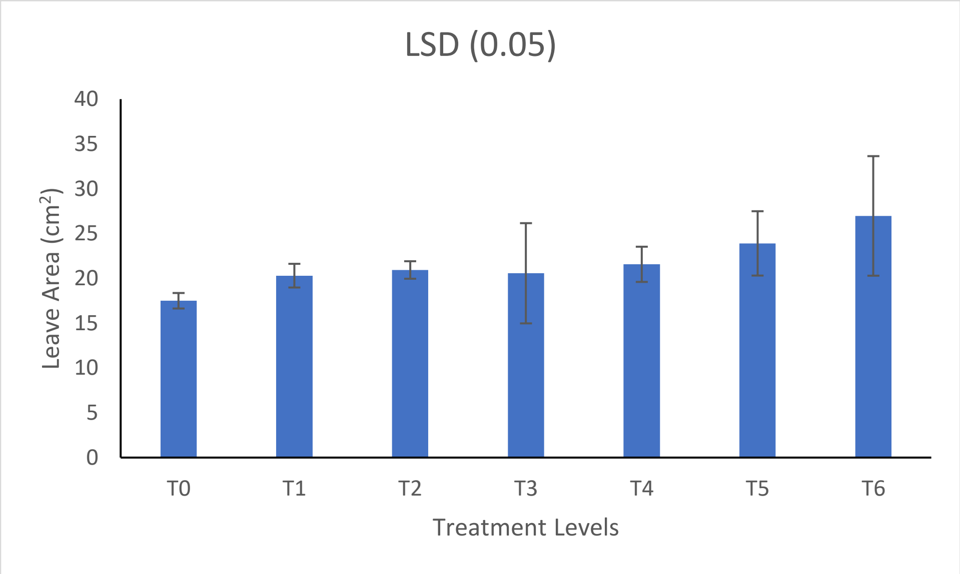

Figure 5: Influence of different rates of soil amendment on leaf area (cm^2) 3 weeks after planting

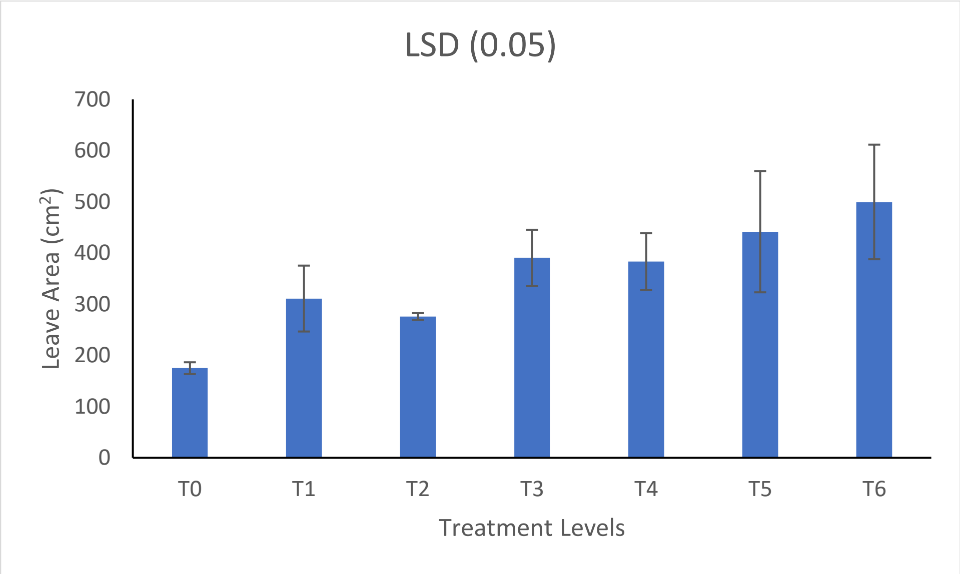

Figure 6: Influence of different rates of soil amendment on leaf area (cm^2) 6 weeks after planting

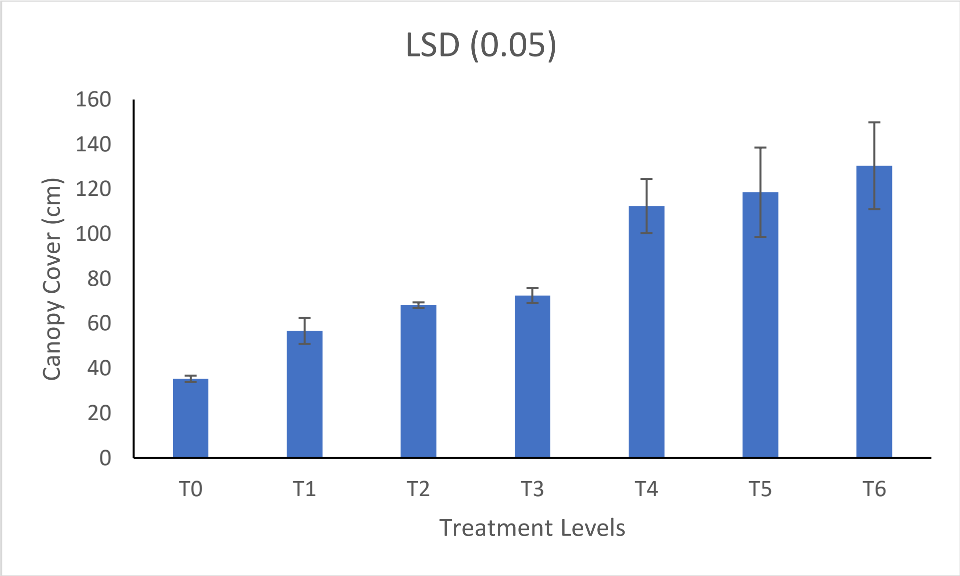

Figure 7: Influence of different rates of soil amendment on canopy cover (cm) 3 weeks after planting

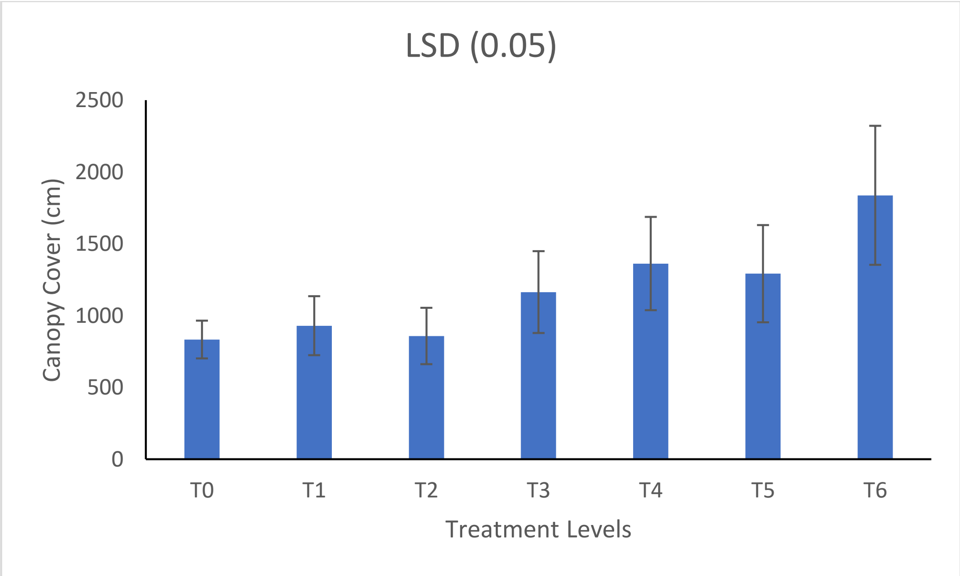

Figure 8: Influence of different rates of soil amendment on canopy cover (cm) 6 weeks after planting.

4.4 Biomass yield

The treatment effects of both the NPK and compost on biomass yield (fresh weight) of the plants were significant. The 20 and 30 kg treatment produced significantly higher fresh weight (biomass) than the control. Also, the 20 and 30 kg compost treatments produced significantly higher fresh weight (biomass) than control (1.295 kg) (Figure 10). However, comparing the effect of NPK and compost, compost was significant at (P<.001).

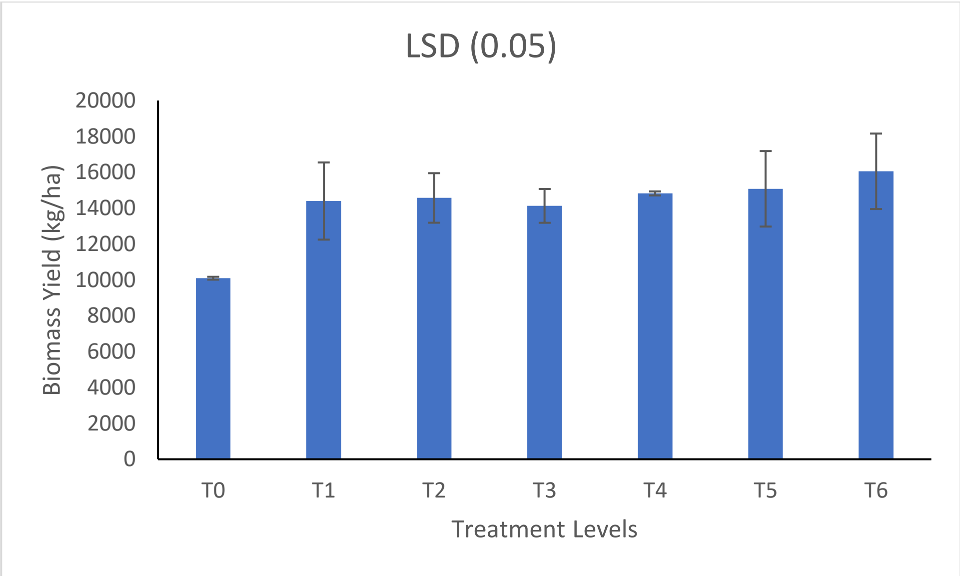

Figure 9: Influence of different rates of soil amendments on biomass yield 7 weeks after planting

4.5 Dry matter

The compost produced significantly much higher dry matter in all treatments then NPK (P<.001).

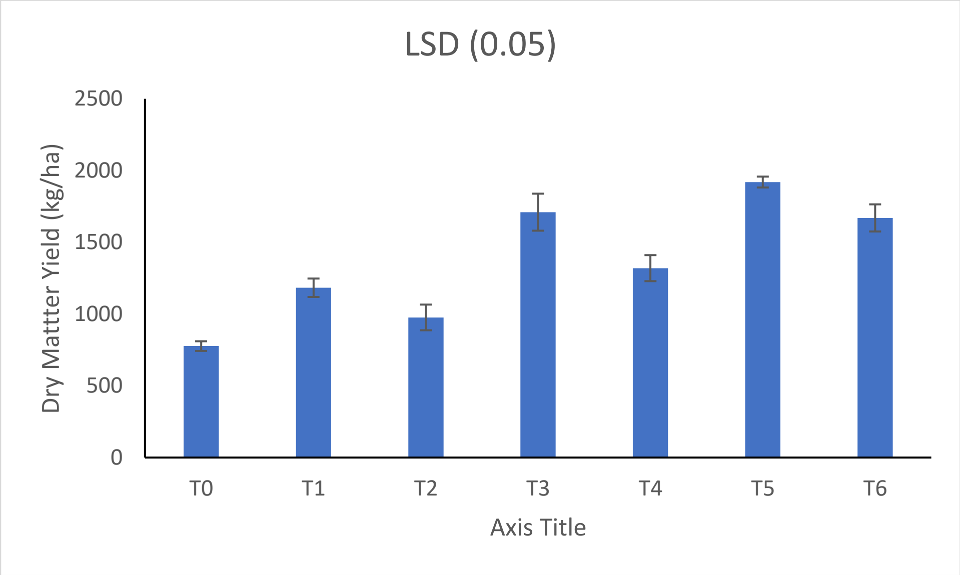

Figure 10: Influence of different rates of soil amendment on dry matter content 7 weeks after planting

4.6 Residual fresh biomass weight

There were highly significant differences observed at the residual harvest of the treatments. Higher values were recorded in plots with the compost treatments, which means that organic manure has longer effect on the soil fertility and therefore influence on the yield of amaranthus, as compared with the yield on the plots treated with the NPK fertilizer. 30 kg/ha compost produced 3.119 kg/ha as against 30 kg/ha NPK which produced 2.719kg/ha.

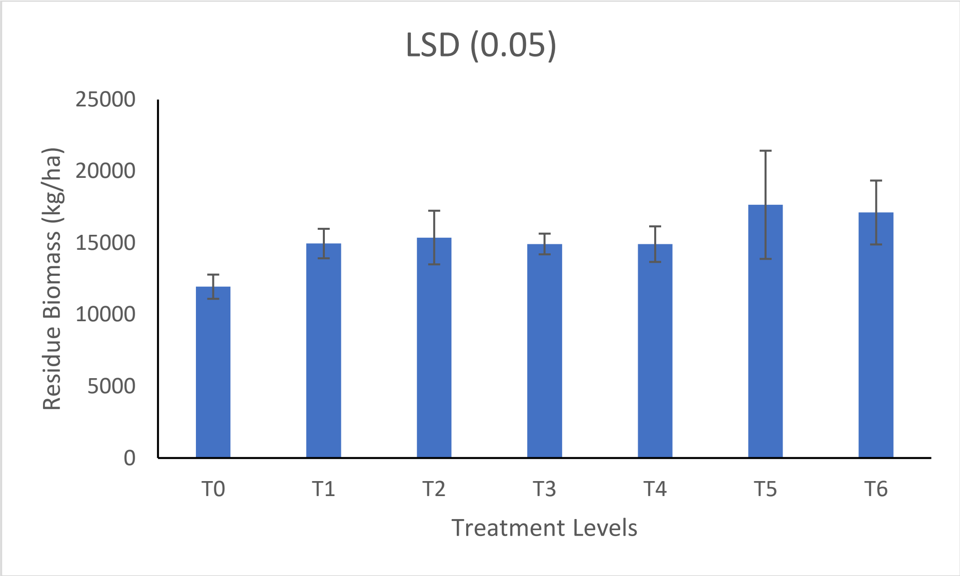

Figure 11: Influence of different rates of soil amendment on residual biomass yield after the 1st harvesting

4.7 Residual dry matter weight

Significant differences were observed among all the treatment levels. There were still available nutrients in the soil after the first harvest which was seen both in the residual fresh biomass and the dry matter.

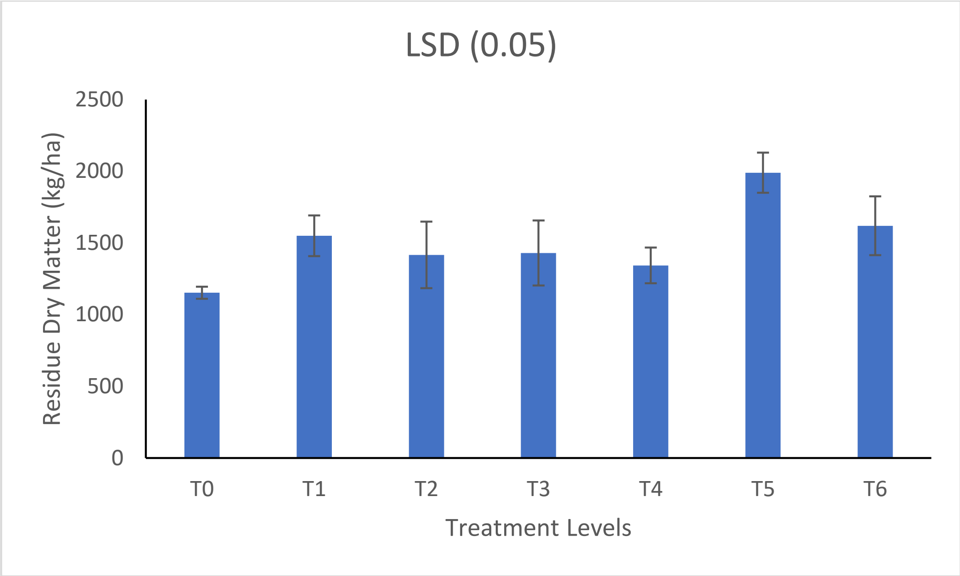

Figure 12: Influence of different soil amendments on residual dry matter yield after the 2nd harvesting

LEGENDARY:

T = Treatment

T0 = Control

T1 = 17 t/ha (10kg/plot) - Compost

T2 = 67 kg/ha (0.04kg/plot) NPK

T3 = 34 t/ha (20kg/plot) Compost

T4 = 133kg/ha (0.08kg/ha) NPK

T5 = 51 t/ha (30kg/plot) Compost

T6 = 200 kg/ha (0.12kg/plot) NPK

CHAPTER FIVE

5.0 Discussion

5.1 Availability of biodegradable materials in Tamale Metropolitan assembly

The study examined the potential of Tamale Metro and its sub-metro to produce high-volume compost manufacturing materials to help improve the fertility of the soils in the study area. Production and profitability will be significantly improved by this. Converting all the waste at this different site to compost will assist in the city's waste management situation and also help reduce the amount of waste that is carried to the site of the landfill, thereby reducing the pressure on the landfill to help expand its life span. High volume organic materials from rice straw, rice husk, shea butter slurry, faecal sludge and degradable municipal waste were identified in over fifteen locations.

5.2 Soil chemical properties

NPK fertilizer treatments reduced soil pH significantly from 5.89 to 5.75, while organic compost treatments increased soil pH significantly from 5.89 to 6.65. Following organic compost treatment, the soil organic content was increased by 4.58 percent. After organic composting treatment, soil nitrogen was also increased from (0.10-1.73) %. In both treatments, phosphorus was increased to about 60% in the soil.

Similar to the phosphorus available, both treatments showed a significant increase in concentrations, but it was more apparent in the treatment of organic compost. After NPK fertilizer treatment, exchangeable calcium was reduced and no changes were observed in the magnesium concentration. The concentration of both calcium and magnesium in the soil was significantly increased by compost treatment.

The results of the study agreed with the finding of several studies showing that organic treatments increase soil pH, while chemical fertilizer treatments, such as NPK fertilizers, decrease soil pH. (Whalen *et al.*, 2000; Liu *et al.*, 2010; Han *et al.*, 2016).

The decrease in soil pH due to NPK fertilizer may be due to the leaching from the soil of basic cations such as potassium, calcium and magnesium due to the absence of binding agents present when the soil is treated with organic fertilizers, such as compost. In general, organic compost (manure) with livestock by-products increases the pH of the soil, but the effects may vary depending on the organic matter composition, treatment rates and soil properties.

The NPK fertilizer treatment acidified the soil, similar to the results found in other studies (Usman *et al.*, 2012; Diacono and Montemrro, 2011). Using NPK fertilizer for longer periods will ultimately lead to inadequacies in other vital nutrients that may impair the soil's physical, chemical, and biological properties.

5.3 Organic matter content

High organic matter composition in organic compost has a positive effect on the increase in soil nitrogen, phosphorus, potassium and major cations. Because of the slow decomposition of organic compost, plants are allowed to use nutrients for a long time and reduce the loss of what is not used by plants (Hunang *et al.*, 2007; Han *et al.*, 2016). In this study, both compost and chemical fertilizer increased the phosphorus content of the soil and the plant was unable to use all the phosphorus content provided by the processing and that resulted in a move of phosphorus in the soil. Similar to the results reported by Song et al., 2017; Li *et al.*, 2011. Major cations, including potassium and nitrogen, and phosphorus and organic carbon have been increased by compost treatment.

5.4 Plant Height (cm)

The results showed that the plant height was higher at 20 and 30 kg/ha NPK rates application, comparing with the 0 and 10 kg/ha. Dlamini *et al.*, 2020 and Mohammed, 2015 recorded that Amaranthus is considered to be a crop with low nutrient management that can grow in poor soils, but yield boosting is as a results of fertilizer application. The application of compost also showed good effects especially with the 20 and 30kg/ha plots. Both soil nutrients and soil structure were affected by the compost amendments positively. Materechera, 2010; Okorogbona and Adebisi 2012 stated that organic or farm manure contains all the nutrients needed for plant growth and therefore it is necessary to use enough manure to meet the requirements of the crop. Babajide and Olujiwola, 2014 and Ama Kaburi, 2015 reported that Amaranthus responds well to organic matter application.

5.5 Number of leaves

The findings showed that the plots with 20 and 30 kg/ha of compost and NPK treatment were the best performing. This could be because the soil was deficient in nitrogen, which may have led to a substantial difference between zero/control fields and modified fields. It may also be that Amaranthus needs more nitrogen for a good yield response and that the rate was appropriate. Haverbeke, 2018 and Magwa-Boboltyani, 2016 clarified that compost manure has all the nutritional requirements for plant growth and that enough of it must be used to fulfil the needs of the crop.

5.6 Fresh biomass and dry matter weight

The mean dry weight of the stems and leaves (biomass) was significantly increased by all the treatment modifications at first harvest and at the residual harvest with the highest values recorded by 30kg compost and 30kg NPK (0.246, 0.242) kg of compost and (0.285, 0.255) kg of NPK, compared to the control. The amount of the fresh biomass and dry matter content for both treatments (compost and NPK) in the control were (1.295 – 0.112 and 1.314 – 0.127) kg respectively, but this was decreased to (1.102 – 0.105, 1.107 – 0.113) at the residual harvest. Mengistu *et al.*, 2017 and Han *et al.*, 2016 found that composting not only provides the plant's essential components and trace elements, but also plant growth regulators and facilitates plant growth.

The results of this study showed that compost, can maintain biomass and dry matter productivity at a similar or higher value compared to NPK fertilizer application and also enhance the quality of the soil. The NPK treatment also significantly influenced biomass and dry matter yield, bit did not enhance the quality of the soil, making it more acidic with potential to impede nutrient uptake by crops in the long run. The nitrogen concentration in the soil was not significantly changed by the NPK treatment, but a significant increase was observed in the available phosphorus.

The outcome of the study suggests that, both soil amendments provided the nutrients accessible in the soil needed by crop for growth and development. The plant biomass was increased by the soil amendments.

CHAPTER SIX

6.0 Conclusions

6.1 Availability of waste for composting

It can be concluded that Tamale Metropolitan area has considerable quantities of municipal waste for the production of compost. This can help address the concerns about sustainable management of waste at the metropolitan level.

Horticulturists such as vegetable, greenhouse and nursery growers, as well as other farmers, are increasingly looking for organic supplements to improve soil fertility. Composting organic waste produced from agricultural and municipal activities can help bridge the gap between waste generators, the agricultural community and the general public.

6.2 Soil properties after application of compost made from waste

The study shows that the composition of the soil was significantly affected by the application of compost. The study confirmed that organic manure from farm by-products and municipal waste did not only promote Amarathus growth but also improved soil properties. Organic manure should therefore be considered in vegetable production systems as a viable alternative to chemical fertilizers.

6.3 Effect of compost on growth and development of Amaranthus

Soil nutrient managing and amendment is vital for maintaining biomass and dry matter production and of the soil quality. The soil pH was increased by compost application which is suitable for the crop, the concentrations of nitrogen, phosphorus, and major cations in the soil, which was essential for the production of *A. cruentus*. Increase of A. Cruentus using compost treatment is comparable to NPK fertilizer treatment and has higher residual yield values.

6.3 Recommendations

This study established that compost originating from municipal waste, shea butter slurry, ash and rice straw/husk not only stimulated the growth of *A. cruentus* but also enriched/amended soil. Hence, compost ought to be considered as a substitute to chemical fertilizers in vegetables or in horticulture production systems. Preceding application of compost produced from waste materials, soil properties, the nutrient requirements of the crop species, and the eco-friendly and hygienic practices in compost production ought to be considered.

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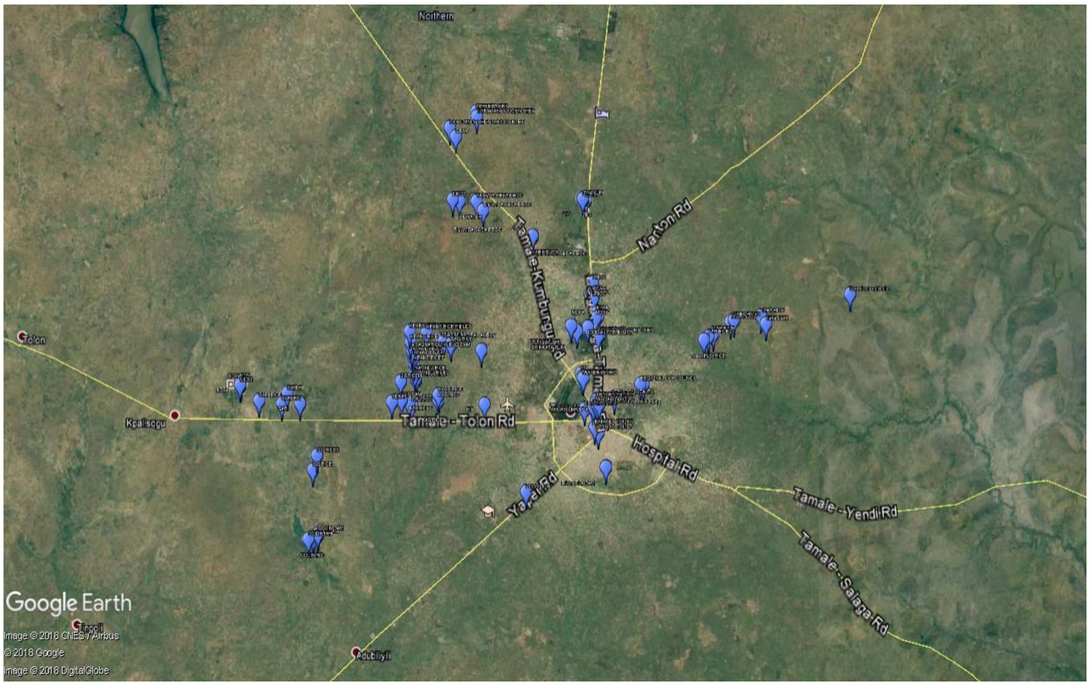
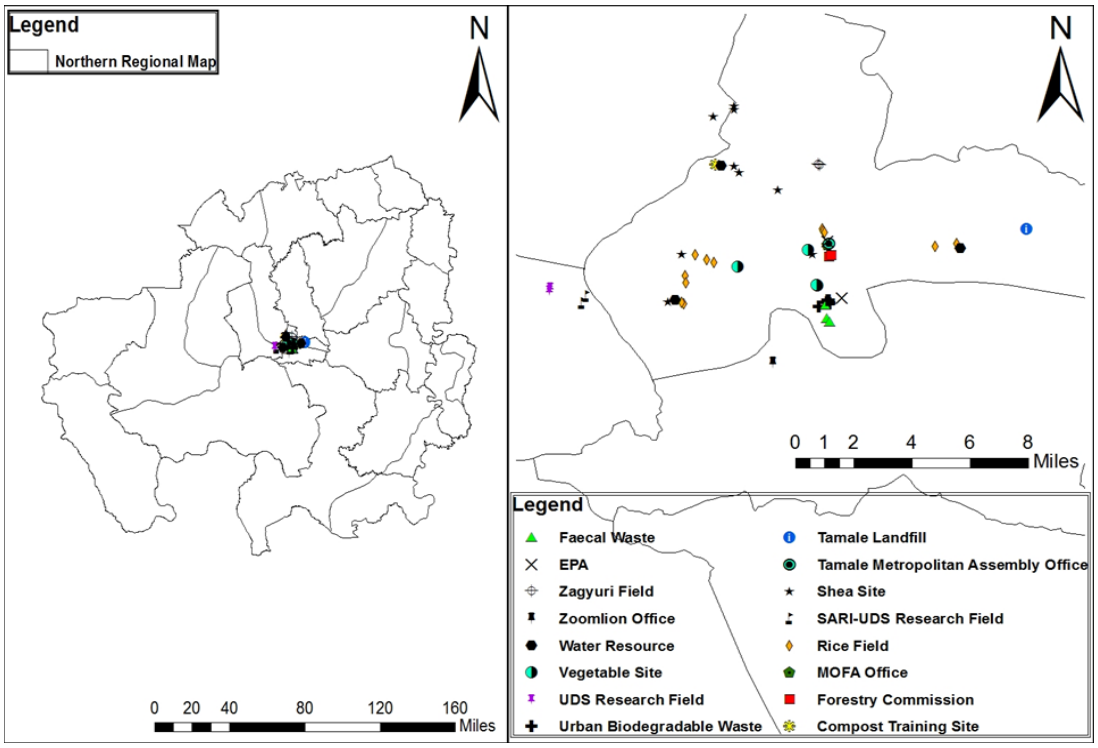
APPENDICES

APPENDIX I: FIELD PHOTOS

APPENDIX II: MAPS REPRESENTING THE VARIOUS POINTS OF ACTIVITIES AND OFFICES OF STAKEHOLDERS





APPENDIX III: COORDINATES OF THE STUDY AREAS

Column1	Column2	Column3
Zoomlion Office/Headquarters	9.373853	-0.870636
Zongo Public Toilet/FS	9.394331	-0.842586
Kaladan Public Toilet/FS	9.396161	-0.843983
Aboabo Market/Urban Biodegradable Waste	9.404257	-0.843726
Aboabo Market/Urban Biodegradable Waste	9.405311	-0.843464
Aboabo Market/Urban Biodegradable Waste	9.405557	-0.842698
Aboabo Market/Urban Biodegradable Waste	9.404106	-0.842244
Aboabo Market/Urban Biodegradable Waste	9.403707	-0.842912
RCC/Regional Minister's Office	9.410872	-0.825111
Environmental Health and Sanitation office	9.406393	-0.83633
Jisonaayili rice fields	9.445876	-0.844722
Jisonaayili rice fields	9.441069	-0.84441
Jisonaayili rice fields	9.441233	-0.844905
Jisonaayili rice fields	9.442118	-0.845058
Jisonaayili rice fields	9.441976	-0.845969
Jisonaayili rice fields	9.441003	-0.845643
Jisonaayili rice fields	9.440136	-0.844766
EPA	9.435391	-0.843387
TAMA	9.434502	-0.842615
MOFA	9.433744	-0.843586
Forestry commission	9.428384	-0.841865

Forestry Commission RES MGT Support centre	9.427584	-0.842615
Sagnarigu rice fields	9.424649	-0.899875
Sagnarigu rice fields	9.426216	-0.903584
Kpane Shea extraction	9.429207	-0.915878
Kpane rice fields	9.425452	-0.915572
Kpane rice fields	9.422492	-0.915057
Kpane rice fields	9.418063	-0.914214
Namadu rice fields	9.414589	-0.913825
kasalgu rice fields	9.412421	-0.91339
Taha Dam	9.431813	-0.777362
Taha rice fields	9.434483	-0.779315
Taha rice fields	9.433151	-0.789785
Taha rice fields	9.432415	-0.791152
Taha rice fields	9.428298	-0.797842
Taha rice fields	9.427311	-0.799765
FUO rice fields	9.426253	-0.801497
Zagyuri expri p1	9.474946	-0.848457
Zagyuri expri p2	9.474985	-0.848585
Zagyuri expri p3	9.474787	-0.84862
Zagyuri expri p4	9.474773	-0.84849
Zagyuri fields	9.474901	-0.848223
Zagyuri fields1	9.47432	-0.847543
Kasalgu rice fields	9.405341	-0.904744

Kasalgu rice fields	9.407303	-0.904734
Kasalgu rice fields	9.403789	-0.914989
Kasalgu rice fields	9.4045	-0.915997
Kasalgu dam	9.405482	-0.919094
SEKAF shea processing centre	9.404841	-0.922765
UDS Research field	9.411856	-0.981441
UDS Research field	9.411973	-0.981465
UDS Research field	9.411898	-0.981761
UDS Research field	9.411768	-0.981734
UDS Research field	9.410717	-0.98185
UDS Research field	9.410717	-0.981735
UDS Research field	9.410539	-0.981729
UDS Research field	9.410567	-0.981856
SARI-UDS Rice Research Fields	9.405328	-0.97448
SARI-UDS Rice Research Fields	9.404221	-0.96561
SARI-UDS Rice Research Fields	9.407795	-0.96357
SARI-UDS Rice Research Fields	9.404307	-0.958535
Golinga Dam	9.359319	-0.951606
Golinga Rice field	9.358675	-0.951709
Golinga Irrigation area	9.357474	-0.95533
Golinga Dam2	9.358292	-0.953472
Golinga rice fields	9.381416	-0.953557
Golinga rice fields	9.386357	-0.951998