ASSESSMENT OF THE POTENTIAL OF SIAM WEED (*Chromolaena odorata*) IN ENHANCING SOIL FERTILITY STATUS IN SERENGETI DISTRICT, TANZANIA

SCHOLA MBALILA

A DISSERTATION SUBMITTED IN A PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (SOIL SCIENCE AND LAND MANAGEMENT) OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2015

EXTENDED ABSTRACT

Siam weed (*Chromolaena odorata*) is a plant that has infested a large area of agricultural land in Serengeti district and has adversely reduced crop land and crop yields. It is encroaching land and especially in the famous Serengeti National Park. The weed has been reported to contain high amount of plant nutrients in its tissue, hence its probable use as an organic soil amendments, with aspect to soil fertility improvement. A study was, therefore, conducted to address the Siam weed growth requirements, nutrient contents in its tissue and its suitability and use as an organic amendments as a way to manage the weed accordingly and appropriately. Soil and Siam weed plant sampling was done in the Serengeti district (Mara Region), an analysis was done in the Soil Science laboratory at SUA, Morogoro. Composite topsoil (0 – 20 cm) samples were collected and analysed for physico-chemical properties hence shows to have slightly acidity with pH (5.8 to 6.5), low to high CEC (11.6 - 29.4 cmol (+) kg^{-1}) and very low to very high soil organic carbon (0.36 - 3.69%). Three soil profiles on a toposequence from the infested soil were excavated, described and sampled for soil laboratory analysis, hence shows medium acidic to medium alkaline (pH 5.84 to 7.93), low to high CEC (10.12 - 35.20 cmol (+) kg^{-1}), low to medium SOC (0.11 - 1.97%) and high exchangeable bases 24.45 cmol (+) kg^{-1} based on the rating by Landon (1991). Using the morphological and laboratory data the soils were classified to the subgroup level of the USDA Soil Taxonomy as Ustic Torripsamments on sloping land, as Haplic plinthustults on midslope and as Plinthaquic paleudalfs on low land and to Tier-2 of WRB as *Rendzic Lithic Leptosols (Eutric, Dystric, Tephric)* on sloping lands, as *Gleyic Plinthic Acrisols* (*Ferric, Humic*) on midslope and as *Haplic Stagnic Gleyic Luvisols* (*Chromic*) on low or flat areas. Incubation study was done by incorporation of different parts of Siam weed plant with soil for 16 weeks. As a result of mineralization after incubation, the leaves released N (0.292%) and Fe (64.15 mg kg^{-1}); bulbs released P (12.39 mg kg^{-1}) and Mg (0.87Cmol (+) kg^{-1}); stems released K

(0.22 cmol (+) kg^{-1}) and Ca (5.13 cmol (+) kg^{-1}) and roots released Cu (6.01 mg kg^{-1}), Mn (77.18 mg kg^{-1}) and Zn (1.65 mg kg^{-1}). Nutrients released were increasing from the 0 to 12th week and started to decrease at week 16 after incubation. Therefore, from incubation results, it is recommended that, farmers should grow their crops before the 12th week following incorporation of Siam weed biomass into soils for plants to absorb nutrients from the Siam weed.

DECLARATION

I, **Schola Mbalila**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for a degree award in any other institution.

_____   _____

Schola Mbalila   Date

MSc. (Candidate)

The above declaration is confirmed by;

_____   _____

Prof. J. J. Msaky.   Date

(Supervisor)

_____   _____

Dr. A. K. Kaaya   Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

Lastly I wish to express my sincere thanks to my beloved parents especially my late mother in law Grace Haule who was taking care of my son and other relatives for their prayers, moral support and encouragement throughout my study period.

DEDICATION

This work is strictly dedicated to my lovely parents; my late mother Yusta Nyikwa and my father Fredrick Mbalila for their role as parents, my husband Chesco Komba and my children Johnson and Jackson for their love, support and patience during my studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AGRA	Alliance for Green Revolution in Africa
ANOVA	Analysis Of Variance
C: N	Carbon to Nitrogen ratio
Ca	Calcium
CAB	Common wealth Agricultural Bureau
CEC	Cation Exchange Capacity
CM	Centimetres
cmol (+) kg^{-1}	Centimol per kilogram
CRD	Completely Randomized Design
Cu	Copper
CV	Coefficient of Variation
DTPA	Diethylene Triamine Pentaacetic Acid
FAO	Food and Agriculture Organisation
Fe	Iron
H_2O_2	Hydrogen Peroxide
HNO_3	Nitric Acid
ISRIC	International Soil Reference and Information Centre
ISS	International Soil Science Society
K	Potassium
mg kg^{-1}	Milligram per kilogram
Mg	Magnesium
Mn	Manganese
N	Nitrogen
Na	Sodium

xv

NO$_3$-N	Nitrate-Nitrogen
^{o}C	Degree Celsius
P	Phosphorus
pH	potential of hydrogen
SMR	Soil Moisture Regime
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
STR	Soil Temperature Regime
SUA	Sokoine University of Agriculture
TEB	Total Exchangeable Base
TN	Total Nitrogen
USDA	United States Department of Agriculture
WRB	World Reference Base
Zn	Zinc

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Characteristics and Importance of the Siam Weed

Siam weed (*Chromolaena odorata* (L) King and Robinson) is a perennial weed that belongs to the family Asteraceae (Abraham and Pradeep, 1995), and is the most notorious perennial scrambling weed that has proven to be a significant economic and ecological burden to many tropical and subtropical-regions of the World (Timbilla and Braimah, 1996). The weed is also known as Triffid weed and is one of the worst invading alien plant species in the humid and semi-humid tropics of the World (Parsons and Cuthbertson, 2001). Characteristically, it is a plant of secondary succession that invades fallows or newly cleared land, and is often shaded out when forest trees and shrubs are fully established (Koutika and Rainey, 2010). Studies conducted by Akobundu (1987) revealed that in areas where Siam weed grows, the growth of other plants is always hampered.

In Africa, the Siam weed was first reported in Ghana and had colonized two third of the total land area of the country (Timbilla and Braimah, 1996). It was originally introduced in Nigeria in the year 1937 and Southern Africa in the 1940s (Wise *et al.,* 2007). Its mode of introduction is uncertain, but it possibly came in as seed in packing material, or as a garden ornamental from Southern Africa (Wise *et al.,* 2007). Siam weed was reported to have been introduced in East Africa: Western Uganda, Western Kenya and North-Western Tanzania in Serengeti District in the year 2007 by wind, (CAB International, 2004). Siam weed is ranked as the fastest-spreading species after aquatic invaders (Wise *et al.,* 2007). The weed can grow on well drained soils. It is affected by water logging and saline soil conditions (Gareeb, 2007). It is commonly found in abandoned or neglected

fields, along forest trails, fence rows and roadsides (Uyi *et al.,* 2008). In waterlogged soils Siam weed becomes very much susceptible to pathogenic fungi (root disease), which include yellow leaves, stem blacken as well as a situation known as die back (Mcfadyen, 2004).

The weed is considered as one of the World's worst tropical weeds due to its quick propagation and establishment hence it invades and out-competes pastures, crops and native vegetation. Siam weed has become a major weed in parts of Asia and Southern Africa (Mcfadyen, 1992). The weed is also a prolific seeder as it produces up to 87 000 seeds per plant within 8-10 weeks (Burton, 2001). The plant is toxic to livestock, and has been reported to kill more than 3000 cattle in every year in the Philippines (Jeff Burton, 2001). Its toxin also causes abortions in cattle and is suspected of being a fish poison in some countries (Parsons and Cuthbertson, 2001). Siam weed plant has been shown to contain nematotoxic compounds such as flavonoids, tannins, alkaloids and saponins (Fatoki and Fawole, 2000). Tourism has suffered too, as unsightly and obstructive thickets of the weed hamper wildlife-viewing, causing some invaded parks and reserves to lose their appeal (Hossain and Zuberi, 2013).

In the 21st Century, *Chromolaena odorata* (Siam weed) has became established together with *Parthenium hysterophorus* as alien invasive species within the World-famous Serengeti–Masai Mara ecosystem of northern Tanzania and South West Kenya as reported by Akter and Zuberi (2009). Also Sheeja (1993) reported that *Chromolaena odorata* produces biochemicals that influence the growth, survival and reproduction of indigenous species. These biochemicals can act as antibiotics in certain soils, possibly impacting on nitrogen cycles (Couto and Betters, 1995). Some use of Siam wee plants as soil amendments have been shown to suppress plant parasitic nematodes in maize

growing areas (Maareg *et al.,* 1998; El-Nagdi *et al.,* 2004). According to Adegbite and Adesiyan (2005), root exudates and extracts of Siam weed plant inhibit nematode egg hatch and cause juvenile mortality of up to 100% when tested in greenhouse studies. Amosu (1981) reported that the root extract of Siam weed is more effective in inhibiting the hatching of *Meloidogyne Incognita* eggs than in causing the death of juveniles after they have hatched. *Chromolaena odorata* in combination with organic fertilizer is a viable option for the control of *Meloidogyne Incognita* on maize (Odeyemi *et al.,* 2009*).* Also, soil amendment with *Chromolaena odorata* and organic fertilizer reduced galling, number of eggs, juvenile population in the soil and reproduction of *Meloidogyn Incognita* (Akhtar and Malmood, 1996). The increase in essential nutrients like nitrogen may be attributed to the increase in soil pH to a level that favourably influences nutrient availability in the soil (Brady and Weil 2005, Osemwota 2010; Iwara *et al.,* 2011). In general, the upward trends of Soil organic matter (SOM), total nitrogen (TN), Cation Exchange Capacity (CEC) and phosphorus in soils under the canopy of *Chromolaena odorata* might be attributed to the increase in *Chromolaena* cover as well as the number of *Chromolaena odorata* plants subsequent to their residues decomposition and mineralization. This weed carries a number of seed borne fungi, like *Fusarium culmorum*, *F. moniliforme*, *F. semisecturm* and *F. solani* which have been reported as pathogens of food crops' (Ambika and Jayachandra, 2001).

 Soils under Siam weed fallow are rich in organic matter (OM) and total nitrogen (Obatolu and Agboola, 1993). It can out-compete other crops and vegetation because of its growth rate (Ilori *et al.,* 2011).

1.2   Effects /Soil Reactions on the pH Growth of Siam Weed Plant

The weed grows in a wide range of soil pH, ranging from 4 to 8 and is adapted to a wide range of soil conditions which is a common characteristic of many successful weed species (Mgobozi *et al.,* 2008). The acidic nature of the soil where Siam weed can grow is attributed to the high rainfall, which is sufficient to leach basic cations especially calcium from the surface horizons of the soils (Foth, 2006 and Abua e*t al.,* 2010). It has been reported that the presence of Siam weed plant causes hydrogen ion (H^+) to displace metal cations from the cation exchange complex of soil components, thereby causing the metals to be released from sesquioxides that have been chemisorbed (McBride *et al.,* 2002).

Also, according to Hauser and Mekoa (2008) slightly acidity nature of the soil influences the availability of the elements in the soil for plant uptake.

1.3   Siam Weed Plant Morphological Characteristics

The root system is fibrous and shallow in most soils reach a depth of 300 mm (Parsons and Cuthbertson, 1992) and develops an enlargement at the junction of the stem and root. Siam weed dies back in the dry season but re-shoots after rain due to the presence of the basal ball; regrowth also occurs rapidly after fire, slashing and inadequate or ineffective herbicide application (Parsons and Cuthbertson, 1992). Adventitious roots sometimes form at the nodes of broken stems (Gautier, 1992). Characteristic pairs of lateral branches develop from axillary buds along the main stems (Gautier, 1993).

1.4   Siam Weeds Leaves and their Mineral Composition

The leaves of Siam weed are arrowhead-shaped, 50 – 120 mm long and 30 –70 mm wide, soft, green, hairy and triangular in shape, with a distinctive three-vein 'pitchfork' pattern (Gautier, 1993). Leaves are of high nutritive value and might have the potential to be used

as a protein supplement of leaf meal as reported by Checke and Myer, (1975). The mineral composition of leaf meal of Siam weed is presented/ shown in Table 1.

Table 1: Mineral compositions of Siam weed leaf   meal

Mineral	Mineral composition (mg kg^{-1})
Phosphorus	4532
Calcium	1155
Magnesium	3202
Potassium	13 800
Copper	37
Zinc	52
Manganese	71
Iron	79

Source: Nwokolo (1987)

Based on the reported high levels of these minerals, the weed can therefore be a potential source of plant nutrients if utilized as a soil amendment in enhancing the fertility status of soils.

1.5   Siam Weed Seeds Production and Dispersal

Siam weed produces huge numbers of windborne seeds of more than 87 000 seeds per plant per season within 8 – 10 weeks after flowering (Sivagnanam and Swamy 2010). The seeds are dark colored, 4 – 5 mm long, narrow and oblong, with a parachute of white hairs which turn brown as the seed dries. Seeds may also attach or stick easily to vehicles, machinery, clothing, footwear and animals (McFadyen, 2004) thus contributing to its propagation to other areas.

1.6   Siam Weed Plant Life Cycle

Siam weed is a perennial plant that can out-compete and smother crops and native vegetation because of its phenomenal growth rate of 20 mm per day or 5m per year and ability to scramble up taller plants to a height of 20 m. It has a minimum life span of approximately ten years (McFadyen, 2004). Plant becomes hard and woody while the branch tips are soft and green (Sivagnanam and Swamy 2010).

1.7   Economic Importance of the Weed in Soil

Siam weed plant serves an excellent fallow crop in arable farming due to its fast growth and ability to suppress other weeds and used as a green manure plant as reported by Iyagba and Offor (2013). Findings by Ibe *et al.* (2008), Atayese and Liasu, (2001) presented the effectiveness of Siam weed as composting material in the cultivation of horticultural crops because of ability of suppressing other grasses. According to Gills *et al.* (2013), Siam weed has ability to reclaim contaminated soil and accumulate higher amount of heavy metals. The weed also can be used in phytoremediation to remove heavy metals from the contaminated soil because of having deep roots giving it the ability to accumulate total heavy metals along with their wide distributions and fast growth (Aiyesanmi *et al.,* 2012; Iyagba and Offor, 2013). Tijani, Eniola and Fawusi (1989) have reported on the allelopathic activities of crude method extract of the weed on seed germination.

Siam weed is a new type of weed currently infesting some parts of Tanzania especially in Serengeti District. Most of the farms in Serengeti are being abandoned because of Siam weed infestations which tend to suppress growth of other agricultural crops, hence low yields. Several studies have been conducted in Africa, revealed that the plant contains a range of secondary chemical compounds including flavonoids, terpenoids and alkaloids,

which make it unpalatable to vertebrate herbivores (Biller *et al*., 1994). The weed also contains high levels of nitrate in the young foliage. The high NO_3-N levels in young foliage could be the cause of livestock death (McFadyen, 2004). The weed is allelopathic and suppresses growth of other plants as reported by Sahid and Sugau (1993), rapidly becomes dominant in native vegetation, significantly increasing fire intensities (McFadyen, 2004) as a result of its dry stem and leaves which are rich in oils (Moni and Subramoniam, 1960). Obatolu and Agboola (1993) also reported that soils under Siam weed fallow are rich in soil organic matter and total nitrogen.

Despite the existence of literature that documents advantages and disadvantages of Siam weed in different parts of the World, there is no current exhaustive research done in Tanzania to assess the soil characteristics which favour its growth and whether it can improve soil fertility. Therefore, this study was conceived such that it would assess soil chemical and physical properties that favour its growth alongside an incubation study that will determine the trend of plant nutrients released from the weed.

1.8   Objectives

1.8.1   Overall objective

The overall objective of the study was to characterize the soils of Serengeti District and assess the potential of utilization of Siam weed as plant nutrient source for crop production in the area.

1.8.2   Specific objectives

(i)   To assess the current fertility status of the soils under Siam weed establishment in the study area.

(ii) To characterize and classify the soils in Siam weed infested areas in Serengeti District, Tanzania.

(iii) To carry out mineralization and nutrient release patterns of Siam weed plants from incubated samples of Siam weed plant.

References

Abraham, T. K. and Pradeep, N. S. (1995). Utilisation of a common weed–*Chromolaena odorata*. King and Robinson, as a substrate for oyster mushroom cultivation. *Mushroom Research* 4: 81– 83.

Abua, M. A., Offiong, R. A., Iwara, A. I. and Ibor, U. W. (2010). Impact of Newly Constructed Roads on Adjoining Soil Properties in Tinapa Resort, South-Eastern Nigeria. *Annals of Humanities and Development Studies.* 176 – 184pp.

Adegbite, A. A. and Adesiyan, S. O. (2005). Root extracts of plants to control root-knot nematodes on edible soybean. *World Journal Agriculture Science* 1(1): 18 –21.

Aiyesanmi, A. F., Okoronkwo, A. E. and Sunday, O. M. (2012). Lead accumulation in Siam weed (*Chromolaena odorata*), Node weed (*Synedrella nodiflora*) and Water leaf (*Talinum triangulare)*: Potential remediators. *Archives of Applied Science Research* 4(1): 360 – 37.

Akhtar, M. and Malmood, I. (1996). Prophylactic and therapeutic use of oil cakes and leaves of neem and castor extracts for control of root knot nematode on Chilli. *Nematol Medit* 22: 127 – 129.

Akter, A. and Zuberi, M. I. (2009). Invasive alien species in Northern Bangladesh: Identification, inventory and impacts. *International Journal of Biodiversity and Conservation* 1(5): 129 – 134.

Ambika, S. and Jayachandra, R. (2001). Suppression of plantation crops by Eupatorium weeds, *Current Science* 49(22): 874 – 875.

Atayese, M. O. and Liasu, M. O. (2001). *Arbuscular mycorrhizal* fungi weeds and earthworm interactions in the restoration of soil fertility in the Guinea Savanna region of Nigeria. *Journal of Agricultural Research* 3: 104 - 109.

Biller, A., Boppre, M., Witte, L. and Hartmann, T. (1994). Pyrrolizidine alkaloids in *Chromolaena odorata*. Chemical and chemoecological aspects. Pytochemistry. Bostan region. *Egypt Journal Agronematol* 2: 111–125.

Burton, J. (2001). Extension Officer (Weeds), NSW Agriculture, Noxious weeds of Australia [http: //www.agric.nsw. gov.au/weeds]. *Journal of Science, Food and Agriculture* 41: 123 -129.

Brady, N. C. and Weil, R. R. (2005). *The Nature and Properties of Soils*, 13th edition. Delhi: Pearson Education. 881pp.

CAB International, (2004). Prevention and Management of Invasive Alien species: Nairobi, Kenya. Weed technology *In: proceedings of a workshop held in Accra, Ghana,* (Edited by Clout, M. and De Pooter, M.A. (2005). 1: 18 – 25.

Checke, P. R. and Myer, R. O. (1975). Protein digestibility and lysine availability in alfalfa meal and alfalfa protein concentrate. *Nutrition Report International* 12: 337.

Couto, L. and Betters, D. R. (1995). Short-rotation eucalypt plantations in Brazil: social and environmental issues (No. ORNL/TM--12846). Oak Ridge National Lab., TN (United States) 8: 33 – 36.

El-Nagdi, W. M. A., Youssef, M. M. A. and Moustafa, Z. R. (2004). Reaction of sugar beet varieties to *Meloidogyne incognita* root-knot nematode based on quantitative and qualitative yield characteristics. *Pakistan Journal of Nematology*. 22: 157–165.

Fatoki, O. K. and Fawole, B. (2000). Identification of nematicidal ingredients from neem leaves, Siam weed leaves and roots. *African Journal Plant Protein* 10: 33 – 38.

Foth, H. D. (2006). *Fundamentals of Soil Science*, 8th Edition. New York: John Wiley and Sons. 23pp.

Gareeb, M. (2007). Investigation in the potted *Chromolaene odorata* (L) R. M. King and H. Robinson (Asteraceae). Thesis: School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban South Africa. 3 – 48 pp.

Gautier, L. (1992). Taxonomy and distribution of a tropical weed: *Chromolaena odorata* (L.) R. King and H. Robinson. *Candollea* 47: 645 - 62.

Gautier, L. (1993). Reproduction of a pan-tropical weed: Chromolaena odorata (L.) R. King and H. Robinson. *Candollea* 48: 179 – 93.

Gill, L. S., Anoliefo, G. O. and Iduoze, U. V. (2013). Allelopathic effects of aqueous extract from Siam weed on the growth of Cowpea. *Chromoleana Newsletter* 8: 1 – 11.

Hauser, S. and Mekoa, C. (2008). Biomass production and nutrient uptake of *Choromolaena odorata* as compared with other weeds in a burned and mulched secondary forest clearing planted to plantain (*Musa spp*.) *Weed Research* 29: 193 – 200.

Hossain, S. and Zuberi, M. I. (2013). Current status of invasive alien plant species in north-western Bangladesh. In: *Proceedings of the 8th International Workshop on Biological Control and Management of Chromolaena odorata and other Eupatorieae.* (Editors Gisaye, T. and Muhammad, I. (2014). Humanities and Development Studies 1(1): 176 – 184.

Ibe, A. E., Onuegbu, B. A. and Iyagba, A. G. (2008). Effects of Siam weed (*Chromolaena odorata* (L.) R M King and Robinson) mulch on weediness and reproductive characters of okra (*Abelmoschus esculentus L. Moench)(Musa spp*.) somaclonal variants in Nigeria. *Acta Agronomica Nigeriana 8*(2): 90 – 95.

Ilori, O. J., Sanni, R. O. and Adenegan-Alakinde, T. A. (2011). Effect of *Chromolaena odorata* on the Growth and Biomass Accumulation of *Celosia argentea*. *Research Journal of Environmental Sciences* 5: 200 – 204.

Iwara, A. I., Ewa, E. E., Ogundele, F.O., Adeyemi, J. A. and Otu, C. A. (2011). Ameliorating Effects of Palm Oil Mill Effluent on the Physical and Chemical Properties of Soil in Ugep, Cross River State, South Southern Nigeria. *International Journal of Applied Science and Technology* 1(5): 106 – 112.

Iyagba, A. G. and Offor, U. S. (2013). Phytoextraction of heavy metals by fluted pumpkin *Telfaria Journal Application Ecology* 45: 1189 – 1197.

Koutika, L. S. and Rainey, H. J. (2010). *Chromolaena odorata* in Different Ecosystems: Weed or Fallow Plant. *Applied Ecology and Environmental Research* 8(2): 131 – 142.

Maareg, M. F., Haaanein, N. A., Allam A. I. and Oteifa, B. A. (1998). Susceptibility of twenty six sugar beet varieties to Root-Knot nematodes, *Meloidogyne spp*. In the newly reclaimed soils of Al Bostan region. *Egypt Journal Agronematology* 2: 111 – 125.

McBride, R. A., Dane, J. H. and Topp, G. C. (2002). *Methods of Soil Analysis*. Part 4: No. 5. In: Soil Science Society of America Book Series. SSSA, Inc. Madison, Wisconsin, USA. 389 – 398pp.

McFadyen, R. E. C. (1992). A critique paper, "*Chromolaena odorata*: friend for resources poor farmers" by S. P. Field, Published in the *Chromolaena odorata Newsletter* (4) 5: 4 – 8.

McFadyen, R. E. C. (2004). *Chromolaena odorata* in East Timor: history, extent and control. In: Day, M. D. and McFadyen, R. E. (eds). *Proceeding of the Sixth International Workshop on Biological control and Management of Chromolaena odorata in the Asia-Pacific region.* 67 – 69pp.

Moni, N. S. and Subramoniam, R. (1960). Essential oil from *Eupatorium odoratum*-a common weed in Kerala. *Indian Forester* 86 (4): 23 – 26.

Mgobozi, M. P., Somers, M. J. and Dippenaar-Schoeman, A. S. (2008). Spider responses to alien plant invasion: the effect of short-and long-term *Chromolaena odorata* invasion and management. *Journal of Applied Ecology* 45(4): 1189 – 1197.

Nwokolo, E. (1987). A nutritional assessment of African yam bean (*Sphenostylis stenocarpa*) (Hoechst. ex. A. Rich.) Harms and Bambara groundnut (Voandzeia subterranea L.). *Journal of Science, Food and Agriculture* 41: 123 – 129.

Obatolu, C. R. and Agboola, A. A. (1993). "The Potential of Siam Weed *Chromolaena odorata* as a Source of Organic Matter for Soil in the Humid Tropics" In: *Organic Matter Dynamics and Sustainability of Tropical Agriculture*. Chichester: John Willey and Sons. 87– 93pp.

Odeyemi, I. S., Olalekana, F. Y. and Sosanya, O. S. (2009). Effect of organic fertiliser and *Chromolaena odorata* residue on the pathogenicity of *Meloidogyne incognita* on maize, Ago-Iwoye, Nigeria. 67pp.

Osemwota, O. I. (2010). Effect of Abattoir Effluent on the Physical and Chemical Properties of Soils. *Environmental Assessments* 167: 399 - 404.

Parsons, W. T. and Cuthbertson, E. G. (2001). Noxious Weeds of Australia, CSIRO Publishing, Collingwood. 45pp.

Parsons, W. T. and Cuthbertson, E. G. (1992). Noxious weeds of Australia Inkata Press, *Melbourne, Australia*). Quality of an ecosystem case study of their uses. *Forest Ecology and Management* 138: 357 – 368.

Sahid, I. B. and Sugau, J. B. (1993). Allelopathic effect of lantana (*Lantana camara*) and Siam weed (*Chromolaena odorata*) on selected crops. *Journal of Weed science.* 22 (4): 303 – 308.

Sheeja, B. D. (1993). Allelopathic effects *of Eupatorium odoratum L. and Lantana camara L.* on four major crops. Dissertation for Award of PhD at State University, Blacksburg, USA. 67pp.

Tijani-Eniola, H. A. and Fawusi, O. A. (1989). Allelopathic activities of crude methanol extract of Siam weed and Wild potential in seed germination and seedling growth in Tomato. *Nigeria Journal of Weed Science* 2: 15 – 20.

Timbilla, J. A. and Braimah, H. (1996). A Survey of the Introduction, Distribution and Spread of *Chromolaena odorata* in Ghana. Agricultural Experimental Station, University of Guam, Publication 202: 6 – 18.

Uyi, O. U., Aisagbonhi, C. I. and Egbon, I. N. (2008). Occurrence and distribution of *Aphis spiraecola* (Patch) on *Chromolaena odorata* (L.) in Nigeria: Implication for pest outbreak and the need to control the weed. *Chromolaena Newsletter* 17: 4 – 7.

Wise, R. M., Van Wilgen, B. W., Hill, M. P., Schulthess, F., Tweddle, D., Chabi-Olay, A. and Zimmermann, H. G. (2007). The economic impact and appropriate management of selected invasive alien species on the African continent. *Global Invasive Species Programme*. 19(2): 282 – 295.

CHAPTER TWO

2.0 Morphological, physico-chemical characteristics and classification of Siam weed infested soils of Serengeti District, Tanzania

2.1 Abstract

Crop production in Serengeti District has been reported to decline due to infestation by Siam weed plant leading to food insecurity. A study was, therefore, conducted to characterize and classify Siam weed infested soils in District and assess their fertility status. For soil fertility evaluation, composite topsoil (0-20 cm) samples were collected and analysed for physico-chemical properties hence shows that For morphological characterization, a toposequence was selected where three soil profiles were excavated on the upper, middle and lower slope positions of the study area according to the Guidelines for soil profile description (FAO, 2006). Using the morphological and laboratory data the soils were classified to the subgroup level of the USDA Soil Taxonomy as *Ustic Torripsamments* on sloping land, *Haplic plinthustults* on midslope and *Plinthaquic paleudalfs* on low land and to Tier-2 of WRB as *Rendzic Lithic Leptosols (Eutric, DystricTephric)* on sloping lands and as *Gleyic Plinthic Acrisols (Ferric, Humic)* on midslope and as *Haplic Stagnic Gleyic Luvisols (Chromic)* on low or flat areas. The results show that, texture of the studied profile was sandy clay loam and Sandy clay. Results from composite surface soils showed to have slightly acidity with pH ranging from 5.8 to 6.5, low to high CEC with values 11.6-29.4 cmol (+) kg^{-1} and very low to very high soil organic carbon (0.36- 3.69%). Laboratory analysis showed that most of the soils profiles were medium acidity to moderate alkaline with pH ranging from 5.8 to 7.9; low to high CEC with values ranging from 10.12 to 35.20 cmol (+) kg^{-1}. Soil organic carbon was low to medium with a range of 0.11 to 1.97%. Exchangeable bases were

generally high with a value of 24.45 cmol (+) kg^{-1} which indicates high soil fertility. Therefore, Siam weed could be used to improve soil fertility and management of the Soil.

2.2   Introduction

Siam weed plant is a new weed plant that has infested some parts of Serengeti district in Mara Region, Tanzania. This weed is of economic importance tends to extract a lot of nutrients from the soil leaving the soil unproductive. Siam weed as a plant grows in several soil types because it tolerates a broad range of soil pH ranging from (Mgobozi *et al.,* 2008). It also prefers well drained soils but its growth is retarded by water logging and saline soil conditions (Gareeb, 2007). This weed plant has been reported to enhance and improve plant nutrient levels in the soil under its canopy through its high litter fall and mineralization and hence enhance sustainable conservation of soil fertility (Obatolu and Agboola, 1993, Ilori *et al.,* 2011; Akobundu *et al.,* 1999). According to Koutika and Rainey (2010), Siam weed is found in different agricultural systems. In Nigeria, Siam weed grows easily and usually dominates newly cleared and abandoned farmlands or fallows (Amiolemen *et al.,* 2012). Siam weed is reported to regenerate and colonise fallow lands or newly cleared pieces of land through its roots or high seed production which enhances its propagation (Koutika and Rainey, 2010). Different studies have been carried out in different parts of the world but not in Tanzania to assess the contribution of Siam weed in improving the fertility status of the soils on which it flourishes (Obatolu and Agboola, 1993; Jubril and Yahaya, 2010) and trends of nutrient build-up of soils under siam weed with other plant species or a mature forest (Slaats *et al.* 1998, Yahaya and Edicha, 2010 and Murphy *et al.,* 2010). Further, the trends of increase in nutrients in soils under the canopy of Siam weed at varying fallow age are not yet investigated. Siam weed prefers nutrient -rich soil, but when it finds itself in a nutrient poor soil, growth is retarded (Robinson, 2006).

The intensity of Siam weed growth is more pronounced on the level landscapes as compared to differences in soil characteristics associated with landscape position are usually attributed to differences in the runoff, erosion and deposition processes which affect soil genesis (Yair, 1990). The degree of surface runoff and soil erosion is mainly related to land physiography and slope gradients as slope gradient becomes high the surface runoff also increases (Birkeland, 1999). The variation in soil properties affecting Siam weed growth might be attributed to topographical variations of mountainous soils (Birkeland, 1999). A broad landscape with gentle slopes will permit rapid vertical movement of water through soil; such level landscape will have thick soil profiles and well developed horizons (Akhtaruzzaman *et al.,* 2014), and hence favours Siam weed growth and proliferation. In more steeply sloping landscapes, particularly on shoulders and back slopes, increased rates of erosion and runoff and decreased vertical percolation of water will lead to shallow and weakly developed soils (Vreeken, 1973) and hence poor vegetation growth. Landscape morphology and topography also affect the distribution of soil properties and soil nutrient status in sloping lands (Sollins *et al.,* 1980). A study on soil characteristics in particular morphological, physico-chemical properties on a representative toposequence will provide basic information for better plant growth and management of the soils affected with Siam weed plant.

This study was therefore carried out to characterize the soils of the Siam weed infested areas of Mugumu in Serengeti District. Specifically, the study was undertaken to characterize the soils based on their morphology and physico-chemical properties of surface soils and hence assess their general fertility status and classify the soil using the USDA Soil Taxonomy (Soil Survey Staff, 2006) and the 'World Reference Base for Soil Resources' (FAO, 2006).

2.3   Materials and Methods

2.3.1   Location and Description of the study area

The study was conducted in Nyagasense village, Mugumu in Serengeti District, Tanzania. The study area is an area predominantly infested with Siam weed located between Longitude 1° 30' to 3° 20' South and Latitude 34° 0' to 35° 15' East.

2.3.2   Soil Sampling for Soil morphology

Three representative soil profiles were made on a selected toposequence in the dominant Siam weed infested area in Nyagasense village. The soil profiles that represented the upper, middle and the lower slopes of the village were excavated to a depth of 2m except where soil depth was limited by bedrock or strongly cemented materials. The profiles were studied, described and sampled according to the Guidelines for Soil Profile Description (FAO, 2006). Bulk soil samples were then taken from each horizon for physical and chemical analysis. At each profile, soil samples were collected in triplicates from different successive horizons using a scoop. The morphological properties of the profiles were described according to the guidelines for soil profile description (FAO, 2006).

2.3.3   Soil Sampling for Soil fertility evaluation

Composite top soil samples (0-20 cm) (40 soil samples) were collected from farms highly affected with Siam weed plant in Nyagasense village at three different landscape positions (high, middle and lower landscape of the farm). The collected composite samples were air dried and grounded to pass through a 2 mm sieve and stored in labelled polythene bags ready for laboratory analysis.

2.3.4 Analysis of chemical and physical properties of the composite soil samples

The pH electrometrically were measured in 1:2.5 soil deionized water suspensions (Okalebo *et al.,* 2002). Organic carbon was determined by wet oxidation method of Walkley-Black (Nelson and Sommers, 1982). Particle size distribution was determined by hydrometer method as described by Gee and Bauder (1986). Soil colour by Munsell soil colour chart at both moist and dry conditions of soils (Munsell colour, 1994). The exchangeable bases (K^+, Ca^{2+}, Mg^{2+} and Na^+) were extracted by ammonium acetate solution and then quantified by atomic absorption spectrophotometer for Ca^{2+} and Mg^{2+}, while a flame photometer was used for K^+ and Na^+ (Sparks,1996). The cation exchange capacity (CEC) was determined by neutral ammonium acetate (Buffered at pH 7.0) saturation method (Sparks *et al.,* 1996). Cation exchange capacity of clay was estimated using the relationship proposed by Baize (1993) as follows:

$$CEC\ clay = \frac{\{CEC\ soil - (\%\ OM\ x\ 2)\}}{\%\ clay}\ x\ 100$$

Where, OM is organic matter.

2.3.5 Soil classification

Using both the morphological data collected in the field and laboratory data, the soils of the study areas were classified using the USDA Soil Taxonomy (Soil Survey Staff, 2006) and the FAO World Reference Base (FAO, 2006); which are the two most common soil Classification system used in Tanzania.

2.4   Results and Discussions

2.4.1   Soil Morphological Properties and Soil Classification

Key morphological properties of the profile are shown in Table 2. Both profiles have developed from parent materials that are coarse textured colluvial deposits from granitic rock hills. The surface horizons are coarse textured with textural classes ranging from sandy clay loam to sandy clay. Sand fraction of these soils is mainly quartz. Generally the sub surface horizons of soil profiles in the mid and lower slopes of Nyagasense village have high clay contents. This observation implies that there has been clay illuviation in these soils as supported by presence of clay cutans. Profile II and III excavated in middle slopes and lower or flat area are characterized by high weathering of parent materials except profile I in upper or high slope area. The soils of Nyagasense village in Serengeti District show evidence of horizon differentiation in terms of structure development and subsurface horizons with different colours. Soil texture is the most stable physical characteristic of the soils which has influence on a number of other soil properties including structure, soil moisture availability, erodibility, root penetration and soil fertility (Msanya *et al.*, 2003; Landon 1991).

Soils of all profiles had higher sand content than silt and clay, therefore the soil texture in the studied area was sandy clay loamy and sand clay with 47-76% it varies within the profile II but it was sandy clay loam in the profile I and III (Table 2). These coarse textures implies low nutrient storage capacity, limit the water holding capacity and roots may grow under sub-optimal soil water due to water deficits (Gachene, 2003). Sand loamy soils wash out nutrients through leaching resulting in very low nitrogen content (Amiolemen *et al.,* 2013). Soil texture is the most stable physical characteristic of the soils which has influence on a number of other soil properties including structure, soil moisture availability, erodibility, root penetration and soil fertility (Msanya *et al.,* 2003).

Table 2: Some morphological and physical and properties of the soil profiles

Profile/ Horizon	Depth (cm)	Boundary	(Munsell Colour, 1994)		Particle size distribution			
			Dry	Moist	Clay (%)	Silt (%)	Sand (%)	Textural class

			Profile I (Upper landscape position)					
Ah	0 – 10/14	dw	dark brown - (7.5YR3/2)	very dark brown (7.5YR2.5/2)	24.7	7.6	67.7	SCL
AB	10/14 – 30/40	cw	dark brown - (7.5YR3/2)	very dark brown (7.5YR2.5/2)	24.7	7.6	67.7	SCL
C	30/40 – 100+	-	yellowish red- (5YR5/8)	very dark brown (7.5YR2.5/2)	26.7	7.6	65.7	SCL

			Profile II (Midslope position)					
Ap	0 - 18/22	cw	dark reddish-brown (2.5YR3/3)	dark reddish-brown (2.5YR3/3)	30.7	5.6	63.7	SCL
BA	18/22 - 40	gw	Dark reddish-brown (2.5YR2.5/4)	n.d	42.7	3.6	53.7	SC
Bt_1	40 - 85	ds	n.d	Dark red (2.5YR3/6)	42.7	1.6	55.7	SC
Bt_2	85 - 110/130	ds	n.d	dark red (2.5YR3/6)	44.7	5.6	49.7	SC
BC	110/130-160	cw	n.d	dark reddish - brown (2.5YR2.5/4)	42.7	9.6	47.7	SC
C	160/170 - 200+	-	n.d	n.d	n.d	n.d	n.d	n.d

			Profile III (Lower landscape position)					
Ap	0 – 18/20	cw	n.d	very dark greyish-brown (10YR3/2)	26.7	13.6	59.7	SCL
AB	18/20 – 50/55	cw	n.d	very dark gray (10YR3/1)	20.7	3.6	75.7	SCL
Btg_1	50/55-90/95	gw	n.d	very dark greyish-brown (10YR3/2)	34.7	3.6	61.7	SCL
Btg_2	90/95- 135	ds	n.d	very dark gray (10YR3/1)	26.7	21.6	51.7	SCL
Btg_3	135-200+	-	n.d	very dark gray (10YR3/1)	n.d	n.d	n.d	n.d

Abbreviations: dw =diffuse wavy; cw = clear wavy; gw = gradual wavy; ds = diffuse smooth; SCL=Sandy Clay Loam; SC = Sandy clay; n.d= not determined.

Addition of manure to coarse textured soils can help to improve the soil structure followed by increased moisture and nutrient retention hence increases crop production (Brady and Weil, 2008). High sand contents in the soils of the upper slope positions are a

result of influence of the sand stone nature of the parent material (Landon, 1991). Also, clay content was relatively higher in different horizons of profile II as compared to that of horizons in profile I and III, (Table 2). Clay has been reported to interact with organic matter and increase water and nutrient holding capacity (Landon, 1991).

2.4.2   Soil classification

The soil was classified to sub group level of the USDA Soil Taxonomy (Soil Survey Staff, 2006) and to level 1-2 of the FAO World Reference Base (FAO/ISRIC/ISS, 2006). Based on the field and laboratory data, the profile in Nyagasense village, Serengeti District was classified to subgroup level of the USDA Soil Taxonomy for profile I as Ustic Torripsamments, corresponding to *Rendzic Lithic Leptosols (Eutric, Dystric)* at Tier-2 in the WRB. Profile II as Haplic Plinthustults, corresponding to *Gleyic Plinthic Acrisols (Ferric, humic)* at Tier-2 in the WRB and profile III as Plinthaquic Paleudalfs, corresponding to *Haplic Stagnic Gleyic Luvisols (chromic)* at Tier-2 in the WRB. The detailed classification is shown in Tables 3.

Leptsols (Entisols) represented by profile I is a shallow or extremely gravelly soil which is limited in depth by continuous hard rock or highly calcareous materials and high degree of biological activity (Soil Survey Staff, 2006). Acrisols (Ultisols) are characterized by acidic pH, higher clay content in the subsoil than in the topsoil and by low-activity clays in certain depths. Acrisols do not have the capacity to hold large amounts of nutrients (Jonas *et al.,* 2013). Luvisols (Alfisols) are soils accumulated with high clay content. These soils have high base status and high-activity clay. Luvisols are results of

pedogenetic processes (Soil Survey Staff, 2006).

Table 3: Morphological, diagnostic features and classification of the studied soil profiles in Serengeti District

Profile number	Classification using WRB (FAO, 2006)						Classification using Soil Taxonomy (SSS, 2006)					
	Diagnostic horizons	Other diagnostic features/materials	Prefix Qualifiers	Suffix Qualifiers	Reference Soil Group (RSG)-TIER 1	WRB soil name TIER 2	Diagnostic horizons	Other diagnostic features/materials	Order	Sub order	Great group	Sub group
I	Lithic, Rendzic	Calcareous rock/weathering, weakly developed shallow soils. STR Iso-hyperthermic, SMR Ustic, slope 28%	Lithic, Rendzic	Eutric, Dystric, Tephric	Leptosols	*Rendzic Lithic Leptosols (Eutric, Dystric, Tephric)*	Ochric-epipedon Argillic - horizon	Steep slope of about 28%, slope length >100m, Calcareous rock/weathering, weakly developed shallow soils, strongly acid to slightly acid. STR Iso-hyperthermic, SMR Ustic	Entisols	Psamm-ents	Ustipsa-mments	Ustic Torripsam-ments
II	Plinthic, Gleyic	Ferric properties, STR Iso-hyperthermic, SMR Ustic, slope 4% straight	Plinthic, gleyic	Ferric, humic	Acrisols	*Gleyic-Plinthic Acrisols (Ferric,humic)*	Ochric-epipedon Cambic - horizon	Gently slope about 4%,slope length 50m, weathering develop deep soil, medium acid to neutral, presence of cutans STR Iso-hyperthermic, SMR Ustic	Ultisols	Ustults	Plithustults	Haplic plinthustu-lts
III	Haplic Stagnic gleyic	STR Iso-hyperthermic, SMR Ustic, slope 2 %	Haplic Stagnic Gleyic	chromic	Luvisols	*Haplic-Stagnic Gleyic Luvisols (chromic)*	Ochric-Epipedon Cambic - horizon	Flat area about < 2%, weathering develop very deep soil, slightly acid to moderate alkaline, presence of cutans STR Udic, SMR Aquic	Alfisols	Udalfs	Paleuda-lfs	Plinthaquic-Paleu dalfs

2.4.3 Chemical properties of the studied soil profiles

Chemical properties of the studied soil profiles are presented in Table 4. Soil pH is the most important chemical characteristic of the soil solution. pH values increased with depth from 5.84 to 6.28 in profile I, 6.06 to 6.97 in profile II and 6.34 to 6.93 in profile III (Table 4) and the soils were categorised as acidic in nature (Landon, 1991). The acidity recorded on these soils might be a result of the acidic nature of the parental rock, which could be associated with leaching of bases. The soil pH of the studied profile tends to increase with increase in depth.

Soil organic carbon contents of the profiles decreased with depth from 1.97 to 1.08% in profile I; 3.39 to 0.57% in profile II and 1.78 to 0.11% in profile   III (Table 4). The low content of organic carbon in the studied soil profile might be due to rapid mineralization of organic matter that was enhanced by favourable temperature and high rainfall condition. For pH values of 5.5 and above, bacterial activity is increases and nitrification of organic matter is also significantly increases hence reduce organic carbon content (Landon, 1991). The low level of observed SOC is a characteristic of soils in semi arid areas, where the high rate of mineralization does not allow high accumulation of carbon (Gachene, 2003). Organic carbon values below 0.6% are considered to be low for agricultural activities (Landon, 1991). Therefore, results from soil profiles studied indicate that the soil in the area can be good for agricultural activities since the organic carbon is above 0.6% (Table 4). Soil organic matter contents in profile I was low to medium ranging from 1.86 - 3.39%; very low to medium between (0.57 - 3.39%) in profile II and very low to medium (0.019 -3.06%) in profile III, and decreases down the profile for all profiles (Table 4). Soil organic matter level in the soil is strongly correlated with the soil's CEC and is a source of many plant nutrients, particularly nitrogen (Brady and Weil, 2008).

The exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) in the studied soil profile have high amount of calcium content ranging between 8.42 cmol (+) kg^{-1} to 10.51 cmol (+) kg^{-1} in profile I; 9.18 cmol (+) kg^{-1} to 14.13 cmol (+) kg^{-1} profile II and 14.32 cmol (+) kg^{-1} to 24.45 cmol (+) kg^{-1} profile III. Level of magnesium content observed was high to very high with ranging from 1.17 cmol (+) kg^{-1} to 5.24 cmol (+) kg^{-1} in profile I; high Mg contents ranging from 1.16 cmol (+) kg^{-1} to 1.48 cmol (+) kg^{-1} in profile II and medium to high ranging from 0.84 cmol (+) kg^{-1} to 1.48 cmol (+) kg^{-1} in profile III. Level of sodium contents observed were very low to high ranging between 0.03 to 0.18 cmol (+) kg^{-1}) in profile I; very low to low (0.02 - 0.25 cmol (+) kg^{-1}) in profile II and medium to high (0.41 - 1.55 cmol (+) kg^{-1}) in profile III. Level of K^+ contents in the studied profile observed were low to high ranging from 0.10-0.20 cmol (+) kg^{-1} in profile I; Low to high (0.09 - 0.48 cmol (+) kg^{-1}) in profile II and low to medium (0.08-0.35 cmol (+) kg^{-1}) in profile III (Table 4) (Baize, 1993; Landon, 1991). Generally the values of exchangeable cations were higher in the soils of profile III as compared to those of profile I and profile II. This might be due to higher losses of exchangeable cations in the soils of the sloping land under study by extreme leaching and/or runoff processes. Higher topography accelerates more cation losses from the soil. Lower land area (profile III) was enriched by base cations from nearby outer sites through surface runoff.

The CEC values ranged from 16.16 to 37.4 cmol(+) kg^{-1} in profile I; 10.12 to 18.72 cmol(+) kg^{-1} in profile II and 21.48 to 35.2 cmol(+) kg^{-1} in profile III (Table 4). Horizon of profile I and III have higher CEC than profile II (Table 4).

High CEC in each horizon might be due to high amounts of organic carbon in surface layers or presence of slightly weathered minerals. However, most subsurface horizon in all profiles observed had higher CEC than in surface layers; this may be due to relatively

higher clay contents (Table2). Some horizons have low CEC, and this is likely due to the coarse texture of the soil probably dominated of 1:1 clays in the clay fraction of the soils (Alam *et al.,* 1993; Hassan, 1991).

Table 4: Chemical properties of the studied profiles

Horizon	Depth (cm)	pH	SOC %	SOM %	CEC-soil	CEC-clay (cmol (+) kg^{-1})	Exchangeable bases (cmol(+) kg^{-1})				TEB (cmol (+) kg^{-1})
							Ca^{2+}	Mg^{2+}	K$^+$	Na$^+$	
Profile I (Upper landscape position)										
Ah	0 – 10/14	5.84	1.97	3.39	37.4	48.57	10.51	1.40	0.12	0.03	12.06
AB	10/14 – 30/40	6.14	1.21	2.08	16.16	94.85	8.42	1.17	0.20	0.05	9.84
C	30/40– 100+	6.28	1.08	1.86	29.04	123.98	9.75	5.24	0.10	0.18	15.27
Profile II (Midslope position)										
Ap	0 - 18/22	6.06	1.97	3.39	12.4	18.32	9.18	1.16	0.15	0.02	10.51
BA	18/22 - 40	6.28	0.67	1.15	10.12	18.30	9.75	1.48	0.17	0.05	11.45
Bt$_1$	40 - 85	6.55	0.59	1.01	14.68	29.63	9.56	1.22	0.09	0.15	11.02
Bt$_2$	85 - 110/130	6.85	0.48	0.83	18.72	38.19	13.56	1.43	0.24	0.25	15.48
BC	110/130-160/170	6.85	0.33	0.57	15.16	32.84	14.13	1.25	0.48	.24	16.1
C	160/170 - 200+	6.97	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Profile III (Lower landscape position)										
Ap	0 – 18/20	6.34	1.78	3.06	27.28	79.24	14.32	1.01	0.14	0.41	15.88
AB	18/20 – 50/55	6.83	1.67	2.87	21.48	76.02	15.46	1.03	0.08	0.80	17.37
Btg$_1$	50/55-90/95	7.04	0.43	0.74	33.32	91.76	20.60	1.30	0.14	1.61	23.65
Btg$_2$	90/95- 135	7.93	0.12	0.21	35.2	130.29	22.55	1.48	0.35	1.55	25.93
Btg$_3$	135-200+	7.93	0.11	0.19	28.08	131.91	24.45	0.84	n.d	n.d	26.82

n.d = not determined

2.4.4   Characterization of surface soils

Table 5 presents some physical and chemical properties of the surface soils of the studied sites. The mean values were obtained from 5 samples. Characterization was conducted from four villages namely Nyagasense, Iramba, Kenyamonta and Buchanchari with different land uses mostly cultivated and grazing lands.

Table 5: Physical and chemical properties of the surface soils from study sites/area

VILLAGE	LUP	pH	SOC (%)	TN (%)	Av. P (Mg kg^{-1})	CEC (cmol (+) kg^{-1})	Exchangeable bases (cmol (+) kg^{-1})				Micronutrients (mg kg^{-1})				Particle size analysis			Textural class
							Ca	Mg	Na	K	Cu	Zn	Mn	Fe	Clay	Silt	Sandy	
Nyagasense	Cultivation	5.88	1.95	0.16	3.86	29.4	10.59	3.47	0.05	0.61	1.96	0.41	4	52.79	18	11	71	SL
	Grazing	6.01	1.85	0.15	4.98	24.4	10.89	3.45	0.09	0.37	2.17	0.2	4.83	55.63	20	11	69	SL
Iramba	Cultivation	6.43	3.69	0.07	5.51	11.6	3.79	0.89	0.03	0.32	0.05	0.4	3.33	22.41	4	3	93	S
	Grazing	6.23	2.67	0.08	3.97	13.2	5.38	1.03	0.04	0.47	0.21	0.77	9.06	43.08	8	8	84	LS
Kenyamonta	Cultivation	6.52	1.22	0.11	5.5	18.4	6.31	1.94	0.04	0.41	0.52	0.78	20.8	26.53	9	8	83	LS
	Grazing	6.41	1.33	0.1	4.17	20.8	9.48	3.16	0.21	0.29	1.65	0.53	47.5	95.57	15	12	73	SL
Buchanchari	Cultivation	6.31	0.82	0.08	10.02	14.8	3.79	0.89	0.03	0.32	0.18	0.4	27.57	53.86	7	5	88	S
	Grazing	6.36	0.36	0.06	8.68	14.2	3.85	0.58	0.02	0.29	0.2	0.73	0.37	21.73	3	8	89	S

Where; LUP - Land Use Practices,   Av. p - Available phosphorus, SL – Sandy Loamy, S- Sandy, LS- Loamy Sandy

2.4.4.1 Soil texture

Soil texture for composite samples collected was mostly dominated by coarse texture (sand). Therefore, from the physical and chemical characterization of the soil studied, the soil texture was sandy, sandy loam and Loamy sand with more than 65% sand throughout the soil surface (Table 5).

2.4.4.2 Soil pH

In Nyagasense village soil pH in cultivated and grazing lands was 5.88 and 6.01 respectively, indicating that the soil was medium acidic. In Iramba village, the soil pH in cultivated land was 6.43 and 6.23 in grazing land indicating that the soil was slightly acidic. In Kenyamonta village, the soil pH in cultivated and grazing lands was 6.52 and 6.41 respectively, indicating that the soil was slightly acidic. In Buchanchari village, soil pH in cultivated land was 6.31 and 6.36 in grazing land indicating that the soil is slightly acidic Landon, (1991).

Based on the soil pH observed, the soils of the studied villages are suitable for cereals crops production. The acidity recorded on these soils might be a result of the acidic nature of the parent rock coupled with intensive leaching of bases due to high sand content of the soils. Low soil pH has potential of causing toxicity problems and deficiency of some essential plant nutrients as well as affecting soil microbial activities (Adamchuck and Mulliken, 2005). Also low soil pH can cause dissolution of aluminium and iron which precipitate with phosphorus effectively causing its fixation and further lowering the soil pH (Brady and Weil, 2008). Presence of Siam weed causes hydrogen ion (H^+) to displace metal cations from the cation exchange complex of soil components thereby causing metal cations to be released from sesquioxides (McBride, 1994).

2.4.4.3   Organic carbon

Organic carbon is one of the most important constituents of the soil, due to its capacity to affect plant growth as well as source of energy and trigger for nutrient availability through mineralization (Walpola *et al.,* 2011). In Nyagasense village soil organic carbon was 1.95% in cultivated land and 1.85% in grazing land indicating medium soil organic carbon. In Iramba village, soil organic carbon was very high with values of 3.69% in cultivated land and high with values of 2.67% in grazing land. In Kenyamonta village, soil organic carbon was low with values of 1.22% in cultivated land and medium with values of 1.33% in grazing land. In Buchanchari village, soil organic carbon was low with values of 0.82% in cultivated land and very low with values of 0.36% in grazing land (Table 5). Medium to very high soil organic carbon contents results into a good soil structure, improved water holding capacity and retention of mineral elements in the soil. The high organic carbon contents on surface soils may be related to litter accumulation due to the abundance of vegetation, topographic variation and slope gradient of a particular land. The level of soil organic carbon content is often taken as a crude measure of soil fertility status (Moukam and Ngakanou, 1997). The observed low organic carbon can be a cause of poor soil structure and low supply of plant nutrients such as nitrogen, phosphorus and potassium (Luffman, 2012).

2.4.4.4   Total Nitrogen

In Nyagasense village, total nitrogen was 0.16% in cultivated land and 0.15% in grazing land indicating low nitrogen contents. In Iramba village, total nitrogen was very low in cultivated and grazing land with with values of 0.07% and 0.08%, respectively. In Kenyamonta village, total nitrogen in cultivated and grazing lands was low with values of 0.11% and 0.10%, respectively. In Buchanchari village, total nitrogen was very low with values of 0.08% and 0.06% in cultivated and grazing lands, respectively (Table 5) Landon

(1991). The low total nitrogen observed may be attributed to low pH which restricts microbial activities (Karuma *et al.*, 2015).

2.4.4.5 Cation exchange capacity

In Nyagasense village, CEC was high in cultivated land with values of 29.4 cmol (+) kg^{-1} and medium with values of 24.4 cmol (+) kg^{-1} in grazing land. In Iramba village, CEC was low with rating of 11.6 cmol (+) kg^{-1} in cultivated land and medium with values of 13.2 cmol (+) kg^{-1} in grazing land. In Kenyamonta village, CEC was medium with values of 18.4 cmol (+) kg^{-1} and 20.8 cmol (+) kg^{-1} in cultivating and grazing lands, respectively. In Buchanchari village, CEC was medium with a value of 14.8 cmol (+) kg^{-1} in cultivated land and 14.2 cmol (+) kg^{-1} in grazing land (Table 5) according to Landon (1991). The CEC levels observed in these villages indicate that the soils have high nutrient retention capacity (Landon, 1991). Based on CEC observed, the areas are suitable for cereals crop production. Higher CEC in surface soils might be due to higher amount of organic carbon in surface layers.

2.4.4.6 Available Phosphorus

The available phosphorus observed was very low with a value of 3.86 mg kg^{-1} in cultivated land and 4.98 mg kg^{-1} in grazing land in Nyagasense village. In Iramba village, available phosphorus was very low ranging from 5.51 to 3.97 mg kg^{-1} incultivated and grazing lands respectively. In Kenyamonta village, available phosphorus was very low with contents ranging between 5.50 mg kg^{-1} and 4.17 mg kg^{-1} in cultivated and grazing lands, respectively. In Buchanchari village, available phosphorus was medium with values of 10.02 mg kg^{-1} and 8.68 mg kg^{-1} in cultivated and grazing lands, respectively according Landon (1991) rating. Low available phosphorus in the soil may also be attributed to low soil pH (<5.8) observed, as could react with iron and aluminium to

produce insoluble Fe- and Al- phosphates that can not make p available for plant uptake (Hodges, 2007). Phosphorus is an important plant nutrient necessary for root development, nodulation which is important for nitrogen fixation process, pod formation and seed filling in legumes (Marschner, 1995).

2.5   Conclusions and Recommendations

Topographic variations associated with leaching, soil erosion and deposition affect the morphological, physical and chemical characteristics of studied soils infected with Siam weed. The sloping land area was drier than the midslope and lower slope land area. The sloping land area was observed to have dark brown, dark brown and yellowish red in colour; midslope land area observed to have dark reddish brown and the lower slope land area observed to have very dark greyish brown and very dark gray.

The studied profiles were classified as *Rendzic Lithic Leptosols (Eutric, Dystric, Tephric)* on sloping land area, as *Gleyic Plinthic Acrisols (Ferric, Humic)* on midslope land area and as *Haplic Stagnic Gleyic Luvisols (Chromic)* on low land area. According to the results observed from the studied area shows that the area is good for agricultural activities because the organic carbon is above 0.6%. This suggests that Siam weed plant should be incorporated in the soil so as to improve nitrogen and hence soil fertility status. Soils with low soil organic carbon reduces microbial biomass activity and nutrient mineralization due to inadequate energy sources (Tanhan *et al.,* 2007).

References

Adamchuck, V. I. and Mulliken, J. (2005). *Precision Agriculture Site-specific of Soil pH (FAQ), Extension Paper 713*. Historical Materials from University of Nebraska-Lincolin. 05 - 705pp.

Akhtaruzzaman, M., Haque, M. E. and Osman, K. T. (2014). Morphological, Physical and Chemical Characteristics of Hill Forest Soils at Chittagong University, Bangladesh. *Open Journal of Soil Science* 4(01): 26 – 30.

Akobundu, I. O., Ekeleme, F. and Chikoye, D. (1999). Influence of fallow management systems and frequency of cropping on weed growth and crop yield. *Weed Research* 39: 241–256.

Alam, M. L., Miyauchi, N. and Shinagawa, A. (1993). "Study on Clay Mineralogical Characteristics of Hill and Terrace Soils of Bangladesh," *Clay Science* 9: 109 - 121.

Amiolemen, S. O., Iwara, A. I., Ndakara, O. E., Deekor, T. N. and Ita, A. E. (2013). Assessment of the nutrient status of soil under C*hromolaena odorata* (siam weed) fallow in Moniya, Oyo State Southwestern Nigeria. *Agriculture and Biology Journal of North America* 4(2): 137-144.

Baize, D. (1993). Soil Science Analyses: A guide to current use. John Wiley and Sons Ltd. West Sussex. 192pp.

Birkeland, P. W. (1999). "Soil and Geomorphology," Oxford University Press, New York. 430pp.

Brady, N.C. and Weil, R.R. (2008). The Nature and Properties of soils. 13th Edn. Pearson Education, Inc. 965pp.

FAO/ISRIC/ISSS, (2006). "*World References Base for Soil Resources*," World Soil Report, Rome. 128pp.

Gachene, C. K. and Kimaru, G. (2003). Soil fertility and land productivity: A guide for extension workers in the Eastern Africa Region. RELMA Technical handout Series 30. Nairobi, Kenya: Regional Land Management Unit (RELMA), Swedish International Development Cooperation Agency (SIDA).

Gareeb, M., Pammenter, N. W. and Bower, J. P. (2007). Investigation into the mortality of potted *Chromolaena odorata* plants in South Africa. Author *International workshop on biological control and management of Chromolaena odorata and Mikania micrantha*. 28pp.

Gee, G. W. and Bauder, J. W. (1986). Particle size analysis. In: *Methods of Soil Analysis. Part 1. 2nd Edition. Agronomy monography No. 9. (Edited by Klute, A.) American Society of Agronomy, Madison, Wisconsin. 383 – 412pp.

Hodges, S. C. (2007). Basics of Soil Fertility. Soil Science Extension North Carolina State University. 89pp.

Ilori, O. J., Sanni, R. O. and Adenegan-Alakinde, T. A. (2011). Effect of *Chromolaena odorata* on the Growth and Biomass Accumulation of Celosia argentea. *Research Journal of Environmental Sciences* 5: 200 – 204.

Jebril, E. and Yahaya, S. (2010). Pattern of Nutrient Distribution under *Chromolaena odorata* in the Federal Capital Territory, Abuja, Nigeria. *European Journal of Scientific Research* 42 (2): 214 – 219.

Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., Gallali, T., Hallet, S., Jones, R., Kilasara, M., Le Roux, P., Micheli. E., Montanarella, L., Spaargaren, O., Thiombiano, L., Van Ranst, E., Yemefack, M. and Zougmore, R. (2013). (Eds). Soil Atlas of Africa. *European Commission, Publications Office of the European Union, Luxemborg*. 176pp.

Karuma, A. N., Charles, K. K. G., Msanya, B. M., Mtakwa, P. W., Amuri, N. and Patrick, T. G. (2015). Soil Morphology, Physico - Chemical Properties and Classification of Typical Soils of Mwala District, Kenya. *International Journal of Plant and Soil Science* 4(2): 156 – 170.

Koutika, L. S. and Rainey, H. J. (2010). *Chromolaena odorata* in Different Ecosystems: Weed or Fallow Plant. *Applied Ecology and Environmental Research* 8(2): 131 – 142.

Landon, J. R. (1991). *Booker tropical soils Manual. A hand book for soil Survey and agricultural Land evaluation in tropics and subtropics*, Longman Harlow. 107– 298pp.

Marschner, H. (1995). Functions of mineral nutrients: macronutrients. In: *Mineral nutrition of higher Plants*. 2nd Edition, Academic Press, Amsterdam, Netherlands. 379 - 396pp.

Mcbride, R. A., Dane, J. H. and Topp, G. C. (2002). *Methods of Soil Analysis Part* 4: No. 5. In: Soil Science Society of America Book Series. SSSA, Inc. Madison, Wisconsin, USA. 389 - 398pp.

Mgobozi, M. P., Somers, M. J. and Dippenaar-Schoeman, A. S. (2008). Spider responses to alien plant invasion: the effect of short-and long-*term Chromolaena odorata* invasion and management. *Journal of Applied Ecology* 45(4): 1189 - 1197.

Moukam, A. and Ngakanon, D. (1997). The fertility status surface soils in the humid forest zone of Southern Cameroon. *East African Crop Science Journal* 5: 273 – 284.

Msanya, B. M., Kaaya, A. K., Araki, S. H. and Nyadzi, G. I. (2003). Pedological characteristics, general fertility and classification of some benchmark soils of Morogoro District,Tanzania. *African Journal of Science and Technology, Science and Engineering Series* 4 (2):101 – 112.

Munsell Colour, (1994). *Munsell Soil Colour Charts*. Revised edition. 34pp.

Murphy, R. K., Raveendra, H. R. and Manjunatha, R. T. B. (2010). Effects of Chromolaena and Parthenium as green manure and their compost on yield, uptake and nutrient use efficiency on Typic Paleustalf. *European Journal of Biological Sciences* 4(1): 41 - 45.

Nandi, A. Luffman. (2012). Erosion related changes to physicochemical properties of Ultisols distributed on calcareous sedimentary rocks. *Journal of Sustainable Development* 5(8): 52-68.

Nelson, D. W. and Sommers, L. E. (1982). Total carbon, organic carbon and organic matter. In: *Methods of Soil Analysis*. Part 2; Chemical and Mineralogical properties, 2nd Edition.(Edited by Page, A. L., Miller, R. H. and Keeney, D. R.). American Society of Agronomy, Madison, Wisconsin. 539 - 579pp.

Obatolu, C. R. and Agboola, A. A. (1993). "The Potential of Siam Weed (*Chromolaena odorata*) as a Source of Organic Matter for Soil in the Humid Tropics" *Organic Matter Dynamics and Sustainability of Tropical Agriculture*. Chichester: John Willey and Sons. 87 - 93pp.

Okalebo, J. R., Gathua, K.W. and Woomer, P. L. (2002). *Laboratory Methods of Soil and Plant Analysis: A working Manual*, 2nd Edition. 128pp.

Robinson, M. (2006). Controlling the spread of one of the world's worst alien wed species, *Chromolaena odorata* in South Africa. *Department of life Science, University of West Indies*. 1 – 11pp.

Slaats, J. J. P., Janssen, B. H. and Wessel, M. (1998). Crop Production in Relation to Cultural (eds.) Soils Organic Matter Dynamics and Sustainability of Tropical Agriculture. Chichester: John Willey and Sons. 87 - 93pp.

Soil Survey Staff, (2006). Keys to Soil Taxonomy, 8th Edition. USDA-Natural Resource Conservation Service, U.S Government Print. Office, Washington DC. 327pp.

Sollins, P., Grier, C. C., McCorison, F. M., Cromack, K. and Fogel, D. (1980). "The Internal Nutrient Budget of an Old Growth Douglas-Fir Ecosystem in Western Oregon," *Ecological Monographs* 50: 261 – 285.

Sparks, D. L., Page, A. L., Helmke, P. A., Loeppert, R. H., Soltanpour, P. N., Tabatabai, M. A. and Sumner, M. E. (1996). *Methods of soil analysis. Part 3. Soil Science Society of America* Inc. 44pp.

Tanhan, P., Kruatrachue, M., Pokethitiyook, P. and Chaiyarat, R. (2007). Uptake and accumulation of cadmium, lead and zinc by Siam weed [*Chromolaena odorata* (L.) King and Robinson]. *Chemosphere* 68(2): 323 – 329.

Vreeken, W. J. (1973). "Soil Variability in Small Loess Watersheds: Clay and Organic Matter Content*," Catena* 1: 18l – 195.

Wakindiki, I. C. and Ben-Hur, M. (2002). Soil mineralogy and texture effects on crust micro morphology, infiltration and erosion. *Soil Science Society of America Journal* 66: 597– 605.

Walpola, B. C., Subasinghe, S., Yoon, M. H. and Arunakumara, K. K. I. U. (2011). *Pterocarpus santalinus Linn. f.(Rath handun)*: a review of its botany, uses, phytochemistry and pharmacology. *Journal of the Korean Society for Applied Biological Chemistry* 54(4): 495 – 500.

Yahaya, S. and Edicha, J. (2010). A Comparative Study of Nutrient Cycling on Soils Under *Daniella oliveri* and *Chromolaena odorata* in the Federal Capital Territory, Abuja, Nigeria. *American Journal of Scientific Research* 10: 26 – 33.

Yair, A. (1990). The role of topography and surface cover upon soil formation along hill slopes in arid climates. *Geomorphology* 3(3): 287 – 299.

CHAPTER THREE

3.0   Decomposition, Mineralization and nutrient release patterns from the Siam weed plant (leaf, stem, bulb and root) in soils from Serengeti District, Tanzania

3.1   Abstract

Chromolaena odorata (Siam weed) is a new type of weed currently infesting some parts of Tanzania especially Mugumu in Serengeti District. Most of the farms in Serengeti were abandoned because of Siam weed plant which suppresses growth of other agricultural crops, hence reduces crop land and crop yields. However, when Siam weed is incorporated into the soil, it is reported to improve soil fertility. An incubation study was therefore conducted to determine the decomposition and mineralization patterns of nutrients from different parts of Siam weed plant. The weed parts namely leaf, stem, bulb and stem were thoroughly mixed with soil from study area into soil so as to evaluate its potential for releasing nutrients through soil incorporation; this was done through incubation studies from 0 week to 16 weeks. The treatments were leaves, stem, bulb and roots which undergo mineralization to sequencially release amounts of N, P, K, Ca, Mg, Zn, Mn, Cu and Fe. The results from Siam weed plants materials before incorporation into the soil showed that leaves contain high amounts of TN and P with values of 1.96% and 0.86%, respectively. Stem contained high amounts of K (1.99%). Roots contained high amounts of N (1.42%) and bulbs contained medium amounts of N (0.47%). The results from incubation study in 12 weeks showed that leaves released more amounts of N, P, K, Zn, Cu, Fe and Mg with values of 0.295%, 40 mg kg^{-1}, 0.79 cmol (+) kg^{-1} , 2.12 mg kg^{-1}, 2.34 mg kg^{-1}, 2.34 mg kg^{-1} and 64.15 mg kg^{-1} respectively, as compared to other parts while stem released high amounts of Ca amounting to 5.1 cmol (+) kg^{-1} and Mg amounting to 77.18 cmol (+) kg^{-1}. During the incubation period most of these nutrients

released was high at 12th week and start to decrease at 16th week. Therefore Siam weed plant attained their maximum nutrient released between eight and twelve weeks of incubation. Farmers are recommended to plant their crops before week 12 so that the plants can absorb nutrients from Siam weed.

3.2 Introduction

Most of the farms in Serengeti have been abandoned because of Siam weed infestation that tends to suppress growth of other agricultural crops, leading to low yields. This weed plant has a long tape root of about 300 mm which absorbs more nutrients from deeper horizons hence making it more competitive in absorbing nutrients from soils as compared to other crops (Parsons and Cuthbertson, 1992). One of the major constraints to crop production in the area affected with Siam weed plant is the low fertility status of most of the soils which is a reflection of the low level of organic matter, nitrogen, phosphorus and exchangeable cations (de Ridder and van Keulen, 1990). When Siam weed plant is incorporated into the soil, it improves soil fertility status as reported in research findings that the plant enhances the build-up of nutrients in soil (Obatolu and Agboola, 1993; Ilori *et al*., 2011). Siam weed plant regenerates and colonizes fallow lands or newly cleared piece of land through its roots or by high seed production and wind which enhances its dispersal (Koutika and Rainey, 2010).

This plant is regarded as an excellent fallow weed in arable farming land since it takes nutrients far away because of its long tape root (Obatolu and Agboola, 1993). Smith and Alli (2005) also reported that Siam weed plant mulch is effective against weed invasion and increase some mineral nutrients when incorporated in the soil. Mulching with residues of weeds such as Siam weed was found to increase yield of crops such as maize (Ojeniyi and Adetoro, 1993; Falade and Ojeniyi, 1997; Awodun and Ojeniyi, 1999) and

soil nutrient contents. Siam weed plant grows very fast and forms dense and impregnable foliage that can completely smother a young plantation of crops or other weeds (Uyi *et al.,* 2013). Research done by Nwokolo (1987) comparing the mineral composition of Cassava and Siam weed, concluded that Siam weed plant on dry matter basis has high amounts of P, Mg, Cu, Mn and Fe compared to those in cassava leaves. The contents of cation exchange capacity and other minerals in soils with Siam weed increased steadily with the age of fallow, meaning that the more the fallow period, more nutrients are added to the soil (Aweto and Dikinya 2003; Offiong and Iwara, 2011). *Chromolaena odorata* L. (Kings and Robinson) also known as Siam weed is a common fallow plant that is usually disc-ploughed into the soil in a short fallow period that produces large quantities of nutrient-rich biomass that could be used as mulch (Baruah and Sarma, 1996; Apori *et al.,* 2000). The plant also known to supports a large and varied insect fauna like *Zonocerus variegates* which has been known to destroy economic crops like cassava, banana and citrus. Atayese and Liasu (2001) found that soils under *Chromolaena odorata* contained arbuscular mycorrhizal fungi spore which enhanced absorption of nutrients from soil to biomass. *Chromolaena odorata* due to its compositions are able to release macro nutrients thereby increasing soil fertility and crop nutrient uptake (Taiwo *et al.,* 2014).

The purpose of this study was to examine the pattern of decomposition and release of mineral nutrients from different parts of Siam weed plant when incorporated into the soil in a given period of time (0, 4, 8, 12 and 16 weeks). The relationship between different parts of Siam weed plant residue characteristics with the nutrient release were tested to quantify the amount of nutrients released from different parts of Siam weed plant to the soil environment.

3.3   Materials and Methods

3.3.1   Materials

The materials used in the experiment include soil and Siam weed plant samples from Serengeti District.

3.3.2   Methods

3.3.2.1   Sampling for incubation study

Composite soil samples were obtained from topsoil, (0 - 20 cm) in sloping land, midslope land and low or flat land area which is mostly affected by Siam weed plants.

3.4   Soil Analysis

3.4.1   Preparation of soil sample for incubation study

Composite soil samples from the field were air- dried, ground and sieved to obtain <2 mm fraction on which the analysis was carried out in the Soil Science Laboratory at SUA. Soil particle size distribution was determined based on Hydrometer method (Gee and Bauder, 1986) while textural class was delivered from the textural class triangle. Soil pH, organic carbon, total N and available P, were determined using the procedure described by Okalebo *et al*. (2002). DTPA Extractable micronutrients were determined using the procedures described by Lindsay and Norvell (1978).

3.5   Incubation Study

3.5.1   Plant samples analysis

Plant samples were sepatately collected from as leaves, bulb of the stem, stem and roots. The samples were then chopped to smaller parts, dried, ground and passed through a 0.5 mm sieve. Sieved plant samples were weighed (0.5 g) and put into tubes for digestion. Total plant materials analysis was undertaken based on methods described by Okalebo

et al. (2002). Plant materials were digested using a mixture of HNO_3 and H_2O_2 as outlined by Jones and Case (1990) and modified by Moberg, (2000). Then 5ml of 68% HNO_3 were added into each tube using an automatic pipette and the mixture was left to stand overnight. The tubes were then placed in a digested block at 125^oC for one hour to digest before being taken off and cooled. This was followed by adding 5 ml H_2O_2 was added into each tube and the contents heated at 70^oC on the digestion block until when the reaction stopped. This treatment was repeated until the digest was colourless. The digest was then heated on the digestion block at 180^oC to almost dryness.

After cooling, 10 ml of 10% HNO_3 were added and the dissolved digest was transferred quantitatively to a 100 ml volumetric flask before being filled to the mark with distilled water. The digest was then analyzed for total N, P, bases (Ca, Mg, K and Na) and micronutrients (Cu, Zn, Mn, Fe).

3.5.2   Duration of Incubation study

An incubation study was conducted in the Soil Science Laboratory at Sokoine University of Agriculture from September, 2014 to January, 2015. Residues from different parts of Siam weed plant (leaf, stem, bulb and roots) were incorporated into the soil in an incubation study.

3.5.3   Characterizations of different parts of Siam weed plant

Characteristics of different parts of Siam weed plant that influence nutrients availability were evaluated. These characteristics were nitrogen content, micronutrients, organic carbon, iron, calcium, magnesium and available phosphorus. Nitrogen content, available phosphorus, organic carbon, calcium and magnesium were determined using the

procedure described by Okalebo *et al*. (2002). Micronutrients of incubated soil were determined using the procedure described by Lindasy and Norvell, (1978).

3.5.4 Decomposition of Siam weed plant residue through incubation technique

Composite topsoil (to a depth of 0-20 cm) was collected from the study area which is the most affected village with Siam weed in Serengeti District. The samples were air dried, ground and sieved through 2 mm sieve to homogenize them and used for the incubation study. Different parts of Siam weed plant were ground to pass through a 0.5 mm sieve. The weights of 2 g of each part of Siam weed were mixed with 200 g of soil. The mixture was incubated in a plastic container of 1 litre and moistened to 60% of soil moisture field capacity and incubated at room temperature of $25^{o}C \pm 1^{o}C$ for 16 weeks.

Soil moisture status was maintained at 60% of soil field capacity by intermittent weighing the containers and correcting weight loss by adding distilled water. Nutrients were analyzed at zero, four, eight, twelve and sixteen weeks of incubation. The following available minerals were involved; N by chemical analysis using Kjedahl method as described by Okalebo *et al*. (2002). Other Plant nutrients like available P, K, Ca and Mg were determined using the procedure described by Okaleb *et al*. (2002), and Cu, Mn, Fe and Zn were also determined using the procedure described by Lindasy and Norvell (1978).

3.5.5 Sampling of incubated soil sample from week zero to sixteen

Soil and plant samples were placed in 500 ml containers. Each container comprised of a mixture of 2 g of plant sample and 200 g of soil sample. Then, a mixture of different parts of the plant (leaves, stem, bulbs and roots) and soil was moistened with distilled water.

Sampling was done from day one (week zero) before decomposition taking place. From each container about 20 g were sampled and brought to the laboratory for nitrogen, phosphorus, potassium and micronutrients analysis and determination of soil pH, respectively. The sampling procedure was repeated after every four weeks.

3.5.6 Treatments and Experiment design for incubation study

The study had five treatments namely, soil incorporated with root part, soil incorporated with bulb, soil incorporated with stem, soil incorporated with leaves and a control. The named five treatments were arranged in a completely randomized design (CRD), with three replications.

3.6 Data Analysis

GenStat statistical software was employed to analyse the collected data. Data for N, P, K, Mg, Ca, Cu, Mn and Fe released from different parts of Siam weed plant when incorporated with soil in week zero, four, eight, twelve and sixteen were analysed by the analysis of variance (ANOVA) technique to test the difference among treatments. Means were separated by using the Duncan's New Multiple Range test at 5% significant level.

3.7 Results and Discussion

3.7.1 Nutrients contents from different parts of Siam weed plant before incubation study

Table 6 presents the results of nutrients content from leaves, stems, roots and bulbs of the Siam weed plant before incubation study.

Table 6: Nutrients contents in leaves, stems, roots and bulbs of the Siam weed plants

Parts of Siam weed plant	total % macronutrient contents				total % micronutrient contents				
	N	P	K	Ca	Mg	Na	Cu	Zn	Mn
Leaves	1.962^M	0.186^M	1.423^M	1.872^{VH}	0.860^H	0.029^{VL}	0.002^{VL}	0.002^{VL}	0.013^{VL}
Stems	0.788^L	0.128^L	1.987^M	0.493^M	0.291^M	0.026^{VL}	0.001^{VL}	0.001^{VL}	0.004^{VL}
Roots	1.424^M	0.028^{VL}	1.189^M	0.416^M	0.369^M	0.039^{VL}	0.001^{VL}	0.003^{VL}	0.024^{VL}
Bulbs	0.468^L	0.068^{VL}	0.391^{VL}	0.255^M	0.188^L	0.024^{VL}	0.001^{VL}	0.001^{VL}	0.005^{VL}

Where; M= Medium, L=Low, VL=Very Low, VH=Very High

Leaves and roots released medium total percent nitrogen with contents ranging from 1.962% to 1.424%. Total percent phosphorus was medium (0.186%) in leaves; low (0.128%) in stem; very low (0.028%) in roots and very low (0.068%) in bulbs. Total percent potassium in leaves, stem and roots was medium with contents of 1.423, 1.987 and 1.189%, respectively and very low contents of 0.391% in the bulbs. Total percent calcium was very high (1.872 %) in leaves and medium contents of 0.493, 0.416 and 0.255% in stem, roots and bulbs, respectively. Total percent magnesium was high (0.860%) in leaves, low (0.188%) in bulbs and medium (0.291%) and (0.369%) in stem and roots, respectively. Total percent copper, zinc and manganese were very low (Table 6) (Landon, 1991). The results of total % macronutrient and micronutrients contents from different parts of Siam weed plant are summarised in figure 1a and 1b.
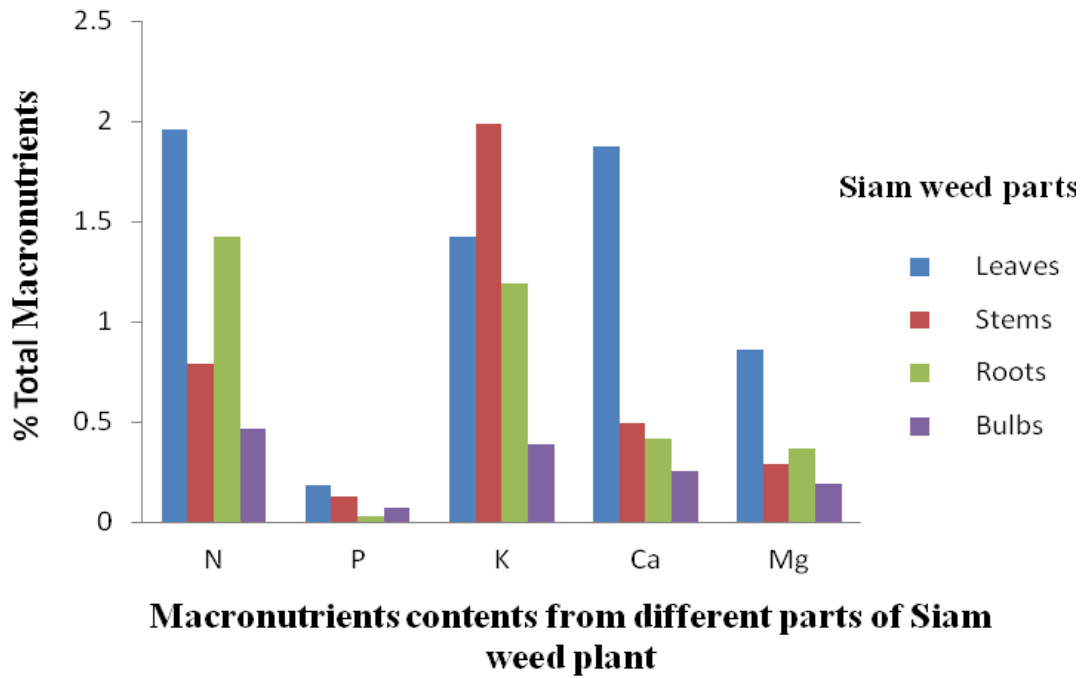
Figure 1a: Total % Macronutrients contents in plant sample of Siam weed plant before incubation study
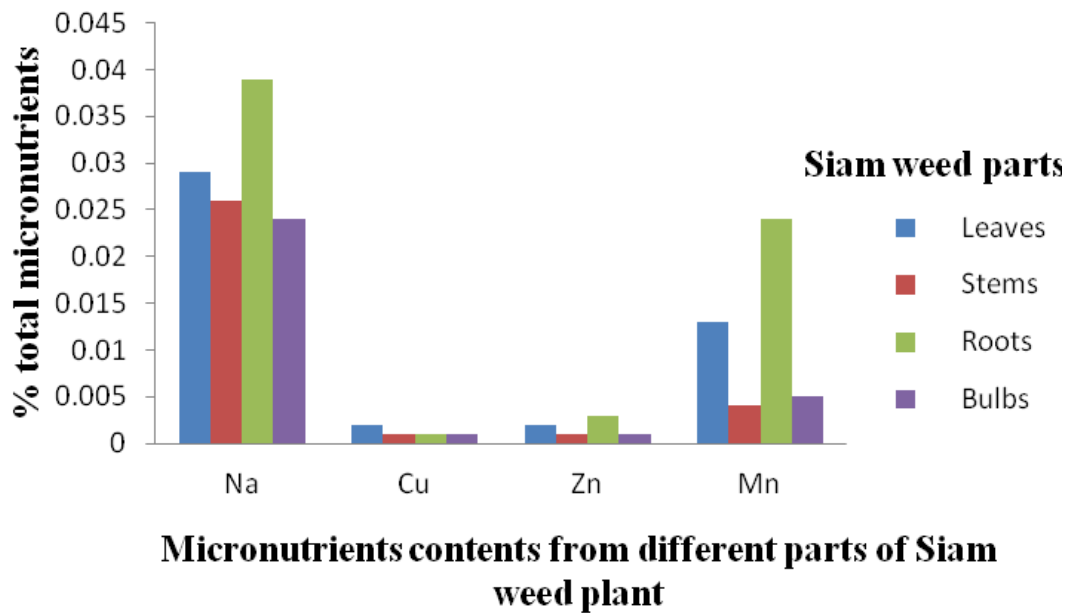

Figure 1b: Total % Micronutrients contents in plant sample of Siam weed plant

before incubation study

The results indicate that the amounts of accumulated nutriens vary from one part of the plant to another. Initially it was presumed that the bulb stored water and nutrients to enable the weed survive adverse climatic and soil conditions. The results of this study have shown that this is not the case.

3.7.2 Nutrients release pattern from different parts of Siam weed plant under incubation study

The results shown in Figure 2 indicate that, the lowest amount of N released was at week zero since decomposition was not taking place. The trend shows an increase in N release from week zero to week twelve which was the time when maximum amount of N was released. This was the same for all plant parts. However, after week twelve there was a decrease in the amount of N released. The results indicated that most of the N was retained by plant leaves followed by the stem. The bulb was assumed to be used as storage for nutrients that could be released for survival of the weed, which in this study it contained low amounts of N. The results further indicate that there was a big potential to use the leaves as an alternative source of N to improve on soil N status.
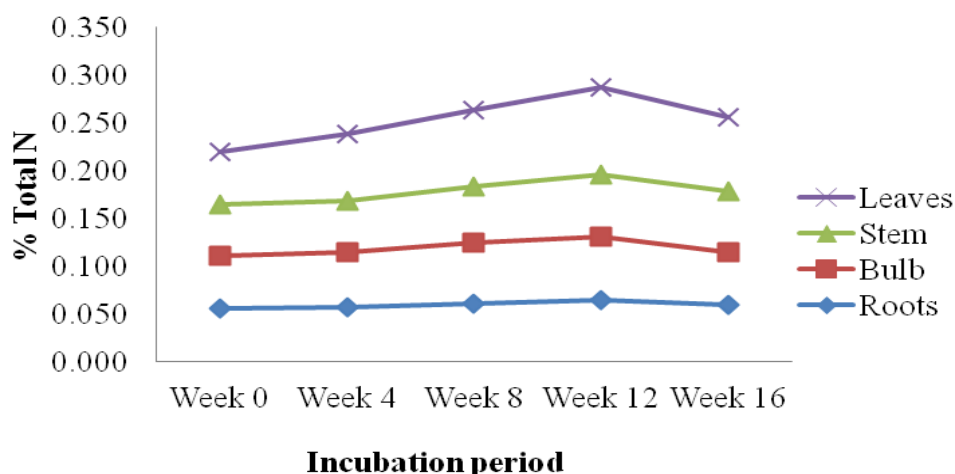

Figure 2: Nitrogen release pattern from incubated Siam weed

The results shown in Figure 3 indicate that, most of the phosphorus was stored in the leaves just like nitrogen. The trend in phosphorus release pattern was also the same as for nitrogen and was of the order Leaves> stem>bulb>roots. The maximum amounts of phosphorus were also released at week twelve followed by a decrease at week sixteen. The bulb was assumed to be used as storage for nutrients that could be released for survival of the weed, which in this study it contained low amounts of phosphorus. The results further indicate that there was a big potential to use the leaves as a green manure or alternative source of P in the soil.
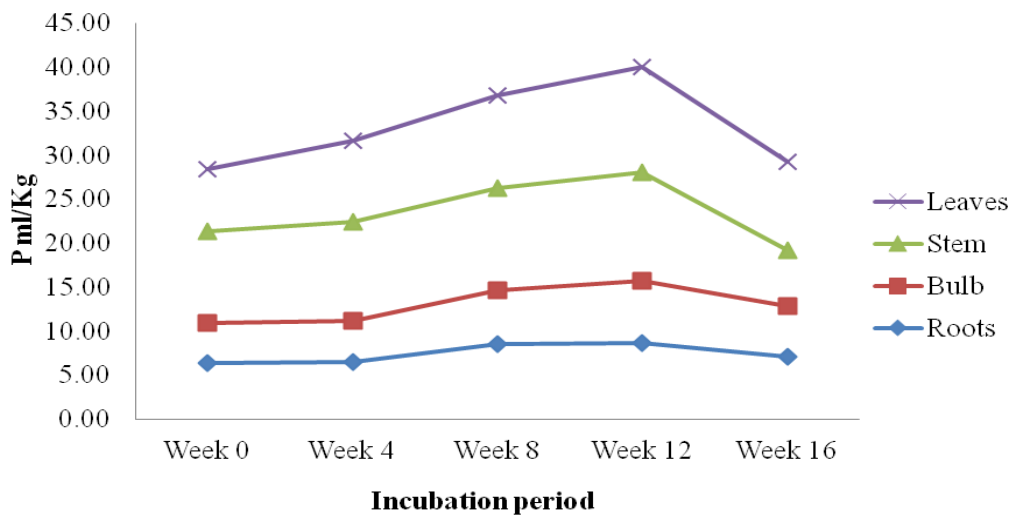

Figure 3: Phosphorus release pattern from incubated Siam weed

The results shown in Figure 4 indicate that, the lowest amount of potassium to be released was at week zero. The trend shows an increase in potassium release from week zero to week twelve which was the time when maximum amounts of potassium were released. This was the same for all plant parts. However, after week twelve there was a decrease in the amount of potassium released. The results indicated that most of the potassium was retained by plant leaves followed by the stem. The results further indicate that there was a

big potential to use the leaves as a mulch or alternative source of potassium to improve the soil fertility status.
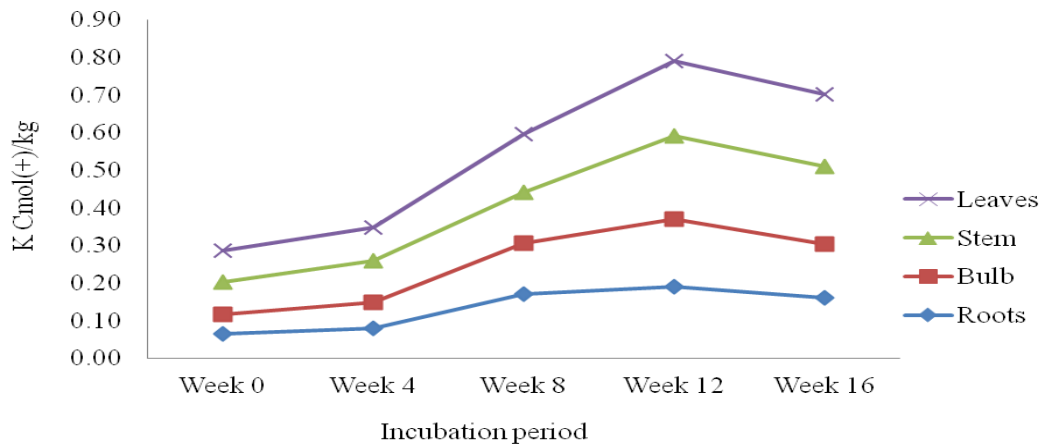

Figure 4: Potassium release pattern from incubated Siam weed

The results in Table 7 show that stem release high amounts of calcium in week twelve followed by bulb, leaves and root. However, after week twelve there was a decrease in the amount of calcium released. Amount of calcium released at week zero to week sixteen did not show significant difference for the all parts of Siam weed plant. Most of the calcium is stored in the stem just like manganese.

Table 7: Amount of Ca (cmol (+) kg^{-1}) released from different parts of Siam weed plant after incubation

Treatment	Incubation time in weeks				
	0	4	8	12	16
Root	3.15a	3.19b	3.92b	4.79b	2.69b
Bulb	3.08a	3.40b	3.65b	5.10b	2.59b
Stem	3.62a	3.35b	4.01b	5.13b	2.41b
Leaves	3.30a	3.29b	3.69b	5.00b	2.37b
CV %	33.3	14.5	25.0	29.7	9.5

Means in the same column followed by similar letter(s) are not statistically different at p<0.05 level of significance

Table 8: Amount of Mg (cmol (+) kg^{-1}) released from different parts of Siam weed plant after incubation

	Incubation time in week				
Treatments	0	4	8	12	16
Root	0.46ab	0.72a	0.44b	0.87b	0.65a
Bulb	0.43a	0.66a	0.39ab	0.81b	0.55a
Stem	0.43a	0.65a	0.44b	0.80b	0.75a
Leaves	0.47ab	2.34b	0.43b	0.83b	0.62a
CV (%)	17.6	24.5	26.5	25.0	47.0

Means in the same column followed by similar letter(s) are not statistically different at p<0.05 level of significance

The results in Table 8 indicate that the lowest amounts of magnesium to be released were at week zero. The increase in magnesium contents from week zero to week twelve which was the time when maximum amounts of magnesium were released. After twelve weeks there was a decrease in the amounts of magnesium released. Table 8 further shows that most of the magnesium was retained by plant roots followed by leaves, bulbs and stems. The amount of magnesium released varied significantly from week four, eight, twelve and sixteen.

Table 9: Amount of Cu (mg kg^{-1}) released from different parts of Siam weed plant after incubation

	Incubation time in weeks				
Treatments	0	4	8	12	16
Root	0.46ab	0.72a	0.44b	0.87b	0.89c
bulb	0.43a	0.66a	0.39ab	0.81b	0.55ab
stem	0.43a	0.65a	0.44b	0.80b	0.75bc
Leaves	0.47ab	2.34b	0.43b	0.83b	0.62ab
CV%	17.6	24.5	26.5	25.0	16.6

Means in the same column followed by similar letter(s) are not statistically different at p<0.05 level of significance

The results in Table 9 indicate that, the lowest amounts of copper were released at week zero. Leaves released high amounts of copper at week twelve followed by stem, bulb and

The results in Table 11 indicate that, roots released the highest amounts of zinc at week twelve followed by stem, bulb and leaves. However at sixteenth week there was a decrease in the amounts of zinc released for all plant parts. Most of the zinc is stored in roots. The amounts of zinc released at week zero, four, eight, twelve and sixteen were not significantly different for all plant parts.

Table 12: Amount of Fe (mg kg^{-1}) released from different parts of Siam weed plant after incubation

	Incubation time in weeks				
Treatments	0	4	8	12	16
Root	6.08a	37.03b	39.81a	50.36bc	36.85ab
Bulb	6.06a	47.31b	38.44a	53.31cd	41.96ab
Stem	5.81a	37.88b	37.67a	39.40b	36.40a
Leaves	36.4b	49.34b	51.27a	64.15d	49.30a
CV (%)	51.9	20.9	37.2	14.2	19.8

Means in the same column followed by similar letter(s) are not statistically different at p<0.05 level of significance

The results in Table 12 indicate that, leaves released high amounts of iron at week twelve followed by bulbs, roots and stem, but at week sixteen there was a decrease in the amounts of iron released for all plant parts. Therefore, the results indicate that most of the iron is retained by plant leaves (like nitrogen) followed by the bulb, root and stem. Amounts of iron released at week zero and eight were not significantly different but amounts of iron released at week four, twelve and sixteen were significantly different.

The results from this study showed that, different parts of Siam weed plant release maximum nutrients in twelveth week and start to decrease thereafter. The results further indicate that there is a big potential to use Siam weed plant as a green manure. The green manure will act as an alternative source of nutrients to improve soil fertility status. The use of Siam weed plant has the ability to amend and add nutrients into the soil. Incubating

the soil with parts of Siam weed plant materials significantly increased the amount of nutrients released in the soil (Murungu *et al.,* 2011). However, the increase in nutrients released differs with parts of incubated Siam weed material.

The significant differences in nutrients released from different parts of Siam weed plant were attributed mainly by time of incubation. The more the incubation time the more were the nutrients released (Molindo, 2008 and Smith, 1995). Also, the observation made by Sukartono *et al.* (2011), showed that Siam weed when incorporated into the soil can increase amounts of nitrogen, phosphorus, potassium, calcium, magnesium and C/N ratio but not the soil pH. According to Tanhan *et al.* (2007), low C/N ratio means poor soil fertility which leads to reduction of microbial activities hence low nutrient mineralization due to shortage of energy sources. The increase or decrease of some nutrients in the soil depends on Soil pH, organic matter and flooding (Flis, 2008; Hesse, 1971; Silanapaa 1982; Welch, *et al.,* 1991 and Shuman, 1991). Pavan *et al.* (1984), reported that pH > 8.4 decrease drastically some amount of nutrients in the soil like magnesium.

When *Chromolaena odorata* used as a mulching material, it reduced soil bulk density and increased soil organic matter, nitrogen, phosphorus, potassium, calcium and magnesium concentrations (Agbede *et al.,* 2013). Organic matter is known to improve soil structure, aeration, reduce soil bulk density and enhance water infiltration and retention (Hsieh and Hsieh, 1990). Using Siam weed as a mulching tend to increase activities of beneficial soil fauna in organic matter decomposition, which leads to enhancement of soil porosity and reduction of soil bulk density. Also, the mulch protect the soil, stabilize the soil structure against raindrop impact and, thereby, preventing soil erosion and soil compaction (Olabode *et al.,* 2007). Farmers traditionally use the succulent biomass of Siam weed as a source of green manure in wetland paddy cultivation (Ambika and Jayachandra, 1992).

Therefore, Siam weed plant can be used as a source of nutrients to poor resource farmers as viable alternative to inorganic fertilizers. Poor resource smallholder farmers can use this technology as a source of nutrients in the soil so as to improve soil fertility status and increase yield at family level. High amount of nutrients were released at week twelve, suggesting that, plants grown just before week eight will benefit more by absorbing most of the nutrients.

3.8 Conclusions and Recommendations

Results from this incubation study show that, different parts of Siam weed plant (bulbs, roots, stems and leaves) when incorporated into the soil from week 0 to 16 release different types and amounts of nutrient contents in the soil. Amounts of nutrients released from Siam weed plants increases in the following order week 0>week 4>week 8>week 12 and starts to decrease in week 16 of incubation. Therefore, Siam weed plant attains their maximum nutrient release in 12th week of incubation study. Hence, If Siam weed plant materials are incorporated into the soil farmers are advised to grow their crops before 12th week so that the plants can absorb the nutrients from the released Siam weed plant.

Acknowledgements

References

Agbede, T. M., Adekiya, A. O. and Ogeh, J. S. (2013). Effects of *Chromolaena* and *Tithonia* mulches on soil properties, leaf nutrient composition, growth and yam yield. *West African Journal of Applied Ecology* 21(1): 15 – 30.

Ambika, S. R. and Jayachandra, P. (1992). Allelopathic effects of *Chromolaena odorata* (L) King and Robinson. In: *Allelopathy in Agroecosystems.* Narwal, S. S. (ed.). *Scientific Publishers, Jodpur.* 139 - 15pp.

Apori, S. O., Long R. J., Castro, F. B. and Orskov E. R. (2000). Chemical composition and nutritive value of leaves and stems of tropical weed Chromolaena odorata. *Grass Forage Science* 55(1): 77 – 81.

Atayese, M. O. and Liasu, M. O. (2001). Arbuscular mycorrhizal fungi weeds and earthworm interactions in the restoration of soil fertility in the guinea savanna region of Nigeria. *Moor Journal of Agriculture Research* 3: 104 – 109.

Aweto, A. O. and Dikinya, O. (2003). The Beneficial Effects of Two Tree Species on Soil Properties in a Semi-Arid Savanna Rangeland in Botswana. *Land Contamination and Reclamation* 11 (3): 339 – 344.

Awodun, M. A. and Ojeniyi, S. O. (1999). Use of weed mulches for improving soil fertility and maize performance. *Application of Tropical Agriculture* 3: 26 – 30.

Baruah, S. and Sarma, D. (1996). Effect of mulching on growth and yield of young tea *Journal of Agriculture Science, North East India* 9(2): 141–144.

De Ridder, N. and Van Keulen, H. (1990). Some aspects of the role of organic matter in sustainable intensified arable farming systems in the West-African semi-arid-tropics (SAT). *Fertilizer research* 26(1-3): 299 – 310.

Falade, I. A. and Ojeniyi, S. O. (1997). Effect of Siam weeds mulch on soil nutrient contents and maize performance. *Application of Tropical Agriculture* 2: 100 – 113.

Flis, S. A. (2008). The effects of high copper dairy manure on manure storage, soil, and plant growth and composition. Specializing in Plant and Soil Science. Dissertation for Award of PhD at University of Vermont, USA. 171pp.

Gee, G. W. and Bauder, J. W. (1986). Particle size analysis In: *Methods of Soil Analysis* Part 1. 2nd Edition. Agronomy monography No. 9. (Edited by Klute, A.) *American Society of Agronomy*, Madison, Wisconsin. 383 – 412pp.

Hesse, P. R. (1971). A textbook of soil chemical analysis. John Murray, London. 265 – 270pp.

Hsieh, S. C. and Hsieh, C. F. (1990). The use of organic matter in crop production. *Extension Bulletin.* ASPAC Food and Fertilizer Technology Centre, Taipei City, China. 315pp.

Ilori, O. J., Sanni, R. O. and Adenegan-Alakinde, T. A. (2011). Effect of *Chromolaena odorata* on the Growth and Biomass Accumulation of *Celosia argentea*. *Research Journal of Environmental Sciences* 5: 200 – 204.

Jones, B. J. J. R. and Case, V. W. (1990). Sampling, handling and analyzing plant tissue samples. In: *Soil Testing and Plant Analysis* 3rd edition. (Edited by Westerman R. L.), Soil Science Society of America Inc, Madison, Wisconsin. 389 – 427pp.

Koutika, L. S. and Rainey, H. J. (2010). *Chromolaena odorata* in Different Ecosystems: Weed or Fallow Plant. *Applied Ecology and Environmental Research* 8(2): 131 – 142.

Lindsay, W. L. and Norvell, W. A. (1978). Development of DTPA soil test for zinc, iron, manganese and cupper. *Soil Science Society of America Journal* 42: 421 – 428.

Moberg, J. P. (2000). *Soil and Plant Analysis Manual*. The Royal Veterinary and Agricultural University, Chemistry Department, Copenhagen, Denmark. 133pp.

Molindo, W. A. (2008). Department of Agriculture (Soil Science Option). Faculty of Basic and Applied Science Benson Idahosa University, Benin City, Nigeria. *World Journal of Agricultural* Sciences 4 (6): 731 – 736.

Murungu, F. S., Cornelius, C., Pardon, M. and Pearson, M. (2011). Decomposition, Nitrogen, and Phosphorus Mineralization from Residues of Summer-Grown Cover Crops and Suitability for a Smallholder Farming System in South Africa. *Communications in Soil Science and Plant Analysis* 42: 2461 – 2472.

Nwokolo, E. (1987). A nutritional assessment of African yam bean (*Sphenostylis stenocarpa*), (Hoechst. ex. A. Rich) Harms and Bambara groundnut Voandzeia subterranea L. *Journal of Science, Food and Agriculture* 41(2): 123 – 129.

Obatolu, C. R. and Agboola, A. A. (1993). "The Potential of Siam Weed (*Chromolaena odorata*) as a Source of Organic Matter for Soil in the Humid Tropics" *Organic Matter Dynamics and Sustainability of Tropical Agriculture*. Chichester: John Willey and Sons. 87 – 93pp.

Offiong, R. A. and Iwara, A. I. (2011). Effects of Fallow Genealogical Cycles on the Build-up of Nutrients in Soils of the Cross River Rainforest, South Southern Nigeria. *Ethiopian Journal of Environmental Studies and Management* 4 (4): 84 – 95.

Ojeniyi, S. O. and Adetoro, A. O. (1993). Use of *Chromolaena odorata* mulch to improve yield of late season okra. *Nigerian Journal of Technical Education* 10: 144 – 149.

Okalebo, J. R., Gathua, K. W. and Woomer, P. L. (2002). *Laboratory methods of soil and plant analysis: a working manual*. Tropical Soil Biology and Fertility Programme 88pp.

Olabode, O. S., Ogunyemi, S., Akanbi, W. B., Adesina, G. O. and Babajide, P. A. (2007). Evaluation of *Tithonia diversifolia* (Hemsl.) A gray for soil improvement. *World Journal of Agricultural Sciences* 3(4): 503 – 507.

Parsons, W.T. and Cuthbertson, E. G. (1992). Noxious weeds of Australia Inkata Press. Quality of an ecosystem case study of their uses, *Forest Ecology and Management* 138: 357 – 368.

Pavan, M. A., Bingham, F. T. and Pratt, P. F. (1984). Redistribution of exchangeable calcium, magensium, and aluminum following lime or gypsum applications to a Brazilian Oxisol Soil. *Soil Science Society of America Journal* 48(1): 33 – 38.

Shuman, L. M. (1991). Chemical forms of micronutrients in soil. *In*: J. J. Mortvedt, F. R. Cox, L. M. Shuman, and R. M. Welch (Eds), Micronutrients in agriculture. *Soil Science Society of America, Madison* 4: 113 – 144.

Sillanpää, M. (1982). *Micronutrients and the nutrient status of soils: a Global Study*. Food and Agriculture Organisation of the United Nations. 48pp.

Smith, M. A. K. and Alli, A. L. (2005). Mulching effect of tropical plant residues on weed control and maize (*Zea mays* L.) yield. In: *Proceedings 1st Annual Conference on Development in Agriculture and Biological Science 27th April* 26 - 30pp.

Smith, W. H. (1995). Over view of research on compost in the USA. In: *Proceedings of a concerence on composting in the Carolinas, Charlotte, NC, January 18-20 Clemson, SC; Clemson University.* 174 – 182pp.

Sukartono, W. H., Utomo, W. H., Nugroho and Kusuma, Z. (2011). Simple biochar production generated from cattle dung and coconut shell. *Journal Basic Applied Science Research* 1: 1680 – 1685.

Taiwo, M. A. and Lawrence, A. A. (2014). Soil fertility improvement potentials of Mexican sunflower (*Tithonia diversifolia*) and Siam weed (*Chromolaena odorata*) using okra as test crop. *Applied Science Research* 6 (2): 42 – 47.

Tanhan, P., Pokethitiyook, P., Kruatrachue, M. and Chaiyarat, R. (2007). Uptake and accumulation of cadmium, lead and zinc by Siam weed [*Chromolaene odorata* (L) King and Robinson]. *Chemosphere* 68: 323 – 329.

Uyi, O. O., Egbon, I. N., Igbinosa, I. B., Adebayo, R. A. and Oigiangbe, O. N. (2013). *Chromolaena odorata* in Nigeria: extent of spread, problems and control. In: *Proceedings of the 8th International Workshop on Biological Control and Management of Chromolaena odorata and other Eupatridae, Nairobi, Kenya.* 43pp.

Welch, R. M., Allaway, W. H., House, W. A. and Kubota, J. (1991). Geographic distribution of trace element problems. In: J. J. Mortvedt, F. R. Cox, L. M. Shuman, and R. M. Welch (Eds). *Soil Science Society of America, Madison* 4: 31 – 58.

CHAPTER FOUR

4.0   GENERAL CONCLUSIONS AND RECOMMENDATIONS

4.1   General Conclusions

The present study has clearly shown that Siam weed plant as a new weed has infested some parts of Serengeti District displaying different characteristics and behaviour. It can be concluded from the present study that:

i.   Siam weed plants grow in sandy loamy soils with low soil moisture condition and in slightly acidic to moderate alkaline ranges of soil pH (5.8-7.9).

ii.   It does not grow in low or flat areas with high soil moisture condition.

iii.   The soils were classified to the subgroup level of the USDA Soil Taxonomy as Ustic Torripsamment*s* on sloping land, as Haplic plinthustults on midslope and as Plinthaquic paleudalfs on low land and to Tier-2 of WRB as *Rendzic Lithic Leptosols* (*Eutric, Dystric, Tephric*) on sloping lands, as *Gleyic Plinthic Acrisols* (*Ferric, Humic*) on midslope and as *Haplic Stagnic Gleyic Luvisols* (*Chromic*) on low or flat areas.

iv.   Colour of the soil in sloping land area was dark brown and yellowish red when soil was dry; very dark brown when the soil was moist. In midslope land, colour was dark reddish brown when the soil was dry; dark reddish brown and dark red when soil was moist. In low or flat land, colour was very dark greyish brown and very dark gray when soil was moist.

v.   Soils of the studied area shows to have high fertility status because the organic carbon is above 0.6%.

vi.   From the incubation study, Siam weed leaves contained high amount of nitrogen, phosphorus, potassium, iron, magnesium and copper.

vii. The stem part releases high amount of calcium and manganese than other parts of Siam weed plant.

viii. Siam weed plant attains their maximum nutrient release in 12th week of the incubation study followed by decrease in 16th and therefore incorporation of the plant's parts as alternative sources of nutrients has to take into consideration the nutrients release patterns.

4.2   General Recommendations

Use of Siam weed plant is suggested to be applied in Serengeti district soil so as

i. Farmers are advised to grow their crops just before week twelve to maximize nutrients absorption released under mineralization study.

ii. Incorporation of Siam weed in the soil is recommended to be used by smallholder farmers to improve fertility status of the soil and increase agricultural yields.

iii. In order to improve morphological, physical and chemical characteristics of the studied soils especially in sloping land area, contour practices and use of Siam weed plant as a green manure or incorporation into soils to protect the soils should be used.

iv. There is need to conduct field work/experiments that will evaluate the performance of crops when applied with Siam weed plants materials as organic fertilizers.