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ASSESSING THE FERTILITY STATUS OF A RECLAIMED SITE PLANTED WITH PINEAPPLE: A CASE STUDY AT GHANA MANGANESE COMPANY- NSUTA

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no materials which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

A three year old reclaimed site revegetated with pineapples, oil palm trees and plantain was observed to have all the planted crops develop, with the exception of pineapples. The influence of soil parameters such as pH, temperature, cation exchange capacity, water holding capacity, organic matter and success rate were examined. Nitrogen was determined with the use of Kjeldahl method, phosphorus extracted using neutral ammonium acetate and analysed with flame photometer whilst the content of potassium was determined using the Bray's Method (No.1). The reclaimed site recorded lower soil parameters of nitrogen (0.04%), phosphorus (0.21ppm), potassium (15.64ppm), cation exchange capacity (4.81cmolc/kg), water holding capacity (47.90%) and organic matter (1.10%) compared to the standard soil requirements by the Food and Agriculture Organisation (FAO). However, the control site recorded soil parameters of nitrogen (0.27%), phosphorus (26.23ppm), potassium (74.39ppm), cation exchange capacity (7.25cmolc/kg), water holding capacity (71.3%) and organic matter (8.31%) which were within the range for standard soil requirements by the Food and Agriculture Organisation (FAO).

This resulted in the higher yield of pineapples (74 %) at the control site than the reclaimed site (12.6 %).

The study revealed that the nutrient cycle at the reclaimed site at Ghana Manganese Company has been broken down; therefore the soil ultimately has become unproductive for the cultivation of pineapples.

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GLOSSARY

AAS	Atomic Absorption Spectrophotometer
BFAP	Bureau for Food and Agricultural policy
CEC	Cation exchange capacity
DAP	Ammonium phosphate
DTPA	Diethylenetriamine - pentaacetic acid
EDTA	Ethylenediamine - tetraacetic acid
FAO	Food and Agriculture Organization
FESS	Foundation for Environmental Security and Sustainability
GDP	Gross domestic product
MAP	Monoammonium phosphate
MC	Moisture content
MoFA	Ministry of Food and Agriculture
NGOs	Non-Governmental Organizations
NPK	Nitrogen, phosphorus and potassium
OC	Organic matter
Ppm	Parts per million
SRI	Soil Research Institute
SSP	Single superphosphate
TSP	Triple superphosphate
WHC	Water holding capacity
WRRC	Western Regional Research Center

CHAPTER ONE

INTRODUCTION

1.1 Background

In spite of the economic benefits that mining presents, it has significant negative impact on the environment. Due to the blasting and excavation processes, opencast mining inevitably leads to serious degradation on ecological and aesthetic values of the landscape. Topography and drainage, air, soil and water quality, vegetation including forest ecosystems, noise levels and ground vibrations, human health and habitation can be enumerated as the characteristic parameters that are mainly affected by opencast mining activities (Kuter, 2013). Mining operations generally and predictably lead to substantial environmental damage. By way of this excavation, the original potential of landscape is extremely altered with the creation of open pits. Disruption of the surface significantly affects the soil, fauna, flora and surface water, thereby influencing all types of land use (Chamber of Mines of South Africa, 2008).

According to Bell and Donnelly (2006), most surface mining methods involve removal of massive volumes of material, including overburden, to extract the mineral deposit. When the extraction of mineral is over, the altered landscape has to be reclaimed in order to make the land return to a suitable condition so it can be useful again. That is, as part of mine operation, mine closure and reclamation is done with the objective of leaving the mined area in a functioning ecological state (to the extent possible), and physically/chemically stable state, thereby making it available for future land uses. A key part of the closure is a commitment to progressive rehabilitation of the mined area. Rehabilitation typically includes closing open pits; stabilizing and preventing public access to underground workings and shafts;

reclamation of slopes; ensuring that water draining from the mine site and waste deposits are not a risk to human health and the environment.

Sheoran *et al*., (2010) described reclamation as the process to restore the ecological integrity of disturbed mine land areas. It includes the management of all types of physical, chemical and biological disturbances of soils such as soil pH, fertility, microbial community and various soil nutrient cycles that makes the degraded land soil productive.

Since the late 20th century, reclamation has been widely accepted by both developed and developing countries as a desirable and necessary remedy in order to: reestablish the environmental conditions in post-mining landscapes at an acceptable level, and increase their economic value to an optimum level (Cao, 2007). According to Ghose (2004), inability of preserve topsoil is one of the basic hindrances to restoration of mined lands. Large areas are continually becoming unfertile in spite of efforts to grow vegetation on the degraded mined lands.

1.2 Problem Statement

Soil is important to everybody but for those who farm, soil is very essential. Farmers have two tangible resources: their know-how and good soil. Lacking either jeopardizes the farm's success. Farmers have many opportunities to increase their know-how, but repairing severely degraded soil may be impossible. It is certainly difficult, time consuming and costly.

Ghana Manganese Company has a three year old reclaimed site, which covers about 20 hectares of land. The reclaimed site was revegetated with oil palm intercropped with plantain and pineapples. It was observed that, all the above mentioned plants were developing well with the exception of pineapples. Questions have been raised about the soil not being able to support pineapple growth since pineapples of the same variety did well at the company's premises.

It is against this backdrop that this study has become imperative to assess the fertility status of a reclaimed site and its suitability to support crop production with pineapple as the test crop.

1.3 Research Questions

The study sought to provide answers to the following research questions.

1. What are the physical properties of the soil of the reclaimed site?
2. What is the chemical/ nutrient capacity of the soil of the reclaimed site?
3. Are the chemical and physical properties of the soil and environmental conditions of the reclaimed site suitable for production of pineapples?

1.4 Research Objective

The main objective of this study was to evaluate the present fertility status of soil supporting proper pineapple growth at the reclaimed site.

1.4.1 Specific objectives

The specific objectives seek to;

1. Analyse the nutritional and physico-chemical properties of the soil at the reclaimed site
2. Use success rate of pineapple to determine the production viability of the reclaimed site.

1.5 Significance of Study

With the economic benefits of mining, more and more lands are being brought under mining operations, as in the case of manganese mining at Nsuta. After the mine is closed and reclamation processes are completed, these lands are then expected to regain its productive capacity. The poor pineapple productivity at the reclaimed site raised concerns about the soil fertility status as to whether the soil would be able to support other shallow-rooted fruit plants in the future. It was the wish of the reclaimed team to cultivate fruit plants on commercial basis but the poor pineapple productivity has become an obstacle for the exercise. This will inform state agencies, NGOs and environmental sustainability-based stakeholders to plan and implement strategies to address any concerns that may arise as per the findings of this study. This would help ensure environmental sustainability and food security in the Nsuta community and the nation at large.

1.6 Scope of the study

The study was carried out on a reclaimed mine site at the Ghana Manganese Company in the Nsuta community. This involved the cultivation of pineapple, plantain and oil palm on the reclaimed land and the control site, to assess the viability of the reclaimed land to support crop production. This included the assessment of the soils for physical, chemical and nutritional capacity to support the production of pineapples. Productivity of the crop was evaluated based on the growth and yield as per the requirement established by the Ministry of Food and Agriculture (MoFA, 2013).

1.7 Organization of study

The study report was chronicled in the order explained subsequently. Chapter one is the introduction and aims to give basic background information regarding mining and reclamation, statement of the problem and justification for the topic. It also covers the objectives and scope of the study. Chapter two looks into the current literature. Relevant literature in relation to the subject matter was reviewed and authors appropriately cited. The methodology used to achieve the objectives and aims of the research study is explained in chapter three. Chapter four captures the results and discussions of the gathered data. Chapter five highlights the conclusions and recommendations based on findings from the study to improve the current status of the reclaimed land at Ghana Manganese Company.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of mining and its importance

Mining is the extraction of valuable minerals or other geological materials (rocks and unconsolidated materials) from the earth, usually (but not always) from an ore body, vein, or (coal) seam. Materials recovered by mining include bauxite, coal, copper, gold, silver, diamonds, iron, precious metals, lead, limestone, nickel, phosphate, oil shale, rock salt, tin, uranium, and molybdenum among others.

Mining in its broadest sense is the process of obtaining useful minerals from the earth's crust (Kunadu, 1994). The process includes excavations in underground mines and surface excavations in open-pit, or open-cast (strip) mines.

Generally, mining process can be put under six steps from opening to closure of mine. These processes are as follows:

- Prospecting to locate ore.
- Exploration to define the extent and value of ore in rocks.
- Conducting a feasibility study to evaluate the total project and make a decision as whether to develop or walk away from a proposed mine project. This includes a cradle to grave analysis of the possible mine, from the initial excavation all the way through to reclamation.
- Development of mine site to create access to an ore body.
- Exploitation to extract ore on a large scale.
- Reclamation to make land where mining had taken place suitable for future use.

The contribution of mining to economic development is undoubted. Acheampong (2004) argued that mining has an essential foundation for human development through creation of wealth. That is, the mining industry has been very influential to the development of civilization, supporting the iron and bronze ages, the industrial revolution and the infrastructure of today's information age. In Ghana, the mining sector contributes significantly to Ghana's economy. For instance as reported by Awudi (2002), the sector was the leading foreign exchange earner and accounted for 41% of the country's foreign exchange in 2002. Gold replaced cocoa as the principal foreign exchange earner, contributing over U$600 million to Ghana's Gross Domestic Product (GDP) in 2002.

Horswill *et al.*, (1999) stated that mineral development can create new communities and bring wealth to those already in existences. New projects can bring jobs, business activities, roads, schools, and health facilities to remote and previously impoverished areas. The existence of the mines provides direct and indirect employment, increase income levels and improved standards of living to mining communities and beyond.

2.2 Impacts of mining on land/ soil

The impact of mining operations on land and soil is immense and needs careful consideration. Bell and Donnelly (2006) attested to the detrimental effect that mining especially surface mining can have on land resources. A blend of good quality soil and different climatic parameters favours the growth of plants which is considered to be the back-bone of the economy of any country. The paper-thin layer of soil as compared to the total crustal thickness of the earth not only provides us food but also the habitat of soil microorganism which are driving force of many ecosystems (Das *et al*., 2012). Many workers around the world have reported various effects of mining such as loss of biodiversity, contamination of soil, erosion, formation of sinkholes etc., (Banerjee *et al*., 2004; Dutta and Agrawal, 2002; Ekka and Behara, 2011; Ghose, 1996 ; Singh and Singh, 2006).

The most serious impact of mining is land degradation as well as habitat destruction of the ecosystem as a whole. The mine spoils or overburden created during open-cast mining are devoid of nutrients and have low water holding capacity. In the process of open cast mining, top soil layer is damaged and it causes several changes to the physical, chemical and microbiological properties of soils (Kundu *et al.*, 1998). Mining operations degrade significant areas of land and replace existing ecosystem with undesirable waste materials in the form of mine spoil dumps (Singh *et al.*, 2007). Mine spoils are anthropogenic which cause a wide range of problems for establishing and maintaining vegetation cover. Leachates generated from overburden dumps may change the characteristic of surrounding top soils. The adverse physico-chemical properties tend to inhibit soil forming process and plant growth. The heavy metal concentration of mine spoils inhibit uptake of nutrients, plant growth and microbial activities. These heavy metals create unfavourable conditions for micro-organisms which are responsible for the uptake of nutrients to plants (Chaubey, *et al*., 2012).

According to Bahrami *et al.*, (2010), on a global scale about 20 percent of deforestation in developing countries may be attributable to mining. Ghosh (1990) report that in India every one million tons of coal extracted by surface mining methods damages a surface area of about 4 hectares. Mined spoils have high content of rock fragments in comparison to fine earth. These spoils are not suitable for both plant and microbial growth because of low organic matter content and unfavourable pH (Agrawal, *et al.*, 1993; Burgharadt, 1993). Pederson *et al.*, (1988) observed that, the nutrient status of overburden soil is also a major factor limiting plant growth.

Leachates generated from overburden dump may change the characteristic of surrounding top soils. The adverse physico-chemical properties tend to inhibit soil forming process and plant development. In mined area soils, there are concurrent decreases in parameters like organic carbon content, existing nutrients as well as exchangeable cation etc., (Maiti, 2007). The dumps of mine spoil are no more in their natural state as a result of the mining activities. Such dumps cause damage of original habitat and land, air pollution, increase in heavy metal concentrations in mined surroundings, water pollution by increasing the suspended solid load in waterbodies. Restoration of mined areas is important to restore the ecological equilibrium of the ecosystem and maintain a self-sustain ecosystem where all essential ecological processes take place (Verma, 2003).

Akabzaa and Darimani, (2001) have noted that large-scale surface mining activities continue to reduce vegetation cover to levels that hamper the sustainable development and conservation of biological diversity. It is estimated that at the close of mining, a company would have utilized 40-60% of its total concession space for activities such as siting of mines, heap leach facilities, tailings dumps and open pits, mine camps, roads, and resettlement for displaced communities. The removal of vegetation during surface mining operations exposes the soil to forces of erosion,wind and precipitation. Agricultural lands are not only generally degraded through the mining process but the loss of land for agricultural production has also led to a shortening of the fallow period affecting traditional bush fallow system, which sufficiently recycled substantial amounts of nutrients.

During surface mining, the excavation, overburden disposal or storage and construction of facilities result in removal of covering of soils and vegetation, disruption or blockage of streams, drainages, wetlands or coastal area and extensive modification of the topography over the entire mined area (World Bank, 1991).

Mining results in removal of fertile topsoil, formation of unstable slopes prone to sliding and erosion, and siltation of water bodies due to wash off of mineral overburden dumps (Salomons, 1995). The metals released from mining, smelting, forging, and other sources would accumulate in the soil, altering its chemistry. Metal contamination is not restricted to the mining site only because considerable release of metals occurs through acid mine drainage and erosion of waste dumps and tailing deposits (Khan *et al*., 2009).

Open-cast excavation of deposits involves the removal of overlying soil and rock debris and their storage in overburden dumps change the natural land topography, affect the drainage system and prevent natural succession of plant growth (Bradshaw and Chadwick, 1980; De and Mitra, 2002; Wali, 1987).

Change in land use in the form of open cast mining affects the local hydrological cycle including ground water. Due to lack of vegetation cover of the large areas of open cast mines, the quantum of evaporation considerably increases, affecting the water balance of the area and as a consequence of which permanent lowering of water table may take place (Gairola, 2010). With the lowering of water table the possibility of occurrence of land subsidence in the mining areas also increases. If an aquifer has beds of clay or silt within or next to it, the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The reduced water pressure is a loss of support for the clay and silt beds. Because these beds are compressible, they compact (become thinner), and the effects are seen as a lowering of the land surface causing land subsidence. The lowering of land surface elevation from this process is permanent. For example, if lowered ground-water levels caused land subsidence, recharging the aquifer until ground water returned to the original levels would not result in an appreciable recovery of the land-surface elevation.

Top soil confines humus, an important food resource for plants. This increase biological activity, soil fertility and control the air and water content of soils. Hence humus determine the suitability of reclaimed sites for revegetation and its successful successional development (Wilson and Tilman, 2002). The process of opencast mining, damage the top soil layer and its effects involve several changes of the physical, chemical and microbiological properties of soils (Kundu and Ghose, 1998b). Mining operations degrade significant areas of land and replace existing ecosystem with undesirable waste materials in form of mine spoil dumps (Singh *et al.*, 2007).

The greatest impact of mining on the nation's soil resource is due to opencast mining, which is having much potential for the deterioration of soil quality than underground operations. According to Kundu and Ghose, (1994), topsoil is an essential component for land reclamation in coal mining areas. The topsoil is seriously damaged if it is not mined out separately at the beginning of the mining stage. This is particularly necessary due to the scarcity of topsoil in mining fields. Therefore, it is necessary to save topsoil for a latter use in a manner to protect primary root medium from contamination and erosion, and hence in productivity. Sendlein *et al*., (1983) indicated that, systematic handling and storage practices can protect physical and chemical characteristics of topsoil while in storage and also after it has been redistributed into the regraded area.

Steenekamp (2011) observed that stripping and replacing of soil will always result in a moderate to severe disturbances of the natural balances in the soil's physical and chemical properties. He continued that with precise execution of well-defined rehabilitation procedures, degradation from pre-mining to post-mining capability is unavoidable.

2.3 Mining and Agriculture

Agriculture and the mineral sector remain the main driving force of Ghana's economy in terms of foreign exchange. Cocoa and gold top the list of exports from Ghana contributing substantially to the GDP of the local economy (World Bank, 1991). However, over the past few years, with the rise in the world's demand for minerals, the rate of expansion in mining activities has been overwhelming. This has resulted in the takeover of agricultural lands by mining activities since that is more profitable. For instance in a study conducted by Mishra and Pujari (2008) on mining around villages in India found that agricultural productivity decreased due to mining activities, but livelihoods improved as workers shifted to mining.

Studies have shown that surface mining operations represent the major cause for land use change from cropland to mining land. Though measures are being taken to reduce the level of undernourished people. Poverty levels among the rural population and especially among crop farmers have remained high in mining communities (Djietror and Appiah, 2012).

Abosede (2013) has reported that in the past years gold-mining has become an increasing problem in Southwestern Nigeria, and has adversely affected biodiversity protection and economic values of the forest at local as well as larger scales. This is fast becoming more and more unsustainable, leaving vegetation cover unprotected, farmlands degraded and the entire area prone to land subsidence. The expansion of mine concessions leads to the claim of lands from farmers which results in higher rents and unfavorable land tenure faced by the farmers as there is shortage of land for farming. This in addidtion to chemical pollution of soils, have direct consequences such as the reduction in farming activities and hence low food production.

2.4 Reclamation

Reclamation is defined as the process of reconverting disturbed land to its former or other productive uses (Alberta, 1992). This involves the removal of structures, decontamination and land surface reconstruction such as contouring, soil replacement and revegetation. Sheoran *et al*., (2010) noted that reclamation involves the process to restore the ecological integrity of disturbed mine land areas. It includes the management of all types of physical, chemical and biological disturbances of soils such as soil pH, fertility, microbial community and various soil nutrient cycles that makes the degraded land soil productive.

Reclamation is a management practice that is usually associated with resource extraction. It is the process of returning damaged land to its original condition or to an acceptable condition through land smoothing and critical area planting. Thus, the essence of reclamation as part of mining operations is with the objective of leaving the mined area in a functioning ecological (to the extent possible), and physically-chemically stable state, thereby making it available for future land uses. Restoration of mined areas is essential to re-establish the ecological balance of the ecosystem and maintain a self-sustained ecosystem where all essential ecological processes take place (Verma, 2003).

2.5 Fertility of Reclaimed Sites

Mining consequently results in drastic changes in land use patterns, as mined lands prior to mining operations may have been used for forestry, agriculture and other productive purposes. This is mainly achieved through reclamation which includes the refilling of the removed overburden and has been successful in most cases. . According to Bureau for Food and Agricultural Policy (2012), soils of mined sites can be improved to 70 % of its pre-mining potential.

Kumar and Kumar (2013) argued that mine spoil, which refers to a mixture of a mineral seam, parent rock and subsoil are deficient in plant nutrients. This they attributed to lack of biologically rich top soil. Mine spoil represents a disequilibriated geomorphic system, and poses problem for the process of pedogenesis, revegetation and restoration. They further observed that there have been reports about slow recovery process of mine spoil due to the constraints of microbial growth, and natural vegetation succession.

Undisturbed topsoil is often less than 0.08m thick, but soil salvage operations usually scrape soils to a standard 0.15m depth. This mixes surface soils with materials from deeper in the soil profile that may contain higher salt and sodium levels or other toxic materials that inhibit plant growth. Once concentrations of physico-chemical properties in surface soils are elevated, returning them to levels suitable for plant growth can be challenging.

Improper reclamation that mixes subsoil with surface soil can push salt and sodium levels above the tolerance level of even the toughest plants (University of Wyoming Extension and Wyoming Reclamation and Restoration Center, 2012).

2.6 Reclaimed Lands Support for Agriculture

Viability of reclaimed mine lands to support any productive venture and in the case of agriculture is incumbent on a variety of factors and conditions. This includes but not limited to the period for the reclamation, the type of mining method and mineral mined, the chemicals and intensity of machinery used and the extent of damage caused to the landscape through the various operational activities (Chaubey *et al*., 2012).

Ghose (2004) in his study on the effects of opencast mining on soil fertility observed that; topsoil is an essential component in abandoned mines for growth of vegetation and has to be preserved for post-mining land reclamation. The period between initial removal of the topsoil and final laying of the same soil over the reclaimed area might be a long time lapse. Hence, the properties of stockpiled soil deteriorate and become biologically unproductive.

Pit scarred landscape with huge dumps of mine spoils, in the form of overburden, generally presents the common scenario in the open-cast mined area. It is deficient in plant nutrients due to lack of biologically rich top soil. This goes to affect its ability to support the growth and sustainability of plants. Soil is polluted due to disposal of mining wastes, wet and dry deposition from the atmosphere, infiltration of contaminated water and acid mine drainage (Aswathanarayana, 2003). This results in several changes occurring in the physical, chemical and microbiological properties of soil and soil fertility gradually deteriorates by the years (Singh and Singh, 2004; Horvat *et al*., 2003)

2.7 The Pineapple Plant

Pineapple (*Ananascomosus*) is a tropical plant, a monocotyledon and a herbaceous perennial, of the family Bromeliaceae, with about 50 genera and 2,000 known species. In addition to the fruit as a food, many species are grown for their leaf fibre from which bagging material is produced, and other species are grown as ornamentals (Cunha, 1999). The plant has a short, thick stem around which grow narrow, rigid trough shaped leaves, and from which auxiliary roots develop. The root system is superficial and fibrous and generally grows no deeper than 30cm and is rarely more than 60 cm from the soil surface. Adult plants of the commercial varieties measure 0.80m to 1.20m in height and 1.00 to 1.50 m in diameter (Coppens d'Eeckenbrugge and Leal, 2003).

2.7.1 Varieties of Pineapples

Varieties grown in Ghana include smooth cayenne, Queen Victoria, MD2 and the Sugar loaf (Py 1987)

2.7.2 Origin and Distribution

Native to southern Brazil and Paraguay (perhaps especially the Parana-Paraguay River) area where wild relatives occur, pineapple was apparently domesticated by the Indians and carried by them up through South and Central America to Mexico and the West Indies long before the arrival of Europeans. Caribbean Indians placed pineapples or pineapple crowns outside the entrances to their dwellings as symbols of friendship and hospitality. Europeans adopted the motif and the fruit was represented in carvings over doorways in Spain, England, and later in New England for many years. Spaniards introduced the pineapple into the Philippines and may have taken it to Hawaii and Guam early in the 16th Century. The first sizeable plantation 5 acres (2 ha) was established in Oahu in 1885.

2.7.3 The Plant Requirement

Climate

The pineapple, a tropical plant, grows best and produces better quality fruit at temperatures ranging from 22ºC to 32ºC and with daily amplitude of 8ºC to 14ºC.In temperatures above 32ºC the plant grows less well and if associated with high solar radiation can burn the fruit during maturation phase. Temperatures below 20ºC also result in diminished growth and favour the occurrence of premature flowering, which increases management problems and the loss of fruits (Bartholomew *et al.*, 2003). The plant is severely damaged by frost, but tolerates periods of low temperatures provided they are above 0ºC. The plant grows best when annual exposure to the sun ranges from about 2,500 to 3,000 hours, or 7 to 8 hours of sunlight per day. As pineapple is a short day plant (Bartholomew *et al*., 2003), natural flowering in the southern hemisphere occurs, for the most part, from June to August, when the days are shorter and night time temperatures are lower.

Water requirement

Pineapple has a lower water requirement than the vast majority of cultivated plants. It has a series of morphological and physical characteristics typical of xerophile plants (Bartholomew *et al*., 2003). It has the capacity to store water in the hypoderm of the leaves, to collect water efficiently, including dew, in its trough-shaped leaves, and to considerably reduce water loss (reduced transpiration) by several mechanisms. Well distributed rainfall of 1,200 to 1,500mm annually is adequate for the crop. A commercial pineapple crop generally requires a quantity of water equivalent to a monthly precipitation of 60 to 150 mm (Almeida, 2001). Relative air humidity averaging 70% or higher is optimal, but the plant can tolerate moderate variations. Periods of very low relative humidity (less than 50%) can cause fruit-splitting and cracking during the maturation phase.

Soil requirement

Pineapple is very sensitive to saturation of the soil with water, which affects its growth and production. Consequently, good drainage and concomitant good aeration are basic requirements because they favour root development and reduce the risk of plant loss from fungal pathogens of the genus *Phytophthora*. The water table should be not less than 80 – 90 cm from the soil surface. It is considered that an effective soil depth of between 80 and 100 cm will be adequate for growing pineapple because the roots tend to be concentrated in the top 15 to 20 cm of soil. However, within the effective soil depth, soil texture changes and/or abrupt increases in soil density inhibit root growth and prevent the roots growing deeper (Py *et al*., 1987). Soils with a sandy texture (up to 15% clay and more than 70% sand), which generally have no drainage problems, are also recommended. But almost always, the incorporation of organic residues and manures is needed to increase their water-holding capacity and the retention of nutrients. Clayey soils (more than 35% clay) that have good drainage, like many Oxisols, may also be recommended for pineapple plantations. On the other hand, silts soils (less than 35% clay and 15% sand) should be avoided.

Soil Nutrient Requirement

Pineapple is well adapted to growing on acidic soils, a pH of 4.5 to 5.5 is recommended with slight variations depending on the variety grown (Bartholomew and Kadzimin, 1977; Py *et al*., 1987). The plant tolerates a high exchangeable aluminium and manganese content in the soil, a condition favoured on highly acidic soils. (Bartholomew *et al*, 2003). An adequate ratio of exchangeable Ca/Mg should be close to 1.0 and even lower (Boyer, 1978). This means that the Mg content should be at least the same as that of Ca if not larger. This ratio is smaller than that recommended for other tropical species.

Macro nutrients

Nitrogen (N)**:** Nitrogen is required second after potassium by pineapple. Nitrogen mostly determines the productivity of the plant. The absence of N in either organic or mineral form, almost always results in compromised development and/or productivity of the plant, with the appearance of typical symptoms of N deficiency. Deficiency symptoms are characterized by greenish-yellow to yellow foliage, small and narrow leaves, a weak plant with slow growth, small and colourful fruit with a small crown and the absence of plantlets. Such symptoms are common on soils poor in organic matter, without fertilization and under hot and sunny conditions (Py *et al*., 1987). In respect of fruit quality, studies conducted in several countries have shown reductions in juice acidity as the amount of N applied increases. Increasing levels of N can result either in a reduction of the Brix value or no significant changes in fruit sugar content. An excess of N contributes to reduction in fruit pulp firmness and an increase in translucency. In hot periods, it increases the risk of appearance of a symptom known as "jaune" (ripening of the pulp, while the skin of the fruit remains green), according to Py *et al*. (1987). The most common sources for N for the pineapple crop are urea and ammonium sulphate. Other sources of N, such as potassium nitrate and ammonium nitrate, as well as organic fertilizers (animal manure, plant cakes, compost etc.) can also be used depending on their economic viability.

Phosphorus (P): Although there is a relatively small demand for P (the macronutrient accumulated in the smallest quantity) increases in productivity have been observed, in Brazil and other countries (Malaysia, Guadelupe and India, for example). This is certainly due to the low availability of P in most soils growing this crop. According to Py *et al*. (1987), the symptoms of P deficiency include dark, bluish-green foliage, which is more pronounced in the presence of excess N, and leaves that completely dry out at the tips, starting from the older ones. The old leaves have dry, brownish-red tips and brown transverse striations with leaves borders turning yellow from the tips. Plants suffering from P deficiency also have more erect, long, narrow leaves and coloured roots with longer and less ramified hairs. The fruit is small and reddish in colour. Such symptoms rarely occur, but they may appear more or less temporarily, especially in periods of drought, in poor soils or where the deeper soil horizons were exposed during soil preparation. Bartholomew *et al*, (2003) pointed out that P deficiency causes a reduction in the growth of all parts of the plant. They called attention to the fact that visual deficiency symptoms are often not seen and are not very specific. This condition could be mistaken for symptoms resulting from damage to the root system caused by water deficiency, nematodes or pests. Little importance has been given to P nutrition in relation to the quality characteristics of the fruit. The main sources of P are fertilizers soluble in water, such as triple superphosphate (TSP), monoammonium phosphate (MAP), ammonium phosphate (DAP) and single superphosphate (SSP). The latter also contains sulphur (10-12% S). Magnesium thermo phosphates (17% P_2O) have also been used as sources of P and magnesium (9% Mg).

Potassium (K): Potassium is the nutrient that accumulates in the largest amount in the plant and also influences productivity, although to a lesser extent than that of N.

The large demand for K often results in the symptoms of K deficiency, especially in soils with low K availability. Such deficiency symptoms are mainly characterized by leaves with small yellow spots, which increase in size, multiply and coalesce around the leaf borders, which dry out. The plant has a more erect stature, a weak fruit peduncle, small fruit with low acidity and fewer aromas. These symptoms are common except in soils rich in K. The symptoms are favoured by unbalanced fertilization, especially with N, strong solar irradiation, intensive soil lixiviation and soils with high pH, rich in Ca and Mg (Py *et al*., 1987). Potassium has a significant effect on fruit quality. Experimental studies have shown that increasing the amount of K increases the acidity of the pulp and/or sugar content, improves aroma, increases peduncle diameter (contributing to reduced fruit drop) and improves pulp firmness (Py *et al*., 1987). Potassium can be applied as potassium chloride (KCl), potassium sulphate (K_2SO), potassium and magnesium bisulphate (20% K_2O) and potassium nitrate (44% KNO_4).

Micro-nutrients

The emphasis would be on iron because according to Swete (1993), pineapples have high requirement for fertilizers containing iron, nitrogen and phosphorus.

Iron (Fe): Development of chlorosis, starting in young leaves; the leaves are generally flaccid, wide, and yellow with a green 'web' of conductor veins. The old leaves are dry and when sprayed with large amounts of iron, the leaves turn to have green transverse lines. The fruit is red with a chlorotic crown. Symptoms can appear when large quantities of nitrate have been added. Iron deficiency can occur under a range of conditions. For example, on soil with high pH, soils rich in manganese (Mn/Fe = 2), compacted soils, areas of termite infestation. These soils are attacked by pests both of which rapidly decrease root activity, drought, as well as other factors. Iron also is an essential nutrient needed by pineapples for their healthy growth. In soils containing large amounts of soluble iron and manganese, pineapples can absorb relatively large amounts of both elements but apparently are unable to effectively utilize absorbed iron resulting in severe iron deficiency (Swete, 1993).

Fertilization

The large nutrient demand of the pineapple means that fertilization is a common practice. Besides the nutritional requirements of the plant and the capacity of the soil to supply nutrients, specific recommendations for each area or producing region should take into account the following factors, which vary from region to region. These factors include the level of technology adopted and implemented, the destination and the value of the product and the cost of fertilizers. In spite of the variations that can occur because of these factors, in many pineapple producing countries, including Brazil, the recommendations per plant vary, in the majority of situations, from 6g to 10 g of N, 1g to 4g of P_2O_5 and 4g to 15g of K_2O. However, decisions about the amount of each nutrient to apply that do not consider data from soil and/or plant analyses, could lead to gross errors that affect productivity, fruit quality and, consequently, economic returns. Souza and Cabral (1999) gave recommendations for an irrigated pineapple crop, based on results of soil analyses. Thus, fertilization should be done during the vegetative phase of the plant's life cycle, i.e. from the planting until the induction of flowering. This is the period in which the plant uses the applied nutrients most efficiently. For crops grown without irrigation and when solid fertilizers are used, the timing of the application should take into account the distribution of the regional rains such that the application coincides with good soil moisture.

Diseases, Insects and Pests

Diseases such as the wilt disease vectored by mealy bugs are typically found on the surface of pineapples. Other diseases include the pink disease are characterized by the fruit developing a brownish to black discolouration when heated during the canning process. The causal agent of this disease is the bacteria *Acetobacteraceti*. Some pests and insects that commonly affect pineapple plants are scales, thrips, mites, mealy bugs, and ants' etcetera. (Bartholomew *et al*., 2003)

2.8 Manganese Mining in Ghana

Manganese is a chemical element, designated by the symbol Mn. It has the atomic number 25. It is found as a free element in nature (often in combination with iron), and in many minerals. Manganese is a very important metal used in industrial metal alloys, particularly in stainless steel. Manganese is a hard, silvery white metal with a melting point of 1,244 °C. Manganese is too brittle to be of a structural value. It is an important agent in steel making, in which it removes impurities such as sulphur and oxygen and adds important physical properties to the metal. For these purposes, it is most often employed as a ferromanganese or silicomanganese alloy; as a pure metal it is added to certain nonferrous alloys.

Ghana is one of the world's leading exporters of manganese with reserves exceeding 6 million tons (World Bank, 1991). The history of manganese ore production in Ghana dates back to 1914, when manganese ore was first discovered at Nsuta-Wassa. The Ghana Manganese mine is situated in the Western Region of Ghana approximately 70km by rail north of the regional capital and port of Takoradi. As part of the Ghana government's privatization policy, the fully state-owned enterprise was divested in November 1995.

Ghana Manganese Company owns and operates the Nsuta manganese mine in the Western Region of Ghana. The concession for manganese mining covers an area of 175 square kilometres in and around Nsuta in the Western Region of Ghana.

2.9 Location of Study Area

The study was carried out at Ghana Manganese Company mine site at Nsuta-Wassa. Nsuta-Wassa is located in the Western Region of Ghana about 54 kilometres from Takoradi. It lies within latitude 5° 15″and 5° 20″and longitude 10° 56″ and 2° 00″. The mine is located in the south-west of Ghana along the Sekondi /Kumasi railway lines about 60km north of Takoradi and about 6.5km south of Tarkwa. A map of the study area is shown in Figure 2.1 below.

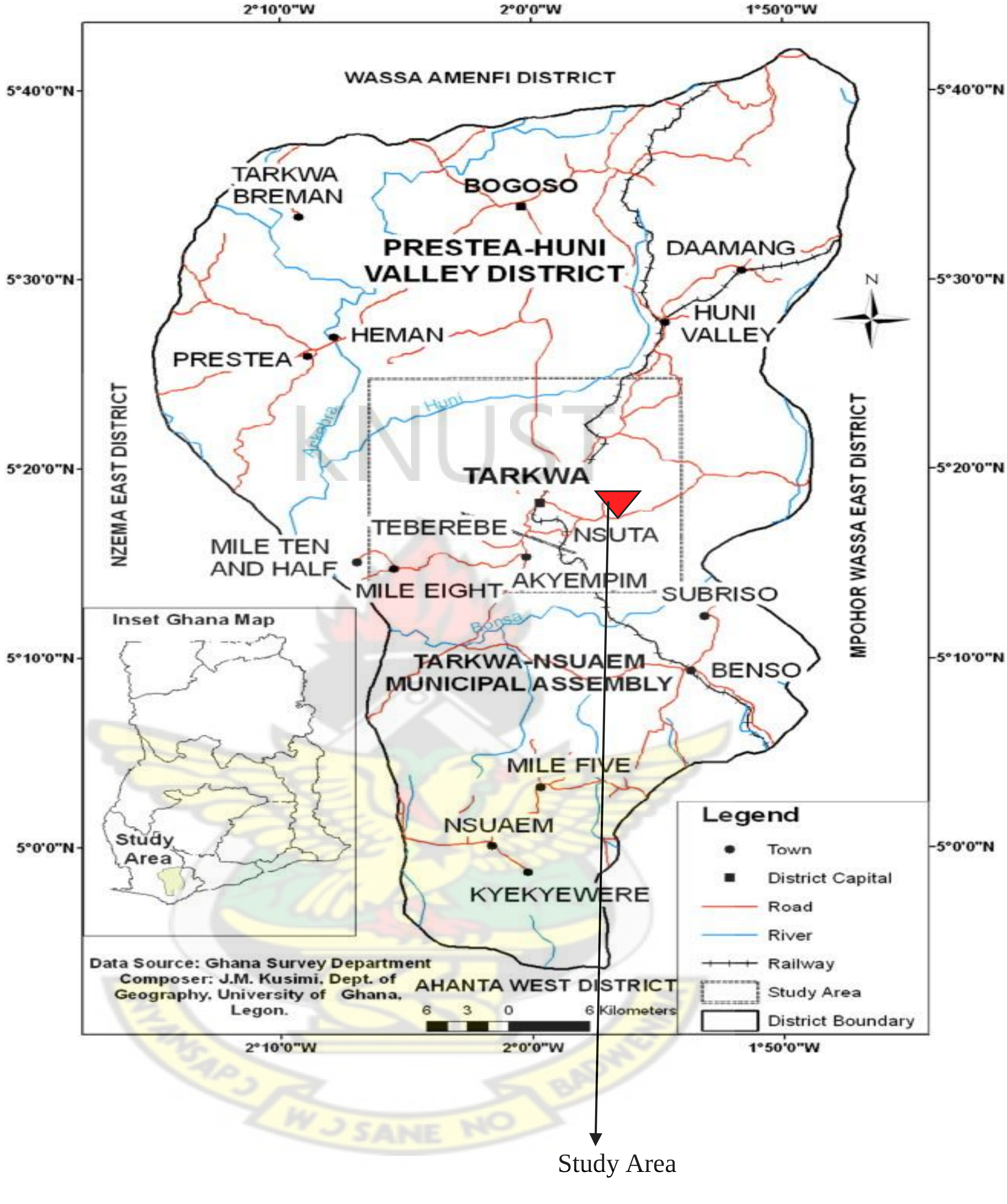

Figure 2.1: Map of Wassa Amenfi District

2.10 Geology of study area

The Nsuta ore deposit occurs in the Birrimian Series which consists of isoclinally folded metamorphosed sedimentary rocks intercalated with metamorphosed tuff and lava (Gyau-Boakye and Dapaah-Siakwan, 2000). Large masses of granite have also intruded the Birrimian System. The Birrimian System is largely folded. It is fissured to a larger extent compared to the Tarkwaian System. This system is divided into two upper and lower Birrimian Series. The sediments are predominant in the lower part of the System. These sediments have been metamorphosed to schist, slate phylite and also there are some tuff and lava. The upper part of System is dominantly of volcanic and pyroclastic origin. The rocks consist of bedded groups of green lava. Lava and tuff dominate this part. Several bands of phyllite occur in this zone and are manganiferous in places. The thickest sequence occurs in Nsuta where manganese is being mined. In the Birrimian System, gold occurs in five parallel northeast trending volcanic belts more than 300km long. The Birrimian System is separated by basins containing pyroclastic and metasedimentary units. The manganese occurrence is 2 to 30ppm in quartz veins of laterally extensive major ore bodies. The mangenese deeply penetrates fissures and shear zones in contact between meta sedimentary and meta-volcanic rocks. The Birrimian System has a higher content of heavy metals than the Tarkwaian System. The Tarkwa Region forms part of an extensive drainage basin known as the Ankobra Basin comprising the Ankobra River and its tributaries such as River Bonsa and Kawere River. The rivers and their tributaries facilitate mining activities in the area (Dzigbodi-Adjimah, 1993; Gyau-Boakye and Dapaah-Siakwan, 2000; Kortatsi and Quansah, 2004).

2.11 Vegetation and Climate of study area

Nsuta Wassa mine area falls within the equatorial climate zone, primarily tropical rain forest zone of Ghana. The daily temperature ranges between $20^{O}C$ and $40^{O}C$ while the mean monthly temperature ranges from $24^{O}C$ and to $30^{O}C$. The mean annual rainfall ranges from 1500mm to 1933mm with most of the rains occurring from April-June and October-November giving it a bimodal rainfall regime (Kortatsi and Quansah, 2004). Relative humidity for the area ranges from 70% to 90%. The vegetation is a Tropical Evergreen Rainforest particularly at low and medium altitudes. The vegetation is characterized by rich undergrowth of climbers and shrubs of varying heights. In and around the mine the vegetation has been affected by mining activities, consequently reducing the vegetation to almost grassland type.

CHAPTER THREE

RESEARCH METHODOOGY

The study was conducted in two phases;

1. Fieldwork
2. Laboratory analysis

3.1 Field work (Soil Sampling)

Soil samples from both the reclaimed and the control sites were taken from Ghana Manganese Company. The mined out pits of the reclaimed site were refilled with soil, rock fragments, tailings removed from the mined land and stockpiled in a 3 year reclamation period. The reclaimed site covering a land area of 20 hectares is cultivated with pineapple intercropped with plantain and oil palm as a replication. Similar crops were also cultivated on the control site of a land area of 2 hectares.

Twenty soil samples were collected from both the reclaimed and control sites. Samples collected from each sampling unit were referred as ‘sub samples’ and were mixed to form ‘composite samples’. Sub samples were collected from random spots, at successive depths of 0 - 15cm and 15 – 30cm. The top soil mostly determines the fertility status of a particular soil, and this therefore informed the use of this sample depth. The composite samples were later conveyed to Soil Research Institute (SRI) at Kwadaso-Kumasi for analysis of the various soil nutrient parameters.

3.2 Laboratory experiments

Laboratory experiments were conducted at the Soil Research Institute (SRI) Kwadaso-Kumasi.

3.2.1 pH Determination

The HI 1292D direct soil pH meter was used to determine the soil pH for both the reclaimed and control sites.

pH meter method

The pH meter was calibrated using buffer solutions of pH (7.0) based on the range of pH of the soil.

Soil sample (25 g) was weighed into a beaker. Distilled water (25 ml) was added to the sample at a ratio of 1:1 and the suspension stirred for 30 minutes. The pH and the corresponding temperatures were determined by putting the electrode into the solution containing the soil solution and the corresponding reading taken.

3.2.2 Organic Matter Determination

Soil organic matter was evaluated through the determination of organic carbon content in the soil samples.

Soil organic matter is often assumed to be about 58% organic carbon (i.e. SOM = 1.724 x OC). The organic carbon present in soils is determined mainly by two types of methods: (1) Quantitative combustion and (2) Qualitative method. Quantitative combustion is where carbon is determined as carbon dioxide through the reduction of dichromate ion by organic matter, the unreduced dichromate is measured by titration or colorimetry. Qualitative methods are based on nuclear magnetic resonance (NMR) spectroscopy and on diffuse reflectance infra-red Fourier transform (DRIFT) spectroscopy. It usually works on the principle of measuring the characteristic energy absorbed and re-emitted or dispersed by atomic nuclei that are placed in a static magnetic field and subjected to an oscillatory magnetic field of known radio-frequency.

Determination: Volumetric Method

Preparation of Reagent

The reagent was prepared as follows;

Potassium dichromate ($K_2Cr_2O_7$)

49.04g of dichromate was weighed in a 1litre flask and topped to one litre with distilled water.

Ferrous Sulphate (Fe_2SO_4)

280g of ferrous sulphate was also weighed and 15ml of sulphuric acid added into a 1 liter volumetric flask and topped to the mark.

Diphenylamine

1g of diphenylamine was weighed and 200ml of concentrated Sulphuric acid was added after which 14ml of distilled water was also added and allowed to cool.

Procedures

1g of the soil sample was weighed into a beaker and 10ml of potassium dichromate added (which helps in colour development by reducing the organic matter present to organic carbon). 20ml of sulphuric acid was then added (which helps in reducing the organic matter to organic carbon).

When the content turned green before titration, it was discarded to further reduce the weight of the soil.

The concentration was allowed to stand for 30 minutes and after which 100ml of distilled water was added. 5ml of orthophosphuric acid which helps in colour change was then added.

Titrating the concentrated solution against ferrous sulphate helps to bring excess colour. Using the diphenylamine helps to indicate the end point.

Formula : $\left(OM = \underline{M_O}\, x100 \right)$ – Eqn 3.1

M_D

$(M_D = M_{PDS} - M_P)$ - Eqn 3.2

$(M_A = M_{PA} - M_P)$ - Eqn 3.3

$(M_O = M_D - M_A)$ - Eqn 3.4

Where

Mo		mass of organic matter
M_D		mass of the dry soil
M_A	-	mass of the ashed (burned) soil
OM	-	organic matter content
M_{PDS}	-	mass of the dish and soil specimen
M_P	-	mass of an empty, clean, and dry Porcelain dish

3.2.3 Total Nitrogen (N)

The total soil nitrogen was determined by the use of the Kjeldahl method (Jackson, 1964).

Procedure

0.2g of soil sample was weighed into a beaker. One Kjeldahl tablet was added as catalyst mixture to raise the boiling point and to promote the conversion of organic – N to ammonium-N). 5ml of concentrated sulphuric acid which helps in conversion of organic-N to inorganic-N was also added. The solution was then digested until it was clear.

Note: High heat causes loss of nitrogen and low heat leads to incomplete digestion.

Solution was then allowed to cool after which 150ml of distilled water, 22.5ml of NaOH for neutralization and bringing excess nitrogen were then added. The solution was distilled with 25ml of boric acid as indicated in Jackson (1964) for about 10 minutes. When the distillate got to 100ml it was then titrated with 0.1N HCl.

This was the formula used:

$$T_N = \frac{T_{VS} - T_{VB} \times 0.02N \text{ nitrogen} \times 14.007 \times 100}{S_w \times 1000} \quad - \quad \text{Eqn 3.5}$$

Where:

T_{VS} - Titre value of sample

T_{VB} - Titre value of blank

S_w - Sample weight

T_N - Total Nitrogen

3.2.4 Potassium (K)

Potassium present in the soil was extracted with neutral ammonium acetate (1M HNO_3). This was considered as plant-available K in the soils. It was estimated with the help of a flame photometer.

The apparatus and reagents required:

- Multiple dispenser or automatic pipette (25 ml).
- Flasks and beakers (100 ml)
- Flame photometer.

Molar neutral ammonium acetate solution: 77g of ammonium acetate ($NH_4C_2H_3O_2$) was dissolved in 1 litre of water. Check the pH with bromothymol blue or with a pH meter. If not neutral, add either ammonium hydroxide or acetic acid as per the need in order to neutralize it to pH 7.0.

Standard potassium solution: 1.908g of pure KCl was dissolved in 1 litre of distilled water. The solution contained 1 mg K/ml. 100ml of this solution was taken and diluted to 1 litre with ammonium acetate solution. This gave 0.1 mg K/ml as a stock solution.

Working potassium standard solutions: 0, 5, 10, 15 and 20 ml of the stock solution were taken and each volume separately diluted to 100 ml with the molar ammonium acetate solution. These solutions contained 0, 5, 10, 15 and 20 µg K/ml, respectively.

Procedure

Preparation of the standard curve: The flame photometer was set up by atomizing 0 and 20 µg K/ml solutions alternatively to readings of 0 and 100. Intermediate working standard solutions were atomized and readings recorded. These readings were plotted against their respective K contents and the points connected with a straight line to obtain a standard curve.

Extraction: 25ml of the ammonium acetate extracting solution was added into a conical flask fixed in a wooden rack containing 5 g of soil sample. It was then shook for 5 minutes and filtered. The potash in the filtrate was determined with the flame photometer.

$$\mathrm{K\ (ppm)} = \frac{A \times 25 \times 2000000}{1000000 \times 5} \qquad \text{Eqn 3.6}$$

Where:

A - Content of K (µg) in the sample

Volume of the extract = 25 ml;

Weight of the soil taken = 5 g;

3.2.5 Phosphorus (P)

Bray's Method (No. 1) was used to determine the phosphorus content of the soils at the reclaimed and control sites.

Bray's Method No. 1

Apparatus

- Spectrophotometer.
- Pipettes (2, 5, 10 and 20 ml)
- Some beakers/flasks (25, 50, 100 and 500 ml).

Reagents

Bray's Extractant No.1 (0.03M NH_4F in 0.025M HCl): 2.22 g of NH_4F was dissolved in 200 ml of distilled water, filtered and added to the filtrate 1.8 litres of water containing 4 ml of concentrated HCl, with the volume up to 2 litres with distilled water.

Molybdate reagent: 1.50g of $(NH_4)2MoO_4$ was dissolved in 300 ml of distilled water. The solution was then added to 350 ml of 10 molar HCl solution gradually with stirring. The solution was then diluted to 1 litre with distilled water.

Stannous chloride solution (stock solution): 10 g of $SnCl_2$ $2H_2O$ was dissolved in 25 ml of concentrated HCl. A piece of pure metallic tin was added to the solution, and stored in a glass stoppered bottle.

Stannous chloride solution (working solution): 1 ml of the stock solution of stannous chloride was diluted to 66.0 ml with distilled water just before use. Prepare fresh dilute solution every working day.

Procedure

Preparation of the standard curve: 0.2195 g of pure dry KH_2PO_4 was dissolved in 1 litre of distilled water. The solution contained 50 µg P/ml. This was preserved as a stock standard solution of phosphate. 10 ml of this solution was taken and diluted to 0.5 litres with distilled water. This solution contained 1 µg P/ml (0.001 mg P/ml). 0, 1, 2, 4, 6 and 10 ml of this solution was put in separate 25ml flasks. 5ml of the extractant solution was added to each flask, 5ml of the molybdate reagent; and diluted with distilled water to about 20 ml. 1ml of dilute $SnCl_2$ solution was added, shook again and diluted to the 25ml mark. After 10 minutes, the blue colour of the solution was read on the spectrophotometer at a wavelength of 660 nm. The absorbance readings were plotted against "µg P" and the points connected.

Extraction: 50 ml of the Bray's Extractant No. 1 was added to a 100ml conical flask containing 5 g of soil sample. It was then shook for 5 minutes and filtered.

Development of colour: 5 ml of the filtered soil extract was taken with a bulb pipette in a 25ml measuring flask; 5ml of the molybdate reagent was then delivered with an automatic pipette. The solution was diluted to about 20ml with distilled water, shook after which 1ml of the dilute $SnCl_2$ solution was added with a bulb pipette.

It was filled to the 25ml mark and shaken thoroughly. The blue colour was read after 10 minutes on the spectrophotometer at 660 nm after setting the instrument to zero with the blank prepared similarly but without the soil.

This formula was used;

$$\mathrm{P(ppm)} = \frac{A}{100000} \times \frac{\mathrm{V(extract)}}{W(soil\ sample)} \times \frac{2000000}{V(estimation)} = 4A \quad - \quad \text{Eqn 3.7}$$

Where:

A- Content of P (μg) in the sample

Weight of the soil taken = 5 g.

Volume of the extract = 50 ml.

Volume of the extract taken for estimation = 5 ml.

Amount of P observed in the sample on the standard curve = *A* (μg).

Weight of 1 ha of soil down to a depth of 22 cm is taken as 2 million kg.

3.2.6 Iron (Fe)

Soil sample of 5g was weighed in container. 25ml of the DTPA (Diethylenetriamine-pentaacetic acid) extracting solution was added to the sample in the container and shaken for two hours. After shaking for two hours, the sample was filtered and the iron present was analysed and determined by the use of Atomic Absorption Spectrophotometer (AAS).

Reagents

Ethylenediamine tetra acetic acid (EDTA) with ammonium acetate is commonly used for the extraction of many elements. Diethylenetriaminepenta- acetic acid (DTPA) is another common extractant and it is widely used for the simultaneous extraction of elements such as Zn, Cu, Fe and Mn. The estimation of elements in the extract was done with the help of an AAS.

Preparation of Extractant

18.04g of EDTA was weighed in one litre volumetric flask. 64ml of ammonia solution was added to it and shaken. It was then topped to the mark using distilled water.

Procedure

5g of the soil sample was weighed into a container. 25ml of the extractant was then added to the sample in the container, shook for two hours using mechanical shake and filtered. The iron present was determined by the use of Atomic Absorption Spectrophotometer (AAS).

Calculation

Content of micronutrient in the sample (mg/kg) = C µg/ml × 5 (dilution factor)

Where:

Dilution factor = 5.0 (soil sample taken = 5.0 g and EDTA used = 20 ml).

Absorbance reading on AAS of the soil extract being estimated for a particular element = X.

Concentration of micronutrient as read from the standard curve for the given absorbance (X) = C µg/ml.

3.2.7 Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) was determined by measuring cations at pH 7 with Ammonium Acetate as employed by Chapman, (1965) at the reclaimed and control sites.

Apparatus:

1. Buchner funnel filtration apparatus.

2. Balance.

3. 250 and 500 ml Erlenmeyer flasks.

4. Apparatus for ammonium determination (steam distillation or colorimetry).

Reagents:

1. 1 M ammonium acetate (NH_4OAc) saturating solution: Diluted in a chemical hood, 57ml glacial acetic acid (99.5%) with ~800 mL of distilled H_2O in a 1 litre volumetric flask. 68 ml of concentrated NH_4OH was added, mixed and cooled. pH was adjusted to 7.0 with NH_4OH and diluted to 1 litre.
2. 1 M KCl replacing solution: Completely dissolved 74.5g KCl in distilled water and diluted to a final volume of 1 litre.
3. Ethanol, 95%.

Procedure:

25.0 g of soil was added to a 500ml Erlenmeyer flask. 125 ml of the 1 M NH_4OAc was also added and shaken thoroughly and allowed to stand for 16 hours (or overnight). A 5.5 cm Buchner funnel was fitted with retentive filter paper, moistened paper, light suction applied and the soil transfered. The soil was gently washed four times with 25ml additions of the NH_4OAc, allowing each addition to filter through but not allowing the soil to crack or dry. Suction was applied only as needed to ensure slow filtering. The leachate are discard, unless exchangeable cations are to be determined.

Note: Exchangeable cations can be determined on the leachate after diluting it to 250 ml.

The soil was washed with eight separate additions of 95% ethanol to remove excess saturating solution. Enough ethanol was added to cover the soil surface, each addition was allowed to filter through before adding more. The leachate was discarded and the receiving flask cleaned. The adsorbed NH_4 was extracted by leaching the soil with eight separate 25 ml additions of 1 M KCl, leaching slowly and completely as above. The soil was then discarded and the leachate transferred to a 250 ml volumetric. The solution was diluted to volume with additional KCl. The concentration of NH_4-N was determined in the KCl extract by distillation. NH_4-N in the original KCl extracting solution (blank) was determined to adjust for possible NH_4-N contamination in this reagent.

Calculation

Where NH_4-N is reported in mg N/L:

$$\text{CEC (cmolc/kg)} = \frac{(NH_4\text{-}N_{inextract} - NH_4\text{-}N_{in\ blank})}{14} \qquad - \qquad \text{Eqn 3.8}$$

Where NH_4-N is reported in mg N/L:

$$\text{CEC (cmolc/kg)} = \frac{(NH_4\text{-}N_{in\ extract} - NH_4\text{-}N_{in\ blank})}{18} \qquad - \qquad \text{Eqn 3.9}$$

3.2.8 Water Holding Capacity (WHC)

The procedure adopted by Yeboah, (2012) was followed to determine the water holding capacity of soil samples at the reclaimed and control sites.

Volumetric method

Procedure:

Five (5) 100 ml glass funnels were picked and a short length of rubber tubing (approximately 8 cm) attached to the mouth of the stem. A clip was placed on each piece of tubing and closed completely. Five (5) lots of glass wool of 0.25-0.30 g were weighed out, but of all the same weight and the glass wool rolled into a compact ball or cylinder and placed in the funnel at the top of the stem. The glass wool was packed down firmly with a narrow spatula and 3 moist portions of 50 g soil weighed out, and place in 3 funnels. Glass wool only was put in the others. Soil moisture content was determined in other portions and 50ml of water was poured into each funnel through a 50ml measuring cylinder and left for 30 minutes to saturate the soil. After this time, the clips were opened on the tubing, and the water that drained from each funnel after the 30 minutes was collected in a measuring cylinder held beneath the funnel stem. The final volume of water collected in each cylinder after this time was recorded.

Calculation

Volume of water retained by the soil from:

$50 - (VA + VB)\ \text{ml} = A$ - Eqn 3.10

To calculate soil WHC (ml water held at 100% WHC per 100g oven dried soil)

$2A + M_c\%$ = WHC (ml per 100g-1 fresh soil) = B ml - Eqn 3.11

Then:

$\frac{B(\text{ml})}{\text{soil DM}} \times 100 =$ ml of water held by 100g oven dried soil at 100% WHC - Eqn 3.12

Where:

VA - Volume of water retained by glass wool

VB - Volume of water collected

A - Volume of water retained by the soil

3.2.9 Success Rate

Success rate here determines the percentage of crops harvested over time. This was determined by calculating the number of successfully grown crops at the maturity phase. Equation 3.13 below was employed for crop yield calculation in this study.

Formula:

$$\frac{N_R}{N_r} \times 100\% \qquad - \qquad \text{Eqn } 3.13$$

Where:

N_R - Number of crops at maturity

N_r - Number of crops planted

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Soil pH

The reclaimed site recorded a pH of 4.80 (figure 4.1) indicating that the soil is acidic, while the control site recorded a pH of 6.85 indicating a slightly acidic condition. The soil pH of the reclaimed site was acidic due to the continuous leaching of basic cations. White (1979) argues that lowering of soil pH values follows as cations such as Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+} are leached from the profile faster than they are released by mineral weathering. The reclaimed area cultivated with pineapples may eventually be deficient in these cations which represents a decline in soil fertility level as compared with undisturbed native soils (Etherington, 1975). Conversely, the proliferation in soil pH of the control site soil is probably due to organic matter input that modifies the pH of the soil (Banerjee et al., 2004). Py *et al.,* (1987) stated that, from a chemical point of view, soil acidity is considered the most pertinent feature with regards to pineapple cultivation. With standard pH requirement for pineapple growth being 6.50 (FAO, 2013), the control site is seen to be more suitable for pineapple cultivation than the reclaimed site due to the acidic soil pH at the reclaimed site. Burgharadt (1993) reported that mining soil has high content of rock fragments in comparison to unmined lands. These soils are not suitable for both plant and microbial growth because of low and unfavourable pH. Physico-chemical and biological properties of soil have complementary relationship with each other to ensure the viability of the soil to support life. For this reason, the increase or decrease in each property could influence the availability of the other soil parameters to support plant growth and yield. For instance, the College of Tropical Agriculture and Human Resources of University of Hawai (2013) reported the relationship that various properties have on each other. The report noted pH as the "master variable" of soil since it affects the biological, physical and chemical processes of soil. The pH controls the availability of the essential nutrients, determines the abundance of soil microorganism as well as which plant species will grow well.

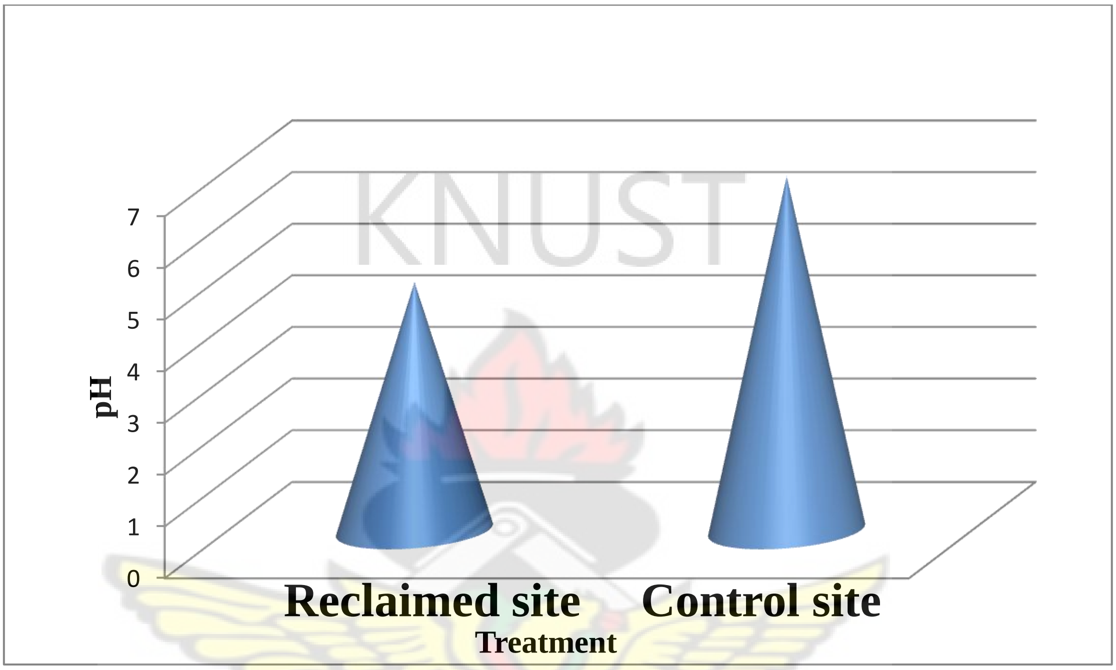

Figure 4.1: pH of land sites

4.2. Temperature (°C)

Mean temperature of the sampled sites as shown in Figure 4.2 indicated that, reclaimed site had a higher temperature than the control site; 26.2°C and 25.6°C for the reclaimed and control sites respectively. Since both treatments had a temperature range within that of the standard temperature (26ºC) for pineapple growth (Morton, 1987); they are said to be suitable for the pineapple growth. Bartholomew *et al.*, (2003) have shown that pineapple plant develops poorly in temperatures above 32ºC, and in cases of high solar radiation, could result in fruit burn during the maturation phase. Bartholomew also indicated that, temperatures below 20ºC also result in diminished growth and favour the occurrence of premature flowering, which increases management problems and the loss of fruits.

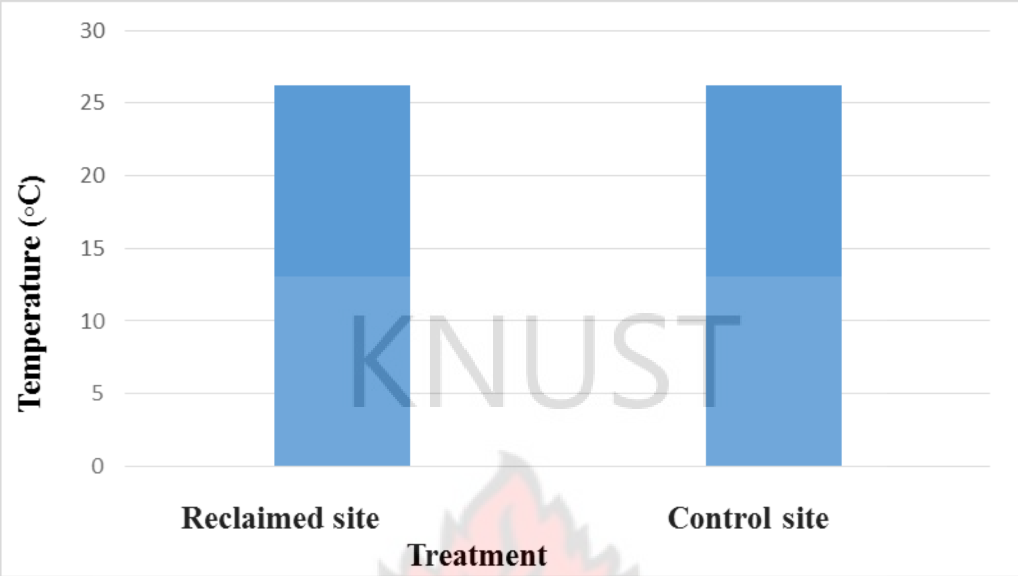

Figure 4.2: Temperature of treatments

4.3 Total Nitrogen (N)

Nitrogen is a major nutrient that occurs in soils suitable for plant growth. The quantity of nitrogen in a particular soil sample could be a determinant of the fertility of such soil for crop growth. From the study, it was observed that total nitrogen levels at the reclaimed site were below the recommended levels for fertile soil which is 2.00ppm (FAO, 2013). The original top soil from the reclaimed site which was stocked piled during the mining period, lost much of its nitrogen content before it was brought back to refill the mined area. As the top soil was moved from its natural abode, it was deprived of its natural conditions. The reclaimed site recorded 0.04ppm nitrogen and the control site, 0.27ppm as shown in Figure 4.3. Reclaimed mine lands usually lack true topsoil and are basically composed of mine spoil or overburden whose properties range from loose, coarse textured material with many rock fragments to highly compacted clay material. This according to Kumar (2013) may result generally in two types of effects: excesses (supra-optimal levels of chemical elements including metal ions) and deficiencies (suboptimal concentrations of essential elements) thus, mine altered soils represent a very harsh environment for crop production and yield.

Stripping, stockpiling and reinstatement has its debilitating effects on the top soil which holds most nitrogen content of the soil. Physical disturbance to the top soil eventually cause unusually enormous nitrogen transformations and movements with its substantial loss. This is further strengthened by a study by Khresat (2008), which accounts that most soil nitrogen is bound in organic matter in unmined sites and as such evident in the results. According to Aghasi *et al.*, (2011), nitrogen variance between the control and reclaimed sites can be ascribed to the fact that soil available nitrogen is more in control sites than reclaimed sites due to litter fall and microbial activity which cause transformation of inorganic forms around roots of plants species. Additionally, the reason for the decrease of nitrogen content in reclaimed sites is the removal of natural vegetation which gets destroyed when outside its natural conditions leading to the loss of large amounts of nitrogen from the soil surface.

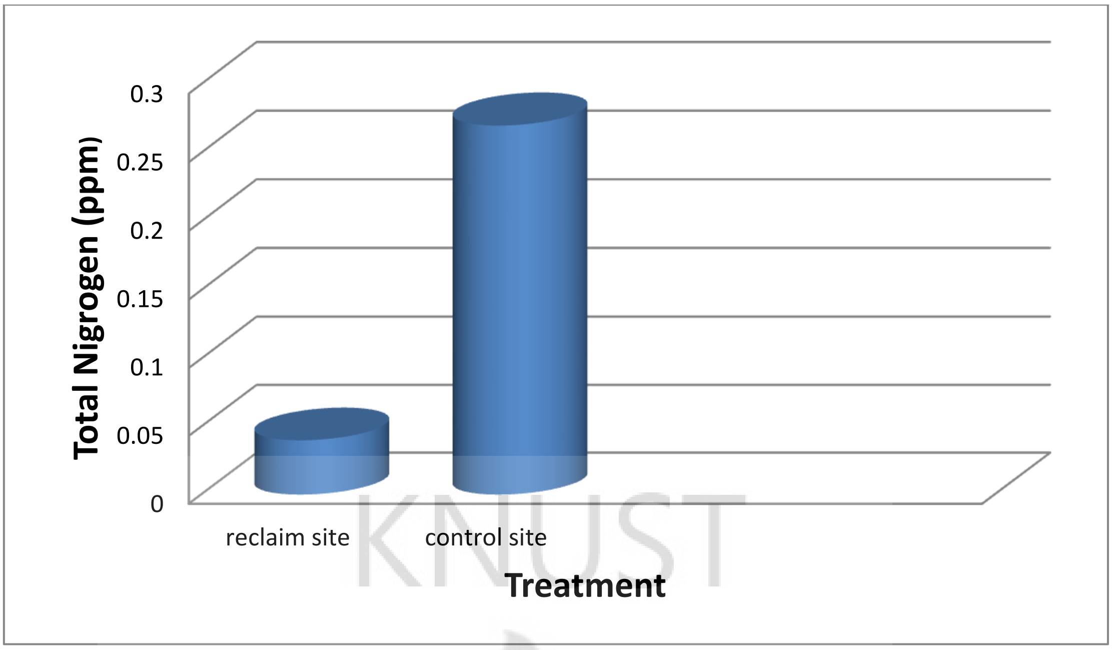

Figure 4.3: Total nitrogen levels at sample sites

4.4 Potassium (K)

As a macronutrient, potassium influences productivity and has a significant effect on fruit quality of crops. Thus, its presence or deficiency could be detrimental to fruit production and subsequently crop yield. The study results indiacted that, reclaimed site had very low levels of potassium recording 15.64ppm, while the control site recorded as high as 74.39ppm as shown in Figure 4.4.

Marschner (1995) gives accounts of the fact that the nutrient interaction between nitrogen and potassium is closely intertwined and in many cases potassium response relies on the quantity of nitrogen available. The results of the study show higher amounts of nitrogen in control site than in reclaimed site. (Figure 4.3) and thereby results in the reduction of potassium in reclaimed sites (Figure 4.4). With the standard Potassium level being 100ppm (FAO, 2013), this resulted in the higher crop yield at the control site because of its higher potassium level than that of the reclaimed site. This could be attributed to an array of factors relating to the disruption of the physical, chemical and biological processes as a result of disturbance of the natural soil formation and its subsequent ability to sustain life (Agrawal *et al.*, 1993). This resulted in the higher yields of pineapples from control site than the reclaimed site.

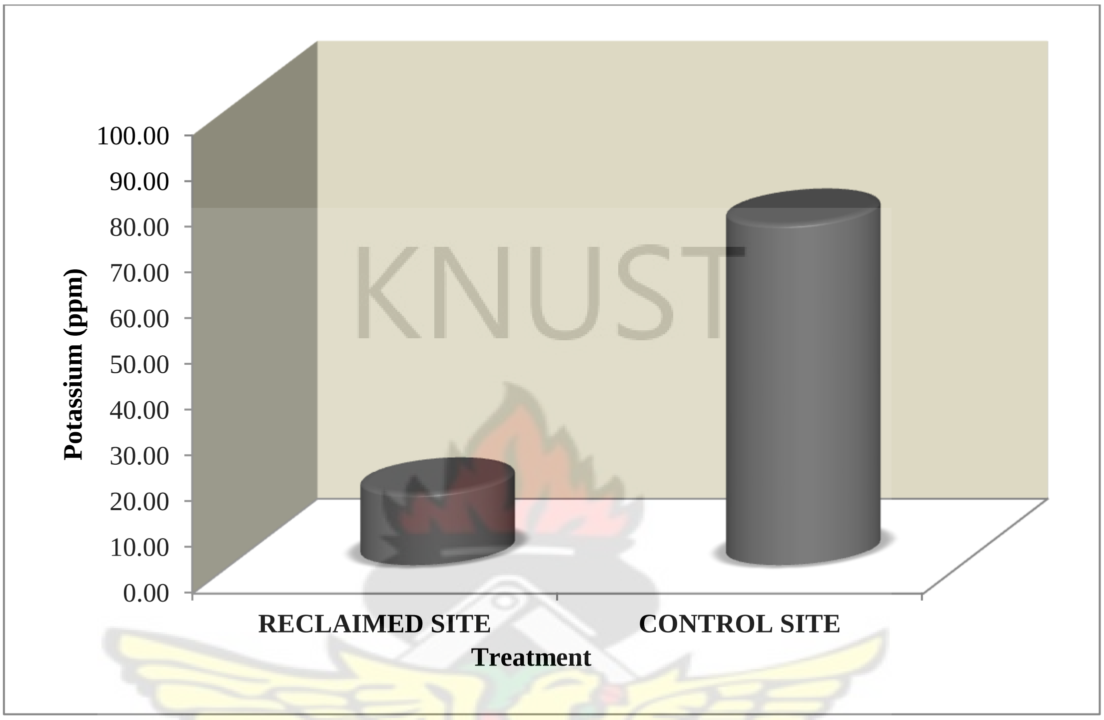

Figure 4.4: Potassium levels at sample sites

4.5 Phosphorus (P)

Phosphorus levels recommended in soils for optimum pineapple production is pegged at 25ppm (FAO,2013). The study indicated that control sites had a phosphorus content of 26.23ppm while reclaimed site recorded 2.10ppm as shown in Figure 4.5. Miller *et al.*, (1976) report that the deficiency of phosphorus in reclaimed sites as compared to the control site may be due to the reduction of soil microbes caused invariably by stockpiling and leaching. Mining operations involves disturbance of the soil thereby altering the physico-chemical and biological composition of the soil, which tend to affect soil development processes and plant growth (Agrawal *et al.*, 1993). That is to say, mining results in soil degradation through destruction of soil structure, accelerated soil erosion, excessive leaching, compaction, depletion of organic matter, decreased plant available nutrients and microbial activities. Evidently in overburden dumps of mine spoils, along with increased heavy metal concentration, there are simultaneous decreases in parameters like organic carbon content and available nutrients including phosphorus (Matti, 2007). This resulted in the poor foliage development and subsequent poor growth of the pineapple crops at the reclaimed site.

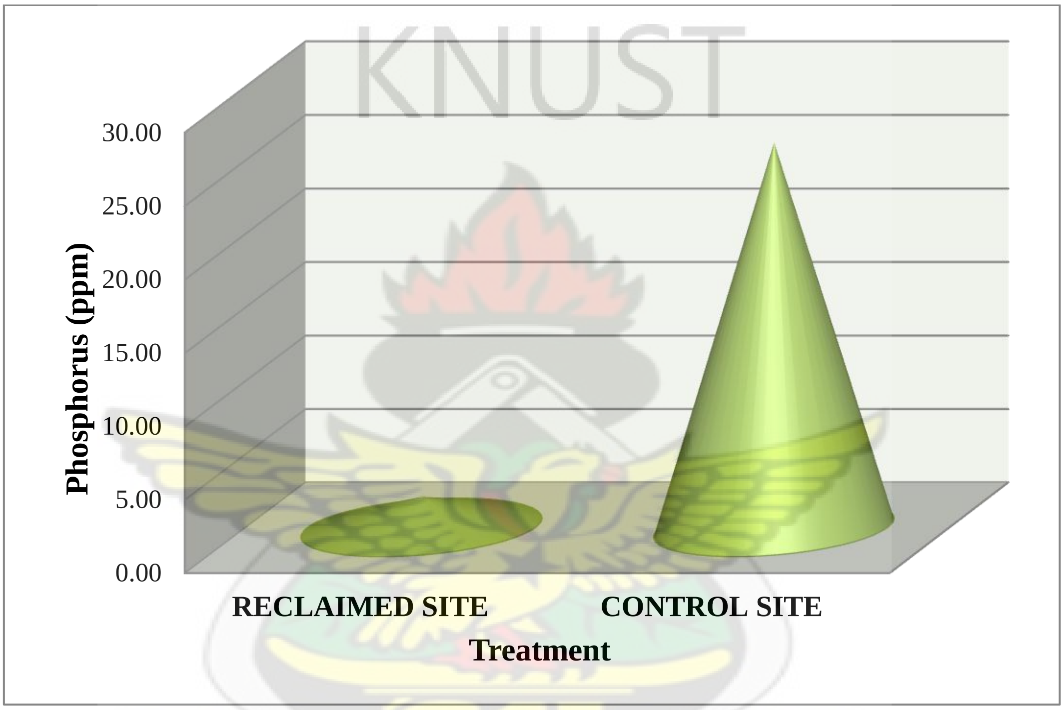

Figure 4.5: Phosphorus levels at sample sites

4.6 Iron (Fe)

Amongst the micro nutrients that are highly required by pineapples to thrive well is iron. The quantity required of this micro nutrient is important. This is to boost crop growth and yield. Deficient soils for example, are often amended with iron containing fertilizers. The study results (Figure 4.6) showed that reclaimed site had higher levels of iron (0.58ppm) whiles control site recorded 0.46ppm of iron levels. This result was observed probably due to continuous weathering of minerals mixed with primary minerals (Donahue et al., 1990; Barcelo and Poshenrieder, 2003; Das and Maiti, 2007). Standard iron requirement for pineapple growth is 5.00ppm (Morton, 1987).

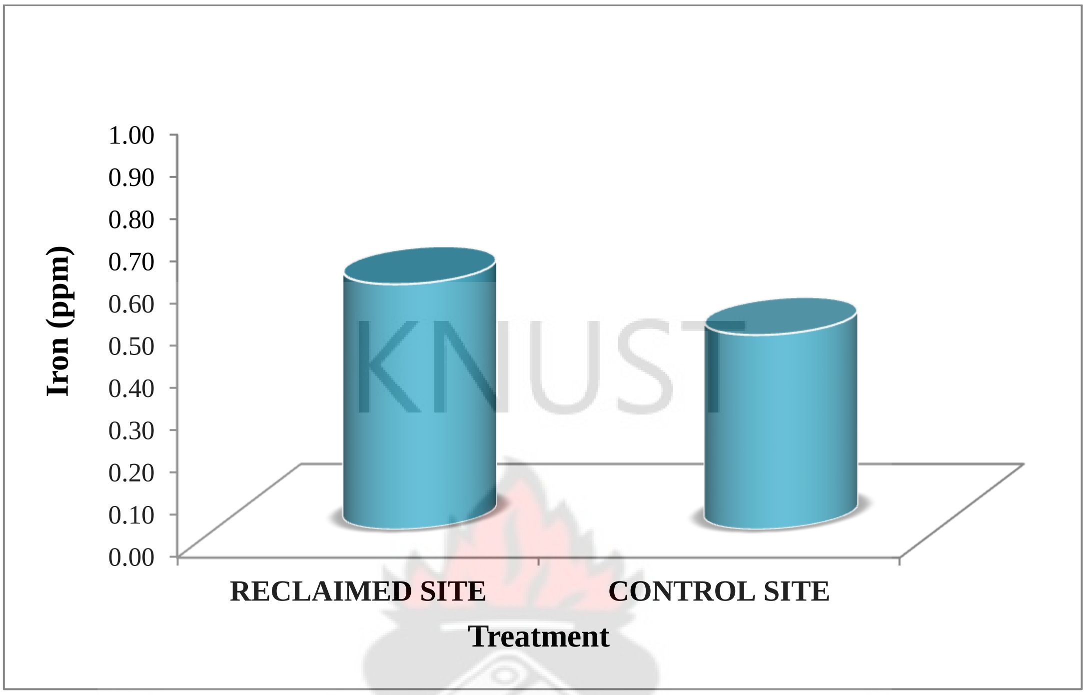

Figure 4.6: Iron levels at sample sites

4.7 Organic Matter

Organic matter of soils as per the results of the study for the treatments showed a wide variation. Organic matter was very high in the control site recording 8.31% while the reclaimed site recorded 1.10%. The optimum requirement of soil organic matter for pineapple growth is 5.17% (FAO,2013). Results are presented in Figure 4.7.

Mined soil has high content of rock fragments in comparison to unmined lands. These spoils are not suitable for both plant and microbial growth because of low organic matter content (Burgharadt, 1993). The reclaimed site compared with the control site had a lower percentage of organic matter, which is seen to have affected the production of the pineapple fruit.

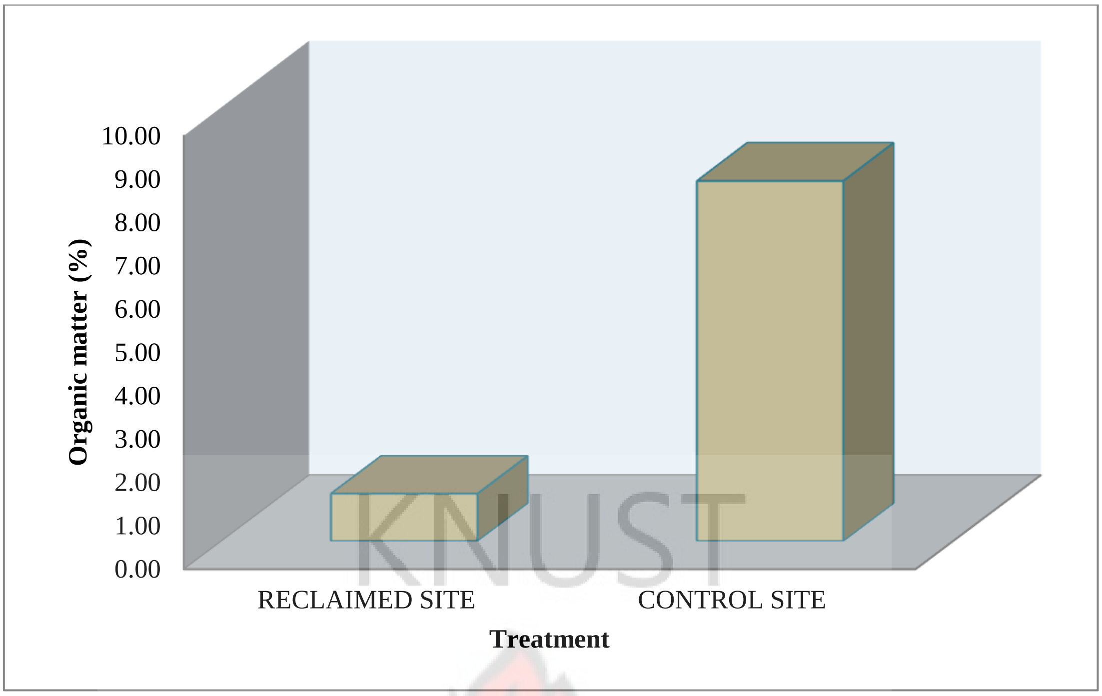

Figure 4.7: Organic matter content of various treatments

4.8 Cation Exchange Capacity (CEC)

The results indicated that CEC was higher in control site (7.25cmolc/kg) than in reclaimed site (4.81cmolc/kg) as indicated in Figure 4.8.

Physico-chemical parameter such as CEC has an impact on the soil formation and biological conditions and hence its ability to support plant growth. Maiti (2007) indicated that in overburden dumps; there are simultaneous decrease in parameters like cation exchange capacity which are important for plant growth. If a soil has a low CEC, up to half of the cations in the soil may be in the water around the soil particles, and not actually held by the particles. These cations are very susceptible to being leached or drained away in the soil water. Soils with high CEC have a much lower percentage of cations in the soil water, so are far less susceptible to nutrient loss by leaching. Hence the higher yield of pineapples at the control site than the reclaimed site.

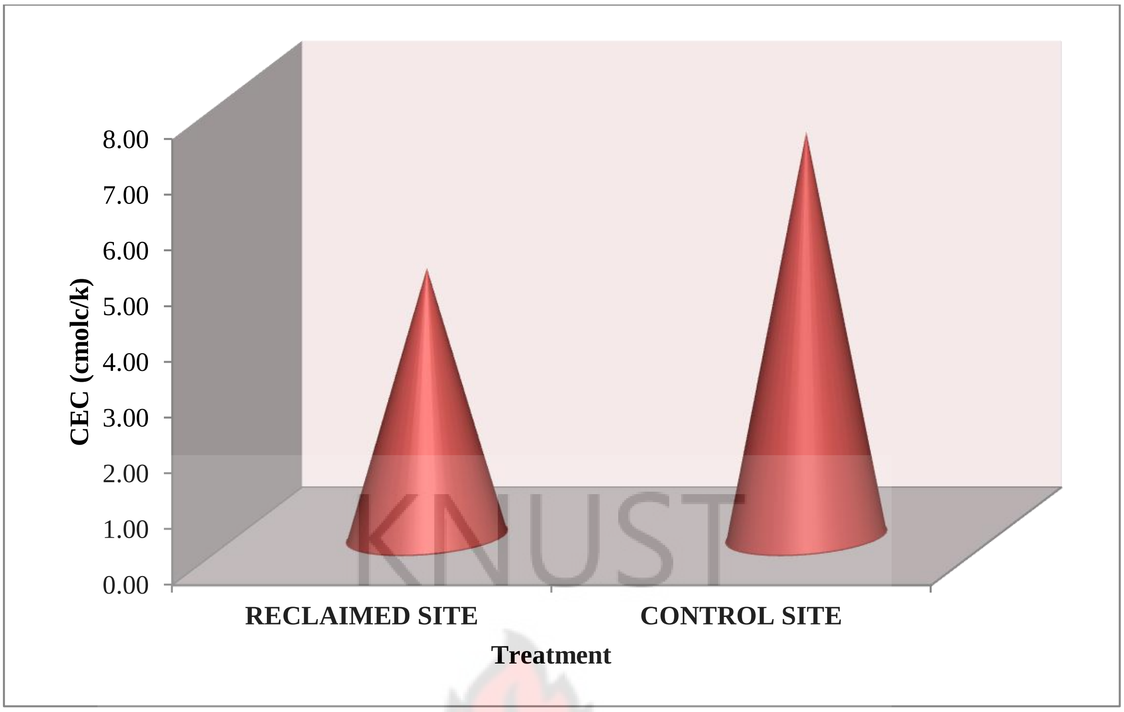

Figure 4.8: Cation exchange capacity of sample sites

4.9 Water Holding Capacity (WHC)

Results from this study as shown in Figure 4.9 below indicate that, water holding capacity of control site had a higher recording of 71.3% whilst the reclaimed site recorded 47.90 % .The water holding capacity was found to be lower in the mine spoil samples than those of the unmined soil due to the decrease in organic carbon /organic matter (Biswas *et al.*, 1989). Miller *et al., (*1976) also highlighted that, the decrease in the water holding capacity of the reclaimed sites is as a result of storage (stockpiling and stripping). The standard water holding capacity for a proper pineapple growth is 80% (FAO,2013). Nutrients released by microbiological activity were lost continually due to the low water holding capacity at the reclaimed site through leaching and erosion. The water holding capacity determines the medium by which most soil nutrients are supplied to growing plants (Department of Environmental and Primary Industries, 2014). The nutrient cycle at the reclaimed site has been broken down due to the low water holding capacity. The reclaimed site ultimately has become unproductive for the cultivation of shallow rooted crops like pineapples. The control site on the other hand is therefore more favourable for pineapple cultivation than the reclaimed site.

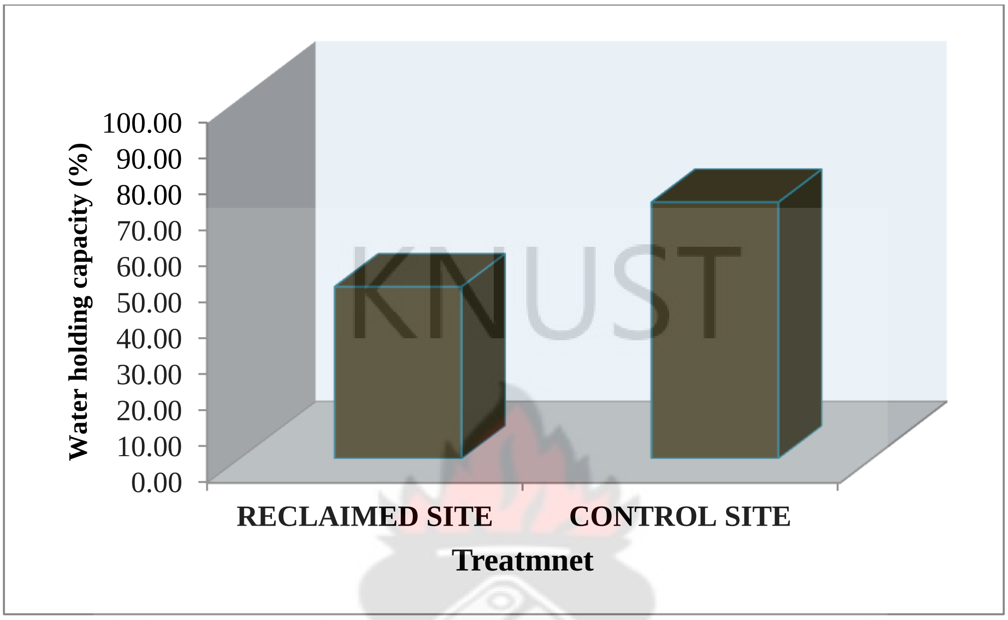

Figure 4.9: Water holding capacity of sample sites

4.9.1 Success Rate

The success rate represents the percentage of crops at the maturity stage. From the results as indicated in Table 4.1, the percentage of pineapple plants at maturity for the control site was 74% whiles the reclaimed site recorded 12.6%. Pineapple has been recorded to have a good intercropping relationship with plantain, oil palm trees among others as observed by Tadesse et al., (2007).

Reclaimed mine land usually lacks true topsoil and composed of basically mine spoil or overburden whose properties range from loose, coarse textured material with many rock fragments to highly compacted clay material. This according to Kumar, (2013) may result in deficiencies (suboptimal concentrations of essential elements) thus, mine altered soils represent a very harsh environment for crop production. This caused the reclaimed site to record lower soil parameters compared to the standard soil requirements by the Food and agriculture organisation (FAO, 2013).

The control site however recorded soil parameters which were within the range for standard soil requirements by the Food and agriculture organisation (FAO, 2013).

This was why the control site had a higher success rate for the pineapples than the reclaimed site.

Table 4.1 Success rate of control and reclaimed sites

Control site			Reclaimed site		
Number of pineapple suckers planted	Number of crops at maturity	Percentage of growth (%)	Number of pineapple suckers planted	Number of crops at maturity	Percentage of growth (%)
50	37	74	500	63	12.6

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study concludes that, the reclaimed site soil ultimately has become unproductive for the cultivation of pineapples. The nutrient cycle at the reclaimed site at Ghana Manganese Company has been broken down. This is because the nutrients released by microbiological activities were lost continually through leaching and erosion as a result of mining operations.

There was a difficulty in the uptake of nutrients by the pineapple plants at the reclaimed site. This was as a result of the low cation exchange capacity at the reclaimed site caused by mining operations.

There was a bad influence on the survival, together with the development of soil microorganisms as well as the control of biological processes of the soil at the reclaimed site, making the soil infertile for the cultivation of pineapples.

5.2 Recommendations

It is recommended that;

- The process of calculating and predicting what will happen in a mine over time as well as a thorough assessment of the topsoil shelf life (period up to which the topsoil will maintain its fertility status to support plant growth should be appropriately executed to enable mine planners draw up best strategies for topsoil excavation).

- In cases where storage is necessary, biological reclamation could be used to preserve stockpiled topsoil if the storage period exceeds the shelf life period (period up to which the topsoil will maintain its fertility status to support plant growth).
- Further investigations could be conducted to assess the chemical composition of the reclaimed site
- Further studies could be done to assess how age of a reclaimed land affects the rate of regeneration of soil nutrients.
- Fertilizers could be applied to supplement the deficiency in soil parameters to increase the soil fertility at the reclaimed site.

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APPENDIX

APPENDIX I: Statistical Summary of Sample Parameters.

NAMES OF SAMPLES	pH	TEMP^0 C	OM (%)	N (%)	P (ppm)	K (ppm)	Fe (ppm)
RECLAIMED SITE	4.80	26.20	1.10	0.04	0.21	15.64	0.58
CONTROL SITE	6.85	25.60	8.31	0.27	26.23	74.39	0.46
STANDARD REQUIREMENTS (FAO)	6.50	26.00	5.17	2.00	25.00	100.00	5.00

APPENDIX I (a): Summary of pH

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Control site	3	20.47	6.8233333	0.0009333
Reclaimed site	3	22.55	4.7166667	0.0006333

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.7210667	1	0.7210667	920.51064	7.03E-06	7.708647
Within Groups	0.0031333	4	0.0007833			
Total	0.7242	5				

APPENDIX I (b): SUMMARY of Temperature

Anova: Single Factor				
SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Control	3	76.2	25.4	0.04
Reclaimed site	3	78.47	26.156667	0.0026333

APPENDIX I (c): Summary of Organic matter

Anova: Single Factor				
SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Control site	3	20.4	6.8	2.4411
Reclaimed site	3	3.21	1.07	0.0009

ANOVA						
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	49.24935	1	49.24935	40.33526	0.003149	7.708647
Within Groups	4.884	4	1.221			
Total	54.13335	5				

APPENDIX I (d): Summary of Nitrogen

Anova: Single Factor

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Control	3	0.7	0.2333333	0.0016333
Reclaimed site	3	0.08	0.0266667	0.0002333

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.0640667	1	0.0640667	68.642857	0.001159	7.708647
Within Groups	0.0037333	4	0.0009333			
Total	0.0678	5				

APPENDIX I (e): Summary of Phosphorus

Anova: Single Factor

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Control	3	79.32	26.44	0.1591
Reclaimed site	3	0.56	0.18666667	0.0006333

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1033.85627	1	1033.85627	12944.778	3.579E-08	7.7086474
Within Groups	0.31946667	4	0.07986667			
Total	1034.17573	5				

APPENDIX I (f): Summary of Potassium

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Control	3	220.89	73.63	0.4557
Reclaimed site	3	46.65	15.55	0.0171

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5059.9296	1	5059.93	21404.1	1.31E-08	7.708647
Within Groups	0.9456	4	0.2364			
Total	5060.8752	5				

APPENDIX I (g): Summary of Iron

Anova: Single Factor

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Control	3	1.26	0.42	0.0013
Reclaimed site	3	1.64	0.5466667	0.001233

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.024066667	1	0.0240667	19	0.012073	7.708647
Within Groups	0.005066667	4	0.0012667			
Total	0.029133333	5				