HEAVY METAL CONTENT OF SOILS USED FOR VEGETABLE CROPPING IN ABUJA METROPOLITAN AREA

BY

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DECLARATION

I hereby declare that this Thesis titled "Heavy metal content of soils used for vegetable cropping in Abuja metropolitan area" has been written by me as an account of my personal research work. It has never been presented anywhere for the purpose of award of same higher degree. All quotations and sources of information from other works have been indented and properly acknowledged by means of references.

Ramatu Suleiman

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Date

CERTIFICATION

This Thesis titled "Heavy metal content of soils used for vegetable cropping in Abuja Metropolitan area" by Ramatu Suleiman meets the regulations governing the award of the Degree of Master of Science in Environmental Managementof Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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To

Raheema and Abdulraheem, for making life worthwhile.

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ABSTRACT

Heavy metals are known to be non-biodegradable,and persist for long durations in the environment. For this reason, the knowledge of accumulation of the material is important for sustainable soil management that will limit the negative impact on the ecosystem, and thereforeenvironmental and public health. This study aimed at determining the extent of heavy metal pollution in soils used for vegetable cropping in the Abuja metropolis. The objectives are to determine the levels of the heavy metals iron (Fe), copper (Cu), lead (Pb), manganese (Mn), and zinc (Zn) in the urban agricultural soils of the city and to find possible dependence on soil physico-chemical properties. Soil sampling was carried out over five farms and one fallow land at different locations within the city. At each location, a quadrat of either quadrats of 15m by 12m or 30m by 6m was first demarcated. Each was subsequently subdivided into 3m by 3m sub-quadrats of which five were randomly selectedfor soil sampling. Composite surface (0-10cm) soil samples were taken over each sub-quadrat. The locations of the studied sites were identified using a "GPS" (Model German). Information onsoil management, including land preparation and fertilizer use, at the corresponding sampling sites was obtained from the farm owners. Beside the total and available heavy metals (Cu, Fe, Mn, Zn, and Pb), other soil properties tested for were particle size distribution, organic matter, available phosphorus, exchangeable Na, K, Ca and Mg, cation exchange capacity and pH. Quantitative data obtained were subjected to both descriptive and inferential statistics at $P<0.05$ *and* $P<0.01$. The soil properties of both the total and available heavy metals analyzed showed varying degrees of significant differences amongst the study locations. However, all soils are sandy, low in organic matter, available phosphorous, exchangeable cations, cation exchange capacity, and are acidic. Nearly all the heavy metals (total and available) showed significantly different amount amongst the various sites. Most of the metals also showed negative correlation with the sand %, and positive with the silt %, clay %, organic matter %, available P, the exchangeable cations, and the cation exchange capacity. Most of the relationships, however, are statisticallyinsignificant. The total heavy metal contents of the soils were generally lower than the comparative levels reported in the literature for similar soils. The exchangeable forms of the metals are low, indicating that under the present conditions, the availability of these metals to plants would be minimal. Factors contributing to heavy metal accumulation over the study area were related to the chemical agricultural products utilized in these practices and the irrigation water used, and road traffic in the area. Result of t-test shows a significantly lower level of the respective heavy metals determined than the EU Regulatory Standard.However, if current practices and anthropogenic input persist, the soils could become progressively contaminated by the heavy metals.

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ABBREVIATIONS

FCT – Federal Capital Territory

UA – Urban Agriculture

UPA – Urban and Peri-Urban Agriculture

CEC – Cation Exchange Capacity

PTE – Potentially Toxic Element

HIA – Health Impact Assessment

EPA – Environmental Protection Agency

GPS – Global Positioning System

SSLs – Soil Screening Levels

DD – Distilled-deionized water

CV% - Coefficient of Variation percent

ANOVA – Analysis of Variance

DTPA – Diethylene Triamine Penta Acetic acid

EU – European Union

CHAPTER ONE

INTRODUCTION

1.1 Background

The UNDP (1996) defines urban agriculture, which is synonymous to urban farming, as 'an industry that produces, processes and markets food on land and water dispersed throughout urban and peri-urban areas'. Based on this definition, urban agriculture is largely in response to the daily demand of consumers within the town, city, or metropolis, and it often entails applying intensive production methods that involve using and reusing natural resources and urban wastes to produce a diversity of crops and livestock (Smit,et al., 1996). It is 'an entrepreneurial activity for people from different levels of income'. For the poorest of the poor, it provides good access to food. For the stable poor, it provides a source of income and good quality food at low cost. For the middle-income families, it offers the possibility of savings and a return on their investment in urban property, and for small and large-scale entrepreneurs, it is a profitable business. Other benefits and services that are less widely acknowledged and documented on urban agriculture include recreation and leisure; health and well-being; landscape beautification; and environmental restoration and remediation (Butler et al., 2002).

The most striking feature of urban agriculture, which distinguishes it from rural agriculture, is that it integrates the urban economic and ecological system. It is embedded in -and interacting with- the urban ecosystem. Such linkages include the use of urban residents as labourers and use of typical urban resources, like organic waste as compost, and urban wastewater for irrigation. There is also a direct link with consumers and direct impacts on urban ecology (positive and negative), being part of the urban food system, competing for land with other urban functions, being influenced by urban policies and plans, etc. Urban agriculture is not a relic of the past that will fade away. It in fact, increases when the city grows. It is an integral part of the urban system.

Urban agriculture may take place in locations inside the cities (intra-urban) or in the peri-urbanareas. The range of productsis equally broad. It includes fish and other aquatic products grown in tanks; ponds and fish cage on sewage lagoons; poultry; orchards, including street trees and vineyards, vegetables grown in small hydroponics solution. Others include market garden, horticulture and vegetable farming on utilities' right of ways, homestead (on-plot), land away from the residence (off-plot), private land (owned, leased), public land (parks, conservation areas, along roads, streams and railways), or semi-public land (schoolyards, grounds of schools and hospitals).Urban agriculture also includes non-food products (like aromatic and medicinal herbs, ornamental plants, tree products, etc.). Often, the more perishable and relatively high-valued vegetables and animal products and by-products are favoured.

According to People and Planet (2005), some 800 million-city dwellers worldwide are involved in urban and peri-urban agriculture. Collectively, they produce about 15% of the World's food. For example, Singapore cities provide 25% of its vegetable and much of its fish. Hong-Kong produces 66% of the poultry and 50% of its vegetable, 25% of Kenya's urban population survives on it and in Buenos Aires, 20% of the city's nutritional needs come from this(UNDP, 1996). Similarly, a recent worldwide survey has shown that 65% and 80% of the inhabitants of Moscow and Kinshasa respectively, practice some forms of urban farming. About 90% of vegetables supplied to Shanghai and other Chinese towns and cities are produced by her inhabitants (Hardy et al., 1996). While in Israel, some 95% of food requirements are obtained from city farming (Freeman, 1996).

Urban agriculture is a dynamic concept that comprises a variety of livelihood systems ranging from subsistence production and processing at household level to fully commercialized agriculture (Van den Berg and Van Veenhuizen, 2005). The products are sold at the farm gates, by carts in the same or other neighbourhoods, in local shops, on local (farmers) markets or to intermediaries and supermarkets. Mainly fresh products are sold, but part of it is processed for own use, cooked and sold on the streets, or processed and packaged for sale to one of the outlets mentioned above. Urban agriculture has existed as long as there have been cities, often evolving as a necessary option for improving food security and supporting the livelihoods of urban residents. Throughout history and around the world, urban agriculture has taken many different forms depending on the climate, available technologies and cultural preferences.

In spite of the benefit from urban farming, the practice has been found to possess a number of health and environmental risks for communities in prolonged contact with the practice, and those in neighbouring areas, as well as for the consumers of produce from it,thereby raising a lot of concern about the practice. The practice provides various potential exposure pathways to agrochemicals, including occupational and environmental exposure and consumption. The intensive use of agrochemicals (fertilisers, pesticides, fungicides) under the system, for example, may lead to residues of agrochemicals in crops or groundwater, with their attendant negative impact on human health. Perhaps the most significant deleterious impact is through heavy metal accumulation in soils.

The main causes of soil pollution from heavy metals (including lead, cadmium, chromium,zinc, copper, nickel, mercury, manganese, selenium, mercury and arsenic) are irrigation withwater from streams and wastewater contaminated by industries and commercial areas, the application ofcontaminated solid waste products, and the use of former industrial land contaminated byspilled oil and industrial waste products. Other important sources of heavy metals are vehicular or automotive emission and burning of wastes.

The rapidly increasing urban populations and industries have led, in many countries to increased solid and wastewater production, with its contamination becoming more complex. It includes industrial wastes, such as heavy metals, acids and derivatives of plastics, and organic components characteristic of human wastes. Similarly, liquid waste from domestic sewage is widely used for irrigation and fertilisation of field crops and fishponds. A large part of the wastewater used is untreated or poorly treated. Yet, wastewaters are known to contain variable forms of heavy metals, bacteria, protozoan parasites, enteric viruses and helminths (WHO, 1992). These risks are not limited to official wastewaters, but often also apply to rivers and other open water sources (Birley and Lock, 1999). Several studies, for example, have revealed that the presence of toxic heavy metals like Fe, Pb and Hg reduces soil fertility and agricultural output (Lokhande and Kelker, 1999). Treated sewage water have also been found to contain variable amounts of heavy metals such as Pb, Ni, Cd, Cu, Hg, Zn and Cr (Sharma and Marshall, 2004), which have the potential to contaminate crops growing under such irrigation. The same thing is true of fertilizer application. Fertilizers contain not only major elements necessary for plant nutrient and growth, but also trace metal impurities, such as Cd, Pb, Hg, As or Ni (Nicholson,et al., 1994; Singh, 1994;Zhan and Shan, 2001)

While soil, naturally, is an important sink for Cd, Pb, Hg, Cr, and other heavy metals (Alloway, 1990),the excessive accumulation and subsequent pollution of the environment by such heavy metals have become, in recent time, an issue of global concern (Nriagu, 1990). Heavy metals are generally present in agricultural soils at low levels. Due to their cumulative behaviour andtoxicity, however, they have a potential hazardous effect not only on crop plants, but also on human health (Das and Rout, 1997).

Despite the risks involved, most urban/peri-urban farmers, view urban agriculture as a profitable and worthwhile venture. Even, not all decision-makers and service providers hold that the use of untreated waste in agriculture is unacceptable and that only appropriately treated waste yields important benefits. This largely, can be attributed to (and therefore calls for research into the subject) a dearth of information, particularly on issues such as farmers' needs and preferences, health and environmental risks, and economics of using waste for agriculture.

1.2 Statement of the Research Problem

Urban agriculture has increased tremendously in the past three decades in many parts of Nigeria (Van den Berg and Van Veenhuizen, 2005). This is probably due to harsh economic conditions created by Structural Adjustment Programme (SAP), as well as encouragement from government, through different initiatives such as the Operation Feed the Nation (OFN), National Poverty Eradication Programme (NAPEP) and the National Directorate of Employment (NDE). Available urban lands, which otherwise have been abandoned, such as waste dumpsites, vicinities of industrial areas and stream channels, have been turned into agricultural sites. Although this practice apparently led to an increase in urban food production, it presented serious implications for community health (Clark, 1992; Cummingham&Saigo, 1996; Margaret, 1986). Elsewhere around the world, where farming activities and land utilization, especially for industrial purposes are regulated, the major anthropogenic sources of heavy metal contamination of agricultural soils are via fertilizer application, sewage sludge or irrigation with wastewater (Devkota& Schmidt, 2000; Frost & Ketchum, 2000; Mangwayana, 1995). In Nigeria, the most important sources of such contaminants are mostly use of untreated wastewaters and polluted stream water, industrial processing plants or leachates from solid waste dumpsites (Margaret, 1986).

While pesticideand fertilizer/manure can be bought, it is difficult to find sites with proper, reliable and cheapwater access. With perhaps little exceptions, urban farmers typically make use of polluted water fromstreams or drains for irrigating their fields.Previous studies have established that although such waters are a rich source of organic matter and plant nutrients, they also contain sufficient amounts of soluble salts and heavy metals (Uwah et al, 1999; Sahoo and Klopker, 1995; Binnset al., 2003; Dawaki and Alhassan, 2008; Olofin, 1999; Tanko, 2004). The possible outcome of use of such polluted water for cultivation of crops over a long period, is the accumulation of heavy metals in the associated soil, with its deleterious consequences on the environment. It has been hypothesized that, the tensions between supply and demand for irrigation water in drylands, generally, are likely to be aggravated by climate change (Perry et al., 2009), thus necessitating an efficient and effective irrigated agriculture, in order to increase and sustain crop productivity (Bates et al., 2008).

Today, concerns about the impact of anthropogenic activities on urban and suburban soils, in Nigeria, are beginning to emerge. Some researches on the subject matter are beginning to emerge. In southwestern Nigeria, for example, Omoloye (2009) conducted an investigation on field accumulation risks of heavy metals and uptake effects on the biology *of Sitophiluszeamais.* The result obtained showed that despite exposure to contaminated irrigation water and domestic and industrial wastes of diverse origin, of all major heavy metals tested, only cadmium (4.50 - 9.63 mg kg^{-1}) and mercury (1.27-2.33 mg kg^{-1}) were accumulated in the soil beyond the EU maximum tolerable limits for potentially toxic elements (PTE). The uptake bio-concentration in the maize stover and grain of all the heavy metals from all the sites were also found to be below the maximum tolerable PTE. In Lagos, Olugbenga et al (2011) undertook an inventory of potential land and water resources that can contribute to urban agriculture within Lagos metropolis. The result obtained showed that Lagos metropolis requires 18 times its present size (3,577 km^2) to be able to feed her people on sustainable basis.

In Benue State, Adamu and Nganje (2010) conducted an investigation on heavy metal contamination of surface soil under different land use. The result obtained showed that heavy metals occur in relatively high concentrations in urban soils as compared to the forest soils, indicating that the forest soils have suffered least anthropogenic input. The non-cropped urban soils accumulated Cu, Zn and Cd and the urban cropped soils accumulated As and to a lesser extent Pb and Cd. Similarly, in Agbor and Abraka in Delta State, Akpoveta,et. al. (2010) conducted a study on the physicochemical characteristics and levels of some heavy metals in soils around metal scrap dumps and concluded that such soils are highly contaminated.In Zaria area, Abdulraheem (2011) investigated the heavy metal content of three cropped sites and a control uncropped plotand concluded that the soil studied are not seriously contaminated yet, but there is a distinct trend towards such condition.

Issues of heavy metal pollution in agricultural lands represents an important and growing area of interest to soil and environmental scientists, because of their high potential to disrupt the delicate balance of the soil biological and physico-chemical processes, upon which soil fertility is built. As at date, no published report of soil condition under urban agriculture, for any part of Abuja, is known to the author, despite the fact that the phenomenon is on the increase in the city. Today, a very high proportion of all perishable vegetables consumed in the city are probably produced in the town. Wherever space allows, urban and peri-urban agriculture take advantage of household organic wastes and any water source for dry-season or annual irrigated farming. The present study aims to investigate the level of some heavy metals in soils used for vegetable production in the city (Abuja), compared to acceptable international maximum permissible concentration of potentially toxic elements (PTE) (EC, 2001). It is hoped that the information obtained, will be useful in the preparation of land use plan for purposeful urban farming policy in the city.

Specific questions that are addressed in the investigation include:

i. What is the nature of soils in the study area?

ii. What are the levels of heavy metals in the soils used for vegetable production as compared with that not in use?

iii. Does the level of heavy metal contents of the soil suggest chemical pollution?

iv. Can the level of available heavy metal in the studied soils be predicted by use of some soil indicators?

1.3 Aim and Objectives of the Study

The aim of the study is to assess the level of some key heavy metals in soils used for vegetable cropping in Abuja metropolitan area. However, the specific objectives are to:

i. determine some key physico-chemical properties of selected soils used for vegetable cropping together with that not used for cropping,

ii. determine the amount of total and available heavy metals (Fe,Mn, Cu, Zn, Pb) of the selected soils,

iii. assess the extent of heavy metal contamination of the selected soils by comparison with the EU regulatory standard, and

iv. establish the extent of dependency of the heavy metals on the measured soil physico-chemical properties.

1.4 Hypothesis

The hypothesis deriving from the aim and objectives of the study is three fold:

i. There are no significant differences in the levels of the examined soil properties and heavy metals in soils under vegetable cropping at different locations in the city.

ii. The level of heavy metals in the studied soils are not significantly greater than the level specified by the EURegulatory Agency.

iii. There are no significant relationships between the physico-chemical properties and heavy metal content of soils studied.

1.5 Scope of the Study

A number of studies have demonstrated that total amount of heavy metal concentration in soils do not provide a good indicator of the levels of the metals that are actually available to plants(Alloway, 1990;Dawaki and Alhassan, 2008;Abdu, 2010). Rather, the level of exchangeable metal does. On the other hand, it has been argued that in order to ensure that the soil is managed in such a way as to prevent the unavailable forms from becoming g available, information on the unavailableforms of the heavy metals (i.e. total amount) is equally of great importance.Based on these arguments, this study had decided to focus on both the total and available heavy metal contents of the soil studied. The heavy metals analyzed for include Fe, Mn, Cu, Zn and Pb.The physico-chemicalsoil properties assessed include particle size distribution, bulk density, total porosity, exchangeable cations, pH and organic matter. The study area is Abuja Metropolitan area and all soils studied lie in the open field within the built-up area. The study does not include peri-urban areas. Given the enormous cost of laboratory analysis, the sampling and analysis of soil properties is limited to the surface horizons but field examinations incorporate the totality of the soil profile.

1.6 Justification of the Study

In as much as many opportunities and advantages can be derived from urban farming, the soil that is the major resource for farming activities cannot be overlooked. Besides, the health and wellbeing of consumers of urban agricultural produce are linked, either directly or indirectly to the chemical composition of the soils on which these crops are grown. The foregoing therefore makes this research very important to environmental sustainability and improved wellbeing of the people, since it will shed more light on issues surrounding chemical contamination of soils.

Heavy metals in the environment may accumulate unnoticed to toxic levels. In spite of the relatively low level of industrialisation in Africa, there is high potential for heavy metal accumulation in the soils. The challenges posed by heavy metals on human health in Africa are issues that need robust studies and appropriate policy responses.

Heavy metal accumulation in agricultural soils pose long-term problem of up-take accumulation with its inherent negative human and animal health implications (Sauveet al., 1996; Ferguson, 1990; Chumbley, 1982) and could strongly influence species diversity and bioavailability (Lester, 1987). However, there is paucity of information on the extent of these contamination and their effects on biodiversity and bioavailability and by implication, on human lives in Nigeria.

A precise knowledge of heavy metal concentrations and their dependence on soil physico-chemical properties provide a basis for careful soil management, which will limit as far as possible, the negative impact of heavy metals on the ecosystem. Knowledge of present heavy metal pollution levels in soils used for urban agriculture would be a starting point in estimating the consequences of poor urban agriculture management regimes, which may mobilize previously unavailable forms of the heavy metals and lead to their incorporation into the food chain.

1.7 Organisation of Study

This study is organised into six substantive chapters. Chapter one introduces the study and presents the statement of research problem, aim and objectives of the study. Chapter two deals with the theoretical framework and literature review. Chapterthree describes the environment of the study area, while chapter four describes the materials and methods used in the study. The results obtained from field and laboratory work are described and discussed in chapter five, and chapter six is the summary and conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter places the research topic in geographical content. It examines the concept of heavy metal pollution of soils and review relevant literature on soil pollution by heavy metals due to urban farming.

2.2 Urban Agriculture

2.2.1 Features of urban agriculture

Urban agriculture (UA) has existed as long as there have been cities, often evolving as a necessary option for improving food security and supporting the livelihoods of urban residents (UNDP, 1996). Throughout history and around the world, urban agriculture has taken many different forms depending on the climate, available technologies and cultural preferences. The territory included within official city boundaries vary enormously across countries and can be more or less built-up; likewise, the "peri-urban" area around cities, ranges from densely to sparsely populated. The distinction between "urban" and "peri-urban" depends on the density, types, and patterns of land uses, which determine the constraints and opportunities for agriculture.

The dimensions to UA include crop and livestock farming, inputs and services delivery, processing and marketing of UA produce. These activities are often related and their significance lie mainly in the integration of the marginal groups, mostly women, into the local economic development and urban environmental management.

The crop production takes place in open spaces within the city such as government lands, un-built sites, along drains, under pylons and in lowlands areas. In cities along the coast such as Port-Harcourt, Accra, Lome, and Banjul, farmers within urban open spaces usually site farms along available sources of water. In Niamey, urban farms are located near and along the river Niger (Graefe, 2004), while in Lagos, farming around the city relies solely on the wetland, which offers opportunity for farmers to cultivate throughout the year using water from ponds, dug wells or wash bores.

Urban Agriculture is not just about crop production, but also includes livestock and a number of other animals and birds. It also includes fishery productions, forestry and non-wood forest products, as well as ecological services provided by agriculture, fisheries and forestry. Often, multiple farming and gardening systems exist in and near a single city (Madden and Chaplone, 1997; Rootpedia, 2008). However, animal farming is not as common as crop production. Poultry and milk production in particular are favoured for their marketing potential and contribution to income generation.

The input used and kinds of service providers vary. Urban farmers adopt different strategies to minimize input use and maximize output. Major input used include labour, land, water, equipment and simple farm tools, organic and inorganic fertilizer, pesticides, and seeds. In most cases, land and water are free. In West Africa, for example, land in urban areas belongs to either government institutions, individuals, families and traditional authorities, or chiefs (Obuobie et al., 2003; Olofin and Tanko, 2003). In Bamako, producers may have access to land through lease, renting and customary estates (Zalle et al. 2003). For soil improvement, most urban vegetable farmers use chicken or cattle manure or/and chemical fertilizers, which are sometimes subsidized as in Dakar. In few cities, farmers apply already sorted municipal solid waste (as in

Cotonou), or burnt waste (as in Kano). Few people are involved in providing input for the farmers. Quite often, they depend on old stock or the open market for input purchase. Many Urban Agriculture farmers in West Africa do not have access to formal credit systems. This is mainly because farmers are not able to meet the collateral demands of financial institutions. The scale of production and technology is usually intensive on very small pieces of land, and may either be for self-consumption (backyard farming) or market-oriented (open spaces within and around the cities), or both. In the case of market-oriented, the products (fresh vegetables, ornamental plants and small livestock) are sold at the farm gate, in local markets or supermarkets.

It is often assumed that the profitability and sustainability of peri-urban agriculture and in some cases, what sets them apart from rural agriculture in general, and vegetable production in particular, is the nearby existence of large populations, relatively low transportation, storage and packaging costs, low post-harvest losses, and availability of fresh perishable food. Others include proximity to services, including waste treatment facilities and waste recycling and re-use possibilities. Enhanced peri-urban farm jobs and incomes, and non-market access to food for poor consumers, would provide the base for investment in value-adding and other high return activities in peri-urban areas while contributing to overall economic growth (Boncodin et al., 2002; Goletti et al., 1999).

Urban agriculture is very often believed to be a response to urban crises, a survival strategy of the migrants who come from the rural part of the country, and after being disappointed at not finding work in the city, they become part of the growing population of the urban poor. Streiffeler (2000) disputed the claims that the migrants from the village to the city are people who are "attracted by the lights of the town". He argued instead that the migrants only hope that by coming to the towns, they can increase the number of different activities they are engaged in, for purposes of survival; and one of such activities is UA.

When carried out properly under safe conditions, UA can contribute to food security in three ways:

First, the quantity of food available is increased through urban agriculture. Poor urban dwellers often lack the purchasing capacity to acquire adequate amounts of food. Urban agriculture appears to reduce food insecurity by providing direct access to home-produced food to households and to the informal market. Much UA is for own consumption, with occasional surpluses sold into the local market. Even for people who have little or no land, part-time farming of vegetables can provide food and income. Simple, popular hydroponics or substrate culture in beds can produce high value and nutritious vegetables on surfaces as small as one metre.

Urban agriculture also appears to enhance food security during times of crisis and severe scarcity. Whether caused by national crises (civil war, widespread drought, currency devaluations, inability to import, etc.), or household crises (illness, health, sudden unemployment, etc.), UA plays an important role in providing emergency supplies of food.

Second, UA enhances the freshness of perishable foods reaching urban consumers, increasing overall variety and the nutritional value of food available. While not universal, case studies have shown differences in nutrition, especially among children, when poor urban families farm. An important reason appears to be that food produced by consumers, or in close proximity to them, is often fresher than food that travels long distances to markets.

Third, UA offers opportunities for productive employment in a sector with low barriers to entry. UA is estimated to involve some 800 million urban residents worldwide (People and Planet, 2005). Based on a combination of national census data, household surveys, and individual research projects in specific cities, it is estimated that one-quarter to two-thirds of urban and peri-urban households are involved in agriculture. According to the Urban Agriculture Network (TUAN), of the roughly 800 million people currently involved in urban agriculture worldwide, 200 million produce for the market and 150 million are full-time employees. UA is often carried out on a part-time basis by women, who can combine food production activity with childcare and other household responsibilities. Case study data indicate that both food availability and incomes in poor farming households are significantly higher, compared to households of non-farmers (Streiffeler, 2000). Interestingly, the urban gardeners are not typically the poorest residents but rather those families that have lived long enough in the city to secure land and water, and become familiar with the market channels for selling surpluses.

Aside from the above, UA is also known to promote improved environmental quality. The problems associated with providing environmental sanitation services are central to the urbanisation phenomena. Urban waste is considered one of the most serious and pressing urban environmental problems. In many urban areas of developing countries, less than 50% of the municipal solid wastes are collected and only an insignificant fraction is disposed of appropriately. This not only increases the rate of diseases and mortality, but also slows down the economic progress of hundreds of millions of people in developing countries. Most cities focus on simply getting rid of their waste and fail to recognise its economic asset. The conventional approach to environmental sanitation is characterised by a linear waste management system, where valuable plant nutrients are often not only wasted, but also create pollution problems in receiving waters. Similarly, growing food in cities requires additional water, and this could exacerbate already prevailing problems of inadequate water supply for household and industrial use. Urban agricultural activities can therefore improve water management for sustainable agricultural production, such as for example through wastewater reuse.

Closing the nutrient loop is one of the main objectives of an ecological approach to environmental sanitation, and reuse of wastewater and organic waste in UA may contribute to closing this nutrient loop. Thus, in addition to food security and income generation, urban agricultural activities can thus help to improve public health and resource management (Nelson, 1996).

2.2.2 Environmental problems related to urban agriculture

Quite often, UA is perceived as an activity that is marginal, temporary and archaic. Some regard it as an activity that is actually harmful to farmers, consumers, the environment, the urban land economy and physical landscape. Recently, some studies have been carried out on the health issues related to urban agriculture. Birley and Lock (1999), and Lock (2001) have made an extensive review of the literature on this subject matter. The main health risks associated with UA fall under the following categories:

- Contamination of crops with pathogenic organisms (e.g. bacteria, protozoa, viruses or helminths), due to irrigation by water from polluted streams, or inadequately treated wastewater or organic solid waste products;
- Human diseases transferred from disease vectors attracted by agricultural activity;
- Contamination of crops and/or drinking water by residues of agrochemicals;

- Contamination of crops by uptake of heavy metals from contaminated soils, air or water;
- Transmission of diseases from domestic animals to people (zoonosis) during animal husbandry, processing or meat consumption;
- Human diseases associated with unsanitary post-harvest processing, marketing and preparation of locally produced food;
- Occupational health risks for workers in the food-production and food-processing industries.

i. Contamination of crops due to wastewater or organic solid waste products

The main use of solid waste (household waste, market refuse, sewerage, night soil, manure, fish waste, and agro-industrial waste)is as a soil improver. Agro-industrial waste, household refuse and market wastes are also used to produce feed for livestock and fish. Composting is the most common form of processing urban organic waste products. Composting reduces several health risks by:

• getting refuse ‘off the street’ and so reducing health hazards related to inadequate refuse collection and disposal (and associated risks such as transmission of diarrhoea and dysentery by houseflies, increased breeding of mosquitoes and contamination through scavenging animals);

• by sanitising waste through heat destruction of some pathogens, including helminth eggs found in night soil.

There are four main health risks related to the reuse of organic waste products:

a) Pathogens may not be destroyed (especially helminth eggs in night soil) if the compost is not properly prepared (too low temperature). The risk is greatly enhanced if organic materials are mixed with human excreta from latrines, manure or hospital waste, causing pathogens to breed.

b) Improperly maintained compost heaps may attract rodents (which may be reservoirs of diseases) and insects (which may be vectors of diseases).

c) Non-biodegradable fragments may cause injuries, skin infections, respiratory problems and other occupational problems of waste pickers, waste selectors and others involved in the composting process.

d) Heavy metal contamination due to mixing of organic materials with industrial waste (caused for example by occasional dumping of industrial waste in open spaces within residential areas).

Liquid waste from domestic sewage is widely used for irrigation and fertilisation of field crops, perennials and trees, biogas production, and fishponds. A large part of the wastewater used is untreated or poorly treated. Yet, wastewaters are known to contain wide range of bacteria, protozoan parasites, enteric viruses and helminths. These risks are not limited to official wastewater but often also apply to rivers and other open water sources, as indicated by figures gathered by Westcott (FAO, unpublished, cited in Birley and Lock, 1999): 45% of 110 rivers tested carried faecal coliform levels higher than the WHO standard for unrestricted irrigation.

Furedy (1996) points out that official attitudes towards the health risks associated with reuse of urban waste products, have historically changed with necessity. Furthermore, she believes that perceived health risks of the reuse of urban waste products in agriculture are overstated and that regulations concerning waste reuse are frequently outdated or lack comprehensiveness. Armar-Klemesu et al. (1998) indicate that the major sources of bacterial contamination of fresh vegetables may draw from the distribution, handling and marketing system rather than from production.

ii. Diseases transmitted by disease vectors attracted by agricultural activities

Malaria occurs in many environments but particularly, in areas where irrigation is practised. Malaria, in relation to urban agriculture, is a serious risk in Africa only. Most malaria is found on the periphery of the cities where mosquitoes (the main one being *Anopheles gambiae*) breed in temporary water pools that contain clean, sunlit and shallow standing water in rice fields and poorly drained water surfaces (due to irrigation or interfering with natural drainage) and uncovered water tanks.The type of crops grown and farming methods used in urban agriculture determine largely whether or not urban agriculture increases malaria risks. The conditions for growing wet crops and forms of ridge cultivation (e.g. rice, sweet potato and yams), for example, are favourable for the breeding of malaria mosquitoes. Cassava growing, on the other hand, is only a problemwhen it is grown in cultivation ridges in wet clay soil. Maize and banana crops, as well as tall grasses, present no particular malaria risk, contrary to popular belief in Africa.

The Aedes mosquito, which is the main vector of dengue, breeds in water containers that include much solid waste (e.g. tin cans, coconut husks, rubber tyres, water storage jars). Chagas disease has recently been emerging in peri-urban areas mainly in Latin America. Poor disposal oforganic solid waste (animal manure, crop residues and other farm refuse) may also attract rodents and flies that may be carriers of diseases (e.g. plague), and scavenging by domestic animals (e.g. cats, pigs and rats) is associated with a range of food-borne diseases such as amoebic and bacillary dysentery.

iii. Residues of agrochemicals

Urban agriculture provides various potential exposure pathways to agrochemicals including occupational and environmental exposure and consumption. The intensive use of agrochemicals (fertilisers, pesticides, fungicides) may lead to residues of agrochemicals in crops or groundwater, and negative effects on the health of agricultural workers. Because of differences in usage, the level of risk of crop or groundwater pollution due to agrochemicals is higher in intensive commercial horticulture, especially for vegetables, than in traditional and subsistence farming (WHO Commission on Health and Environment 1992). Acute poisoning due to agrochemicals can cause a range of symptoms which are often not correctly diagnosed (e.g. dizziness, diarrhoea, headache, memory impairment, convulsions, coma, liver and kidney impairment and lung fibrosis). Ingestion of agrochemicals is a common way of committing suicide throughout the world.

Chronic illnesses have been associated with residues in foodstuffs due to concentration of agrochemicals in the food chain, including vegetables, red meat, poultry and eggs, and residues can be found in human milk (FAO and WHO 1998).

iv. Uptake of heavy metals from contaminated soils, water and air

The main causes of soil pollution from heavy metals (including lead, cadmium, chromium, zinc, copper, nickel, mercury, manganese, selenium, mercury and arsenic) are irrigation with water from streams and wastewater contaminated by industry, the application of contaminated solid waste products and the use of former industrial land contaminated by spilled oil and industrial waste products.Important sources of heavy metals are smelters, refineries, manufacturing plants, vehicles, metalliferous mines, ceramic industry (lead and cadmium), leather tanneries (chromium salts), lignite-based power plants, aluminium industry, electronics industry, and metallurgical industry. Some heavy metals precipitate in sewage sludge, which can therefore contain rather high concentrations.

The heavy metals may accumulate in the edible parts of crops that are consumed by people, or fed to animals. Plant uptake of heavy metals varies, which opens up the possibility of adapting the choice of crops in relation to the degree and type of contamination. Generally, the highest amounts of heavy metals accumulate in the leaves, whereas the lowest contents are located in seeds. Beans, peas, melons, tomatoes and peppers show very low uptake figures. Plant uptake of heavy metals (especially of cadmium and lead) also varies with soil pH (Iretskaya and Chien, 1998).

In contrast to pathogenic contamination, the risk of heavy metals in wastewater used in urban agriculture is less conclusive as few studies have examined this issue. The risk depends primarily on the upstream sources of pollution. The extent of industrial pollution in an area is an important factor.

Puschenreiter et al. (1999) conclude that, after considering the several available pathways to reduce the transfer of heavy metals to the human food chain, urban soils with slight heavymetal contamination can be used safely for gardening and agriculture if proper precautions are followed. However, Birley and Lock (1999) argue that little is known of the chronic health effects of consuming tiny amounts of heavy metals over long periods, and that further research is needed. Increased concentration in the human food chain over a long period can provoke detectable damage to health (carcinogenic and mutagenic effects).

v. Zoonosis

Zoonotic diseases are infectious diseases transmitted through direct contact of human beings with animals during production processes or ingestion of contaminated animal products. Two major bacterial diseases carried by cattle are bovine tuberculosis and brucellosis. Bovine tuberculosis is transmitted via the ingestion of contaminated unpasteurised milk from infected cows, and causes symptoms similar to respiratory tuberculosis. Bovine tuberculosis is transmitted via the ingestion of contaminated unpasteurised dairy products or through direct contact with infected animal material (blood, urine) and forms a main occupational hazard for livestock farmers and slaughterhouse workers. It can also spread by air-borne transmission and inhalation (e.g. in the neighbourhood surrounding a slaughterhouse).

Taeniasis and cysticercosis (beef and pig tapeworm) are transmitted by consumption of meat infected with tapeworm eggs ingested by animals that scavenge on human faeces, or of crops irrigated with improperly treated sewage. Pig tapeworms create more severe effects in humans than beef tapeworm. Trichinosis is transmitted by consumption of infected meat of pigs that scavenge on food waste and dead animals.

Anthrax is most common in people who work with livestock or work in animal product industries (e.g. tannery). It can be transmitted through a cut in the skin, by inhalation of bacterial spores or consumption of infected meat.Leptospirosis (Weil’s disease) is transmitted through the contact of humans with infected animal urine or contaminated feedstuff or by swimming in or drinking from water supplies contaminated with animal urine.Salmonella and campylobacter can be transmitted through contamination of animal feed. Animals (especially poultry) shed pathogens in their faeces in slaughterhouses, which may infect the meat. The wastewater discharge from intensive poultry farms can carry heavy loads of these micro-organisms and may contaminate drinking water supplies.

vi. Summary and conclusion of impact

It is common knowledge that if not practiced properly, urban agriculture can indeed be both unsanitary and polluting. One well-known example, vegetable irrigation with untreated wastewater from Chilean peri-urban farms, resulted in a few cases of cholera in 1992 because the vegetables were not cooked. This same problem was more pronounced in Peru, but now both countries have instituted water management regimes that have prevented a recurrence.

Government authorities have frequently responded to these problems by prohibiting urban farming rather than trying to resolve them. In Nairobi, for example, it is illegal to grow crops above a certain height. Lusaka, Kampala and other cities, once banned maize cultivation, which was believed to spread malaria. Most North American cities ban poultry production. Lomé, Togo prohibits growing sorghum in the city because authorities think it makes the city dirty. Bamako, Mali has prohibited straw-producing cereals since 1989 because they are believed to breed mosquitoes and serve as hiding places for criminals (Smit et al., 2001).

The main problems that may emerge from urban farming occur because of its close proximity to densely populated areas sharing the same air, water, and soil. Food production in the polluted environment of cities may cause contamination. Livestock rearing and use of chemicals and waste in farming can contaminate the soil and water used by city residents. Although these problems are shared with rural farming, the population concentration in cities makes their impact more serious. Many problems are caused by poor practices through lack of information and extension assistance.

The consideration of the public health and environmental risks associated with urban agriculture is an important element in policy decisions on urban agriculture. However, the review of the available literature indicates that, although insight into the potential health risks of urban and peri-urban agriculture is growing, detailed information on the actual health impacts of urban agriculture is scanty. Many of the health risks that are brought in relation to urban agriculture are not specific to urban agriculture and many of the perceived risks are based on research in rural agriculture. One can encounter cases in the literature where warnings are given about e.g. heavy metals in urban produced food due to use of contaminated soils or irrigation water, when later it turns out that rural produce sold in the same town contains similar levels of heavy metals.

There is little information available that allows comparison of the global burden of disease foreach of the categories of health risks mentioned above. Most of the available data are of the snap shot type and there are few longer term studies available, which would enable the assessment of the impacts of accumulation over time (e.g. for heavy metals).

Little of the available literature can assist in the formulation of adequate policies to mitigate the health and environmental risks associated with urban agriculture and there are even fewerstudies that monitor and evaluate the impacts realised by such policy measures and their costefficiency. In order to be able to formulate adequate policies, more research has to be undertaken that specifies:

• The environmental conditions under which health problems related to urban agriculture occur (i.e., type of agriculture, farm management practices, characteristics of the location, etc.)

• The groups that are most vulnerable to those impacts and the factors that determine this vulnerability (e.g. poverty, gender, age, main occupation).

• The factors that currently restrict the urban poor from engaging in less risky agricultural and food practices

• The resources and technical capacity available in cities to implement risk mitigating policy measures.

2.2.3 Future of urban agriculture

Demographic and urban growth is one of the major challenges of the present century. While the world's population is doubling, the world's urban population is tripling. Within the next few years, more than half the world's population will be living in urban areas Available statistics show that more than half of the world’s 7 billion people live in urban areas, crowded into 3 percent of the earth’s land area (Angotti, 1993; UNFPA, 1993). The proportion of the world’s population living in urban areas, which was less than 5 percent in 1800 increased to 47 percent in 2000 and is expected to reach 65 percent in 2030 (United Nations, 1990; 1991). However, more than 90 percent of future population growth will be concentrated in cities in developing countries and a large percentage of this population will be poor. In Africa and Asia where urbanization is still considerably lower (40 percent), both are expected to be 54 percent urban by 2025 (UN 1996; 2002). In nearly all these areas, the food insecurity is expected to continue to draw more and more people to the burgeoning practice of urban agriculture.

As is the case with most human endeavour, there is real risk and opportunities in food production in and near cities. Thereis also the possibility of improving the urban environment if food production and forestry are managed appropriately. The long-term viability of Urban and Peri-Urban agriculture (UPA)itself, depends on how successful farmers and urban officials are at exploiting the potential environmental benefits, minimizing the problems. The scale of production, the product or service provided, and the alternatives available are factors in determining the relative advantage. Broadly stated, a comparative advantage exists when either supply conditions or demand conditions allow UA or UPA to better serve the urban market by supplying something otherwise unavailable or by producing at a lower cost, including environmental cost. A comprehensive assessment of the impacts is therefore needed before policies and guidelines are implemented. It is suggested that city authorities make Health Impact Assessments (HIA) of UA policies and projects in order to provide evidence-based information for decision making. During the HIA the potential health impacts of such policies and projects are carefully analysed in multidisciplinary teams, involving the direct and indirect stakeholders.

2.3 Heavy Metals in Soils

2.3.1 Definition of heavy metals and importance in soil

Heavy metals refer to those elements with a density higher than 5g/cm^3. Naturally, some of them (such as Cu, Fe, Zn and Mg) are essential nutrient elements, which play very important roles in many physiological processes such as metabolism, growth and development. They often occur as cations on the soil colloidal complex and therefore, potentially exchangeable. Nevertheless, many problems arise when cells take in an excess of these essential elements, or other heavy metals such as arsenic and lead, which are not known to have any essential functions, but rather are toxic and cause damages to living organisms.

Excessive heavy metals in plants adversely affect plant growth and development, causing for example, decreased chlorophyll and growth of roots. Heavy metals can be passed on from plants to animals with consequent deleterious impact on animals and human health. Under natural condition, the sources of these elements in soils are parent materials, water and air. In recent time, however, anthropogenic input, associated with industrialization and agricultural activities, such as waste disposal, waste incineration, urban effluents, traffic emissions, fertilizer application and long-term application of wastewater in agricultural land,have become the major sources in many soils (Bilos et al., 2001; McLaughlin et al., 2000; Koch et al., 2001). Thephysicochemical properties of the soil also affect the concentration of heavy metals in soils. Organic matter and pH are the most important parameters controlling the accumulation and the availability of heavy metals in soil environment (Nyamangara, J. et al., 1999).

2.3.2 Sources of heavy metal contamination in soils

Most potentially harmful substances often endup in soils because of human activities. Some substances, such as pesticides and fertilizers, which are sources of heavy metals, areintentionally added to soils, while other substances, such as commercial and industrial chemicals, cause contamination through accidental spills or leaks. Contaminants can also spread through the air, as dust, or by precipitation (Shaylor et al., 2009). The sources of contamination in urban soils are mainly from domestic wastes, exhausts from automobile and emissions from industries (Terry&Banuelos, 1999; NVSWC, 2008). These pollutants may finally get into public sewage system, which ultimately discharges into rivers that are usually utilised in various ways, including irrigation. The exhausts of motorized machines and vehicles are also of great concern in metropolitan areas, so also organic wastes and corrosive metals (NVSWC, 2008).

About half of the zinc and copper contribution to the environment from urbanization is from automobiles. Brakes release copper, while tire wear releases zinc. Motoroil leakage is another pathway of heavy metalcontamination of the environment. On the road surface, most heavy metals become bound to the surfaces of road dust or other particulates. During precipitation, the bound metals will either become soluble (dissolved) or be swept off the roadway with the dust. In either case, the metals enter the soil, or are channelled into a storm drain. Whether in the soil or aquatic environment, metals can be transported by several processes. These processes are governed by the chemical nature of metals, soil and sediment particles, and the pH of the surrounding environment.

Fertilizer application constitutes an important source of environmental pollution(Mortvedt et al., 1981; Nriagu, 1990). Efforts have been made in recent times to improve the productivity of the low nutrient status soils in tropical Africa, for example, in order to enhance food productivity and sustain the projected population growth, using inorganic fertilizer. However, fertilizers contain not only major elements necessary for plant nutrient and growth, but also trace metal impurities such as Cd, Pb, Hg, As or Ni (Williams and David, 1973; Frieberg et al., 1992; Singh, 1994; Nicholson and Jones, 1994; Zhan and Shan,2001). It is therefore an important anthropogenic source of soil contamination with heavy metals.

In many cases, heavy metal contamination of soil is the result of past land uses. For example, gas stations and mechanics’ workshops use different fuels and lubricants on-site. These heavy metal contaminants generally enter the soil inadvertently because of poor storage practices or spillage onto the ground. Other sources of heavy metal contamination may be more indirect, and include rain runoff from roofs, roads, and other structures. Contaminants can also be introduced from adjacent land through the movement of groundwater and soil water. Depending on the specific hydrological features of the surrounding area, heavy metal contaminants can ultimately end up in soil designated for gardening (Shaylor et al., 2009).Soil contamination tend to be more likely when the land is, or has been the site for the production or use of lead paint, high traffic, fertilizers or pesticides, industrial or commercial activity, treated lumber, petroleum spills, automobile or machine repair, junk vehicles, furniture refinishing, fires, landfills or garbage dumps.

2.3.3 Forms of heavy metals in soils

According to Aydinalp and Marinova (2002),heavy metals in soil may be found in one or more of the following forms:

a) as dissolved material (in soil solution),

b) as exchangeable cation(in organic and inorganic components),

c) as structural components of the lattices of soil minerals,

d) as insoluble precipitates with other soil components.

Only the first two forms are currently available to the plants, while the other two are only potentially available in the longer term.

Understanding the mechanisms by which a heavy metal element changes from one form to another, and the speed at which it does so, is imperfect but improving. In general, the concentration of an element in the soil solution is believed to be dependent on the equilibrium between the soil solution and the soil solid phase; with pH playing the decisive role (Lindsay, 1979). The soil's ability to immobilize heavy metals increases with rising pH and peaks under mildly alkaline conditions.

Heavy metal mobility is related to their immobilization in the solid phase. Fuller (1977), in discussing the relatively high mobility of heavy metals with regard to pH, considered that in acid soils (pH 4.2 - 6.6), the elements Cd, Ni, and Zn are highly mobile, Cr is moderately mobile, while Cu and Pbare practically immobile. Inneutral to alkaline condition (pH 6.7 - 7.8), Cr is highly mobile, while Cd and Zn are moderately mobile and Ni is immobile.Apart from pH, other soil properties, such as cation exchange capacity (CEC), organic matter content, quantity and type of clay minerals, the content of the oxides of iron (Fe), aluminum (Al), and manganese (Mn), and the redox potential, determine the soil's ability to retain and immobilize heavy metals. When this ability is exceeded, the quantities of heavy metals available to plants increase, resulting in the appearance of toxicity phenomena.

Organic matter (humic and fulvic acids) plays an important role not only in forming complexes, but also in retaining heavy metals in an exchangeable form (Stevenson, 1982). These two properties affect each heavy metal differently. For example, Cu is bound and rendered unavailable chiefly through the formation of complexes, while Cd is retained in an exchangeable form and is more readily available (Kirkham, 1977). The CEC of a soil depends upon its organic matter content and clay type and content. In general, the higher the CEC of a soil, the greater is its ability to retain heavy metals. The type and quantity of clay determines the CEC, which increases with clay content, particularly when it contains a high proportion of 2:1 lattice-type minerals (e.g., montmorillonite). The specific soil surface is also closely related to clay content and type. Korte et al. (1976) reported that the soil's ability to retain heavy metals is more closely tied to the specific surface than to the soil CEC.

2.3.4 Acceptable levels of heavy metal contamination in soils

Certain chemical elements exist naturally in soils as components of minerals, yet may be toxic at high concentrations. Ideally, garden soils should not have contaminant levels exceeding those that are naturally occurring in the soil. In urban settings in particular, it is likely that soil contaminants will exceed natural levels. This raises the question – how much contamination is acceptable?

There is no single standard that defines acceptable levels of contaminants in soils. In 1996, the U.S. Environmental Protection Agency (EPA) established Soil Screening Levels (SSLs) to facilitate the evaluation and clean-up of contaminated properties intended for residential land use in the future or Superfund sites. These values were designed to direct resources for site evaluation and clean-up to those areas most in need. SSLs are risk-based values developed for specific land use scenarios using assumptions about how soil contaminants may affect people or the environment. SSLs serve as a general guide; however, it is important to remember that these values were developed for certain programmes to be used under specific conditions and may not be relevant for assessing all properties. It should also be noted there are different standards for different potential land use types (i.e. industrial, residential, or agricultural use). Of these three, the agricultural standard is the strictest, as it is important to have relatively minimal levels of contaminants present in soils that will be used to grow food.

2.3.5 Effects of heavy metals on soil

The quality of life on earth is linked, undeniably, to the overall quality of the environment, particularly the soil. The contamination of soils by heavy metals is a significant problem, which leads to negative influence on soil characteristics and limitation of productive and environmental functions. Pollution of the biosphere by heavy metals due to industrial, agricultural and domestic activities, has created a serious problem for the safe and rational utilization of soils (Volesky, 1990;Kandori,et al., 1993; Avery, 2001; Igweet al., 2005;Srivastavaet al., 2005). Industrial input and the agronomic application of fertilizers, pesticides and metal-contaminated sewage continue to contribute to the metal accumulation in the soil (Herland,et al., 2000).

The soil microbial community has a fundamental role in the process of organic matter degradation and mineralization, which allows the recycling of nutrients (Castaldi,et al.,2004). Heavy metals affect the number, diversity and microbial activity of soil microorganisms.

The pollution of the ecosystem by heavy metals, is a real threat to the environment because metals cannot be naturally degraded like organic pollutants. Rather, they persist in the ecosystem, having accumulated in different parts of the food chain (Smejkalova,et al., 2003; Igwe,et al., 2005). Metal toxicity may affect all forms of life in the soil, including microorganisms, plants and animals, but the degree of toxicity varies for different organisms. Physical, chemical and biological processes may combine under certain circumstances to concentrate metals rather than dilute them (Igweet al., 2005).

Several researchers, using isolation-based techniques, have demonstrated that heavy metal contamination can cause shifts in microbial populations (Gringellet al., 1976; Barkayet al., 1985; Doelmanetal., 1994; Roane& Kellogg, 1996). The immediate toxicity of metals to soil organisms is moderated by metal immobilization by soil colloidal components. Heavy metals may be mobilized by local and global changes in soil conditions i.e., changes in physical and chemical conditions of soil environment, including decrease in pH, redox potential and enhanced decomposition of organic matter (Gupta, 1992; Hattori, 1996; Kelly et al., 2003).

Heavy metals exert toxic effects on soil microorganism (Pawlowska&Charvat, 2004), hence results in the change of the diversity, population size and overall activity of the soil microbial communities (Gupta, 1992; Hattori, 1996; Kelly et al., 2003; Smejkalovaet al., 2003). Gaspar et al., (2005) reported that the after-effect of the observed heavy metal (Cr, Zn and Cd) pollution influenced the metabolism of soil microbes in all cases. In general, an increase of metal concentration adversely affects soil microbial properties e.g. respiration rate, enzyme activity, which appears to be very useful indicators of soil pollutions (Brookes, 1995; Szili-Kovacs et al., 1999).

In general, there are three ways in which people are exposed to contaminants in soil: ingestion (eating and drinking), dermal exposure (skin contact), and inhalation (breathing) (Angima& Sullivan, 2008; Rosen, 2002; Shaylor et al., 2009). People may accidentally ingest small amounts of soil during activities such as yard work, gardening, or playing. Ingestion also occurs when people eat garden produce grown in contaminated soil or groundwater. Some contaminants, such as pesticides, can be absorbed through the skin when people come into contact with the soil. In addition, people can inhale airborne soil particles, such as dust, or contaminants that have vaporized from the soil after precipitation. The possible health effects of exposure to any contaminant depend on the toxicity of the contaminant, the level at which it is present, and how long and how often the exposure occurs. An individual's response to a given level of exposure to a particular contaminant is also affected by gender, general health and lifestyle, age, and inherited family traits (Shaylor et al., 2009).

Toxicological effects of lead on man include inhibition of haemoglobin formation, sterility, hypertension and mental retardation in children (Amdur, et al., 1991). Mercury causes brain damage, chest pain, stomach and cough, while the major hazard to human health of Cadmium is its chronic accumulation in the kidneys where it causes dysfunction, if the concentration in the kidney cortex exceeds 200 mg/kg fresh weight (Alloway, 1990).

2.3.6 Bioaccumulation of heavy metals

Bioaccumulation takes place when substances are taken in the food chain from food and water. These substances accumulate because they cannot be broken down and used up by the organism or they are taken in faster than they are used up by organisms. Bioaccumulation is not hazardous when the substance accumulated is not harmful, but when compounds and heavy metals that are harmful to human health accumulate like Mercury,then bioaccumulation becomes dangerous (Brookes and Grath,1984).

When Cadmium, Zinc, Lead, Mercury, Arsenic, Copper, Chromium, Nickel and Manganese accumulate in the soil over long times, they reduce food quality and quantity. A high heavy metal load in the soil reduces the functioning of soil biota resulting in reduced microbial activity (Kandeler et al., 1996).

Investigations by Abdolkarim et al., (2009) on soil microbial properties, which included the measurement of microbial biomass, respiration, N-mineralization and 13 soil enzymes involved in cycling of C, N, P and S, showed that increased heavy metal pollution decreased the microbial biomass activity and enzyme activities. It also showed that the amount of decreased enzyme activity differed among the enzymes. For instance, enzymes involved in the C-cycling were least affected, whereas various enzyme activities related to the cycling of N, P and S showed a considerable decrease in activity. Points in case were arylsulfatase and phosphatase, whose activities were adversely affected. Heavy metals affect communities through functional disturbance, protein denaturation or the destruction of the integrity of cell membranes affect the growth, morphology and metabolism of microorganisms in soils (Leita et al., 1998).

Uptake of metals is considered to involve complexation, ion exchange, adsorption, inorganic micro precipitation, oxidation and/or reduction processes. Metal ions are adsorbed first to the surface of cells by the interactions between the metal ions and metal-functional groups such as carboxyl, phosphate, hydroxyl, amino, sulphur, sulphide, thiol present in the cell wall and then they penetrate the cell membrane and enter the cells (Wang and Chen, 2006). Soil characteristics which include pH and organic matter content affect the heavy metals adsorption in the soil (Jones, 1991) and therefore the heavy metal content in the soil is not an indicator for heavy metals in plants because accumulation is plant and heavy metal specific.

Reclamation and remediation are used to reduce the heavy metal accumulation in soils and plants grown using waste water irrigation (Six,et al., 2004) because, there is possible long term accumulation of heavy metals due to waste water farming (Nordgren,et al., 1985).

Heavy metals accumulation varies from one plant to another, one heavy metal to another and the plant parts and also is in line with human tolerance to heavy metal amounts accumulated in plants (Linden, et al., 1994). Uptake of Cd, Cu, Ni and Pb from air and soil by *Achilleamillefolium*(milfoil) and *Hordeumvulgare*(barley) in Denmark showed that Cu and Pb plant concentrations correlated with airborne deposition but not with soil concentrations. In contrast, Ni and Cd content in the plants correlated with deposition and soil content (Pilegaard and Johnsen, 1984).

In a study done by Abdolkarim et al., (2009), five dominant vegetations, namely *Amaranthusretroflexus*, *Polygonumaviculare*, *Gundeliatournefortii*, *Noeamucronata*and

*Scariolaorientalis*were shown to accumulate heavy metals. Based on the results, it was concluded that *N. mucronata*is the best accumulator for Pb, Zn, Cu, Cd and Ni, but the best Fe accumulator is *A. retroflexus.* The study further revealed that the accumulation of metals in the root, leaf and shoot portions of *N. mucronata*varied significantly but all the concentrations were more than natural soils. The results indicated that *N. mucronata*is an effective plant for reducing heavy metals accumulation in polluted soils (Smit, et al., 1996).

Recent studies have shown the importance of the activity of earthworms (Nannipieri, 1984) and termites (Wielemaker, 1984) for the physical and hydrological properties of tropical soils. Macro fauna and nematodes are also causal agents for the incorporation of organic matter in organo-mineral complexes derived from their excrements, affecting carbon sequestration and nutrient release (Six,et al., 2004). In general, soil macro fauna breakdown and redistribute organic residues in the soil profile, which increases their surface area for microbial activity.

The subsequent deposition of faecal pellets also has important ecological implications (Lavelle et al, 1999). Thus, many components of soil quality are direct or indirect manifestations of organisms living in the soil. The influence of soil fauna on soil structural properties has been considered to be the best long-term indicator of soil quality (Mehlich, 1984).

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter describes the elements of the soil forming factors prevailing over the study area, including geology, relief, geomorphology, drainage, climate, vegetation, soil, population and land use.It also describes the field and laboratory methods employed in the study which covers four main areas: nature, type and sources of data required and equipment/instruments used; the field work; laboratory analysis of samples and analysis of data.

3.2 Location of Study Area

Abuja is the new Federal Capital of Nigeria, having been created in 1976 in pursuant to Decree No. 6. It lies in the northeastern part of the Federal Capital Territory (FCT) and occupies some 250 km^2(Fig. 1).The area is characterized by a hilly, dissected terrain and is the highest part of the FCT with several peaks that are 760 m above sea level (Balogun,2001). The FCT covers some 8,000 km^2, between latitude 8.25^0 N and 9.20^0 N and longitude 6.45^0 E and 7.39^0 E. The FCT is bounded to the North by Kaduna State, to the East and South East by Nasarawa State, to the West by Niger State, and to the South by Kogi State. The FCT falls within the geographical centre of the country and consists six Area Councils, namely: Abaji, Abuja, Bwari, Gwagwalada, Kuje, and Kwali.

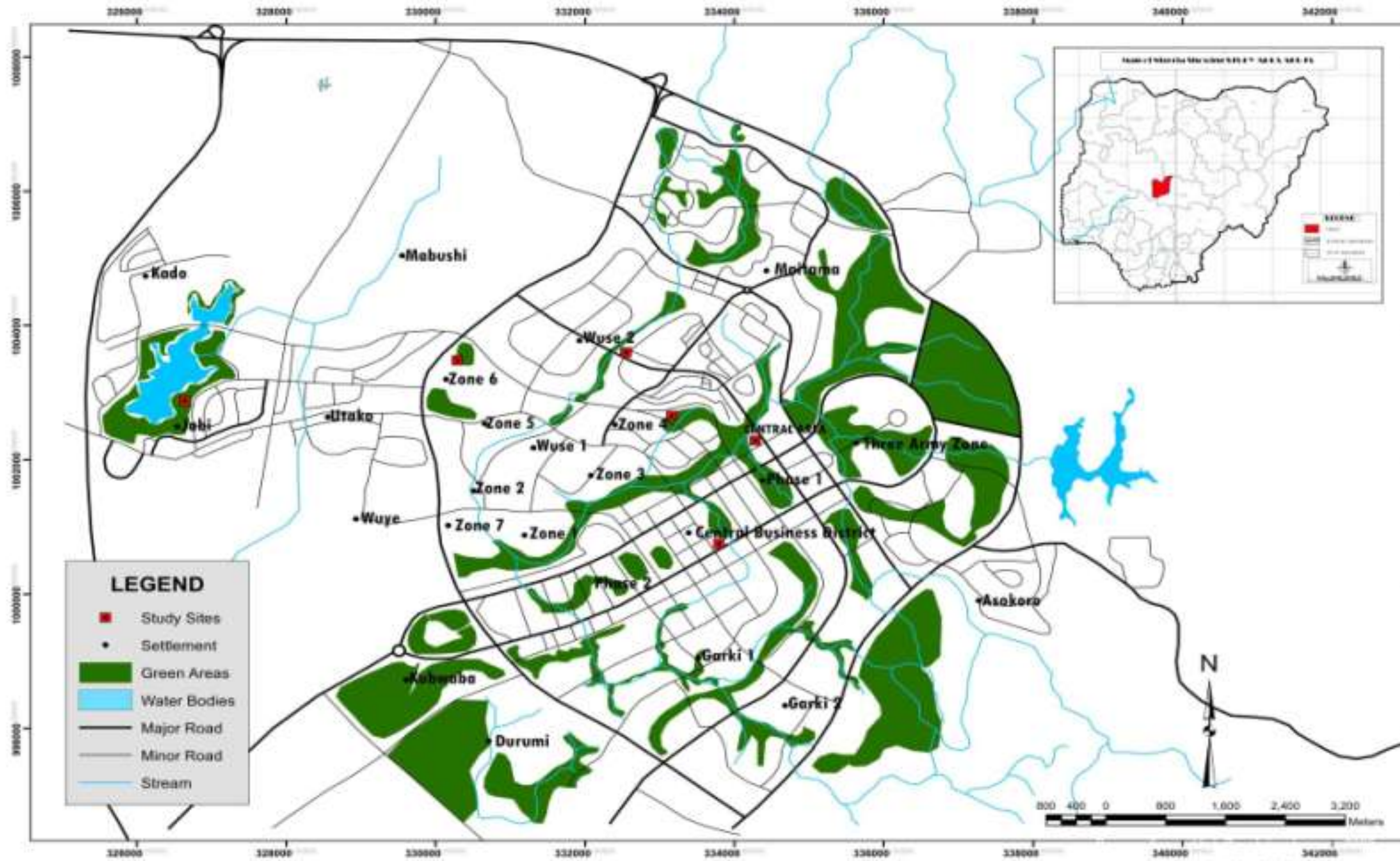


Fig.3.1: ABUJA METROPOLITAN AREA, SHOWING THE STUDY SITES

Source: Digitised from Google Earth Imagery

3.3 Climate

The climate is the hot, humid tropical type. The rainfall is largely governed by the Inter-Tropical Convergence Zone (ITCZ), which is defined by both the moisture-laden south-west winds (Tms) and the northeast dry continental winds (Tcs). Rain normally occurs south of the ITCZ. Whenthe ITCZ passes northwards through the territory between the middle of March and June, it heralds the beginning of the rainy season. On its return southwards about the middle of October, it heralds the onset of the dry season. Consequently, there is a distinct rainy season that starts in April and ends in October, and a dry, cold season that begins in November and ends in March.

The entire region of the FCT, and portion of some of the adjourning states, represents a wet ‘island’, disturbing the otherwise east-west alignment of the isohyets in this part of Nigeria. Such rainfall distinctiveness is as a result of the position of the land mass of the Jos Plateau and associated hill ranges in relation to the south-westerly and westerly rain-bearing prevailing winds. As the winds are forced upward by the high southerly aspect of the Plateau and associated lines of hills, it result in a zone of higher rainfall, both on the plateau surface itself, and on the lowland plains before it. The area also enjoys a rather longer rainy season than is to be expected for the latitude, about 170 days on the average. Of great importance is the fact that rainfall of the area is seasonal in character, and occur as intense thunderstorms. About ninety percent of the rains fall between April and October, the months with the heaviest rains being July and August. Monthly total can vary widely, so also the annual total. The highest intensity rainfall is associated with conventional thunderstorms at the beginning and end of the wet season. These storms occasionally produce hail, implying high erosive potential.

With respect to temperature, this is always warm. Every month has an average temperature close to 27^0C, usually with no perceptible seasonal variation. The annual temperature range (fluctuation between the average temperature of the coolest and warmest months) is minuscule, typically only 2^0Cor 3^0C and only rarely over 7^0C or 8^0C. Daily temperature variations are somewhat greater, although still not impressive. On a typical afternoon, the temperature will rise to the high (low 30s^{0}C) and dropping to the middle or low 20s^{0}C in the coolest period just before dawn.

The highest temperatures and the greatest diurnal ranges are recorded during the dry season months. At this period, the maximum temperature ranges between 30.4^0c and 35.1^0c. During the rainy season, on the other hand, the maximum temperature ranges between 25.8^0c and 30.2^0C. Also, the diurnal range is much reduced but the cloud cover is much less during the dry season, hence, the high temperatures at this time of the year.

During the dry season, relative humidity falls very considerably in the afternoons. The desiccating effect of the dry season is accounted for by both the very low relative humidity and the high afternoon temperatures of this period, which is also characterised by the harmattan haze. The relative humidity rises everywhere during the rainy season. The afternoon relative humidity rises to well over 50 percent during this season, but it is as low as 20 percent during the dry season (Balogun, 2001).

3.4 Geology

The area is underlain by the Precambrian Basement Complex rocks and consists mainly of gneisses and schist with migmatitte, granites and small occurrences of quartzite, pegmatite, amphiboles, granitic gneisses and diorites. The rocks date back to the Paleozoic era and are generally less resistant to weathering than for example the Younger Granites found on the Jos Plateau.

3.5 Landform

The FCT is located largely on the Gwagwa Plains. The plain stands at an elevation above sea level, of between 305m in the southwest, 488m in the north and northwest, 518m in the east and 566m in the south. The plains are a roughly circular physiographic unit, bounded by hilly or dissected country in the north west, north east and south. Overmuch of the plain, relative relief (the height range between interfluves crests and the valley bottom) is less than 20m. Theaverage slope (average inclination of the landscape from the horizontal) really exceeds 6^0 and is very rarely more than 10^0. Taking the relative relief and the average slope together, we can characterize the terrain as gently rolling to undulating, studded with residual hills of various shapes and sizes.

The plain area is stunted by a large number of mostly small residual hills, either as isolated features or grouped together, including:

(i) **low ridges** on quartz and pegmatite veins, rising less than 10m above the surrounding terrain

(ii) **low whalebacks** on migmatite, granite-gneiss and granite; the inhabitants of the area use these as drying, grinding and pounding surfaces and often build their granaries on them, safe from the fierce fires which rage through the more grassy woodland and parklands in the dry season.

(iii) **Inselbergs,** more commonly, perhaps, on granites and migmatites. Occurring often as impressive, steep-sided domes, they are also found as elongated and assymetricalfeatures .They may be relatively free of boulders, but more commonly carry boulders of various sizes on their tops and on fairly gentle side slopes.

(iv) **broken rocky hills or tor -** these rise abruptly (many as much as 200m) from the gently-sloping plains surrounding them which also differ by carrying weathered and transported regolith of various depths.

Some of the hills occur within a short distance of stream channels, although they may be separated from it by gentile ramp slopes (FCDA, 2004).

3.6 Drainage

The entire Gwagwa Plains on which the entire FCT is located belong to the basin of the Usman River, which rises in the Bwari-Aso Hills to the north east, flows first westwards and then south westwards on to the Iku-Gurara plains. The two major tributaries of the Usman, namely, the Wupa, and the Wosika focus on it from the north and north east and from the east, south east and south, respectively, bringing the drainage waters from these areas.

In general, the drainage pattern is dendritic to rectangular, with widely spaced drainage pattern lines. Stream flow in the area strongly reflects the climatic environment and, in particular, the seasonal and torrential nature of the rainfall. Thus, three main types of stream flow patterns have been recognized in the area:

(i) Perennial flows: low dry season discharges; flash floods superimposed on high rainy season discharges. This flow pattern occurs on the largest stream;

(ii) Seasonal flow: zero dry season flow; flash floods superimposed on rainy season flow which may be high or low depending on catchment area;

(iii) Flash flow only i.e., there is flowing water in the stream channel only during and for a short while after run-off-producing storms (FCDA, 2004).

3.7 Soils

The character of soils in the area is related to the lithology, topography, climate, vegetation and other environmental controls. In terms of soil distribution,however, the lithological and topographical factors, are perhaps more important.

Most soils in the area are ferruginous tropical soils. Others include the lithosols, alluvial soils, and fadama soils. The ferruginous soils are developed on the deeply weathered Basement Complex rocks. The exact character of the soils is dependent on such factors as nature of parent material, topographical relation, and anthropogenic modification. However, the top horizons are generally sandy loams or loamy sand. The subsoil is less sandy, often sandy clay loams or sandy clays. The topsoil develops a moderate medium sub-angular blocky structure, and the lower horizons weak fine or strong coarse sub-angular blocky structure. The soils are highly porous and are well drained over most of the year.

Thelithosols occur principally close to rock outcrops, or over an impenetrable ironpan. They include very shallow and very gravelly soils containing within 30cm of the surface, abundant ferruginised fragments of rocks. The alluvial soils include juvenile soils with A and C horizons developed from recently deposited materialsfrom riverine and lacustrine alluvium. The fadama soils are hydromorphic in character and occupy the valley and low terraces of the major rivers. The surface horizons are dark grey, becoming grey brown down the profile. Quite often, clay loam topsoil overlay clayey or silty clay subsoil. The soils have well developed sub-angular blocky to prismatic structure in the surface horizons, but usually massive and permanently moist at lower horizons. The soils have poor to very poor drainage, but where the stream has incised into the valley the soil tend to be imperfectly- to well-drained (Tuley and Alford, 1975).

3.8 Vegetation

Given the climate of the area, the original vegetation must have been a thick woodland or dry forest. Evidence of such vegetation still exists in few reserves areas within or around the city. As in many parts of Nigeria, the long period of occupation of the region has led to profound modification of much of the vegetation cover. The main plant or physiographic communities now found in the area include (i) tree savanna\cultivation parkland, (ii) shrub savanna, (iii) woodland and savanna woodland, (iv) fadama grassland, (v) riparian forest, (vi) inselberg vegetation, (vii) ionpan vegetation, and (viii) afforested vegetation. The communities are largely an expression of climatic and edaphic factors, which have been modified by man’s activities.

TheSavanna parkland/shrub savanna/savanna woodland communities have evolved from the system of bush fallowing practice in the area, and forming distinctive pattern around settlements.In the suburb area, the immediate vicinity of settlement, and over otherwise intensively farmed areas, is man-made parkland or tree savanna. The trees are largely indigenous and represent either the few surviving species of once-dense tree savannah woodland, which formally covered the whole area, or trees deliberately planted by man. A little further out from the suburb settlements, the parkland or parkland savanna extends into shrub savanna, which consists typically of shrubby coppice and sucker regeneration from stumps and rootstocks that have not yet been eliminated by cultivation.On the outer perimeter of the shrub savanna, especially where suburb villages are widely spaced or absent, the shrubland zones merges with the remaining tree savanna or savanna woodland vegetation, representing the remnants of the climatic climax form.

Bottomland sites, consisting of basal slopes, floodplains or fadama, marshy oxbow lakes, shallow backwaters and river banks of matured rivers, support characteristic grassy vegetation. Where livestock grazing or fuelwood cutting have eliminated the tree stands, typically low and creeping grassesremain.River levees, stream banks and seasonally dry watercourses that are not utilized for farming, are often clothed with the remnants of a dry forest, just as remnants of a dry forest often fringe the base of inselbergs/mesas in the suburb and government reserve areas. Planted vegetation communities are rare but nevertheless abound, especially within built- up areas. They often serve as avenue and compound planting on watershed sites, and combine both indigenous and exotic species, such as *Danielliaoliver*, *Khayasenegalensis*, *Mangiferaindica*, and*Dalbergiasissoo*(Tuley and Alford, 1975).

3.9 Population and settlement

Up to late 1970s the study area remained a somewhat cultural island of the native Gbagis. The creation and subsequent relocation of the nation's capital from Lagos to the FCT triggered intense socio-political and economic activities, attracting the hasty and massive migration of people from all over Nigeria. The spiraling economic and socio-political activities of the new city, with the attendant strains on housing and living conditions, however, led to an upsurge of squatter settlements in the territory. These settlements (with the exception of Garki Village within Garki II District of the city) are predominantly situated in the citySuburbs. Notable among them are Karu/Nyanya, Karmo, Kubwa and Gwagwa, occupied by workers and growing service population. These settlements grew rapidly within areas otherwise earmarked for specified city development projects and in some cases at very close points to the city center or at sites originally designed to protect Abuja's periphery from development encroachments or unplanned expansions. They were generally overcrowded and lacked basic amenities and infrastructure.

Since 2003, the FCDA has embarked on several forced evictions and demolitions of communities, markets, shops, places of worship, commercial and private buildings. The hardest hit areas are the satellite communities along the Abuja Airport Road, including Chika, Aleita, Galadimawa, Lugbe, Kuchigoro, Piwoyi, Pyakasa, Gosaand Karamajigi. Others are Karmo, Kubwa and Gwagwa. In all reported cases, the demolitions resulted in the massive displacement of several hundred thousands of people from entire communities with corresponding deleterious effects on such areas of health, education, means of livelihood and family cohesion**(**SERAC, 2006).

3.10 Landuse

The entire Abuja Municipal area has been earmarked for residential housing development, interspersed with commercial, educational and ministerial departments. The educational institutions include secondary and primary level institutions. As the area is yet to be fully developed, however, it harbours a wide range of squatters, utilizing the area for varying purposes. These include agriculture, livestock grazing, quarrying, and hunting and gathering.

3.10.1 Agriculture

Urban and peri-urban agriculture represent an important activity in the area. Cultivation, on the basis of location, is of two categories: household or home gardening, and open or vacant-space cultivation. Household or home gardening of mostlyvegetables, such as okra, peppers, tomatoes, eggplant, and pumpkin, takes place within and around homes while vacant-space cultivation, again of mostly vegetables in addition to some food crops like maize, sorghum, rice, yam and cassava, is carried out in open spaces, undeveloped plots, reservation areas along drainage channels, and rights-of-way buffers. Cultivation is done almost entirely by hand, with manure and or fertilizer application at low rate. Maize, millet, sorghum and cassava are grown in ridges. Yams are grown on large circular mounds. Rice is grown on ridges or on the flat in wetland sites.

In the suburb villages, homestead trees and gardens are common. The trees are planted around the houses for shade and for fruit, nuts, edible leaves and medicinal products. These trees include neam (*Azadirachtaindica*), oranges, tangerine and lime (*Citrus spp*.), oilpalm (*Elaeisguineensis*), mango (*Mangiferaindica*), pawpaw (*Carica papaya*), guava (*Psidiumguajavca*) and the calabash tree (*Persea Americana*).

3.10.2 Livestock grazing

The species of farm livestock that are found in the villages include goat, sheep, chickens, pigs and ducks. In most cases, all livestock, except chickens, should have been housed although in some cases this custom or law is blatantly ignored.

Extensive grazing by Fulani cattle represents a distinct land use category in the area. The area, prior to establishment of Abuja, for example, is said to provide one of the finest grazing land in Nigeria. It is free from tsetse infestation. It has adequate water supplies, and there is vast area of open pasture. Like elsewhere in northern Nigeria, however, relations of the herders with the indigent farmers have often been unfriendly and in recent years have turned sour, resulting into clashes.

3.10.3 Forestry

The villages would seem to have ample supplies of woody vegetation on farmlands and to some extent, from forest dieback or branch fall. Large scale felling of the savanna woodland which are along the road and major tracks, solely for fuel-wood production, is on the increase and this more than anything else contributed to the observed land degradation in the area.

3.11 Characteristics of urban agriculture in the Federal Capital Territory (FCT)

The population of Abuja was approximately 330,000 in 1990 and 590,000 in 2000 (Word search, 2013). According to census figures, the population of Abuja was approximately 776,298 in 2006 (Census, 2006) and 1,995,000 in 2010 (Word search, 2013). Data on urban farming in the city is not available anywhere, but casual observation indicate that the phenomena is on the increase in the city.

The farming systems fall into four broad categories: crop production, vegetable farming, small ruminant/poultry and commercial livestock farming. Staple crops like maize, millet, yam and cassava are the most common crops, but vegetable production ranks highest with species like green vegetables, garden eggs (white variety), pumpkin leaves, pepper, lettuce and cabbage being the most widely grown. Animal rearing are mainly in the suburb. Poultry and small animal rearing are carried out at the backyards and in small scale, while the large scale animal rearing are done in areas further away from settlements, though; there are occasional incursions into the city centre. Two major cropping systems are discernable in the area: Fadama cropping and dry season irrigation cropping. The fadama cropping is carried on over the clay and clay loam soils in the seasonally flooded areas (fadama), which are inherently more fertile due to annual alluvial deposition. The alluvial soil farming on the other hand is practiced over the coarse textured upland halomorphic soils of deltaic alluvium, which are mostly weakly developed, low in organic matter and nutrient elements. Generally, farming is on household property, but informal access to land is rampant. Urban farmers, farm mainly along streams and valleys, and each farmer have only a small plot of land and practice intensive crop rotation to maximise the use of land and maintain soil fertility. Hired labour and household members are used for planting and harvesting, and involve an intensive use of local manure, traditional hoes and cutlasses.

3.11.1 Fadama cropping

The fadama are a very important class of agricultural land in the area. The fadama crop comprises rice/sugarcane cultivation during the flood periods, and recession cropping after floods have receded. The rice farmer usually broadcasts his rice seeds and then harrows them in the soil and waits for the first major rain after which the rice will germinate. Flooding of the tender rice seedlings then follow with the natural flood from rivers as source of water. Common recession crops include cowpea, maize and vegetables such as okra, pepper, and tomato. Around the edge of flooding land, there is a zone that floods only briefly, or not at all, but which has a high water table for much of the year. This zone is used for planting of orchards of mango and guava. In addition, field crops, particularly cassava are planted. In some areas, cassava fields are extensive and most households have a plot.

3.11.2 Alluvial soils farming

During the raining season, the alluvial soils that lie alongside rivers are cropped to both cereals and vegetables. During the dry season on the other hand, they come under irrigation cropping of mostly vegetables. To retain water for irrigation in the dry season, farmers often dig small ditches or channels from the main river channel, fadama or river to their fields. Few farmers lift the water directly from the river, while few have an open well. Water lifted is conveyed through channels built by raising the soil and by flows under gravity into ridges into prepared micro basins seedbed, submerging each subplot in turn.

Lifting irrigation water with engine pump is widespread. The engine uses petrol and is mostly 2 or 3 inches pore pump. Some farmers still use the traditional calabash or shadoof irrigation but use of these devices is rapidly dying out. Land is irrigated by flooding small basin, each approximately two metres square. The practise, which form quadrangle around the furrows in which crops are sown, serves to trap irrigated water and increase the time available for infiltration.

There are high returns to irrigation crop production as most high valued crops are involved. Irrigated dry season crop production has high labour demands and therefore provides labour opportunities at a time when there is a surplus of available labour in the wetlands as a whole. The major irrigated crops cultivated are, pepper, watermelon, tomato and onion. Farmers tend to intercrop, mixing slow growing species, such as tomatoes or carrot and cabbage, with quick maturing species such as lettuce in the same plots. This is primarily for financial reasons, as the sale of the early maturing ones yield the resources needed to tender the slower maturing ones. In order to maximize space, some farmers will plant crops requiring little space, such as green-leaf, or onions, on the ridges of the subplots. The practise also serves as security against drought and pest hazards, since the mixed crops may respond to such hazard differently.

3.11.3 Soil manuring methods and sources of water for urban agriculture

Soil fertility under UA generally, is maintained by use of both organic manure and chemical fertilizers. Farmers interviewed, however, contended that both practices are fraught with problems in the area, including slow rate of manure decomposition, and high prices and rarity of both materials. For example, the farmers argued that animal manure, most especially, those from sheep and goats, tend to decay very slowly if moisture is inadequate in the soil. It is also said to result in increased soil temperature, often compounding the problem of excessive heat experienced during dry spells. Direct land application of raw or untreated organic wastes is common practice. Field observation in the area reveals that the farmer's primary interest lie not in maximizing the amount of material that can be applied to his field but in the maximization of his net return on his input investment.

Sources of water for urban agriculture in the city include rain, and rivers or streams. Treated pipe water is seldom used. As is the common practise in Nigeria, wastewaters from homes and industries are simply channelled, untreated, into water bodies or out land. Although health risks are implied with the use of such polluted water, the combined factor of water availability and market opportunities, which supports intensive year-round production could not deter the farmers from using such polluted waters. This practise is often either ignored or only condemned by the public and the government officials.

3.12 Nature, Type and Sources of Data Required

The data required for the study and sources are summarized in table 1 below:

Table 3.1: Summary of data required and sources

Data required	**Sources**	**Materials to be used**
Qualitative information on management practices of Abuja urban farmers	Interview of farmers in the study area	Questionnaire check list, GPS
Analytical properties and heavy metal content of soils under continuous vegetable cropping in the study area	Field and laboratory analysis of samples from field	Base map, auger, tape, GPS, ranging poles, hand trowel, cutlass, soil sampling bags, soil testing kit, soil and water laboratory
The environment of the study area	Field observation and library	Topographical and road map of area to serve as field base maps

Information on the management practices of urban farmers is primary as well as qualitative in nature, and was obtained through informal interview with farmers of the identified plots used in the study. Information on soil properties and heavy metal content of soils under continuous vegetable cropping form the bulk of the primary data type and was collected through appropriate field and laboratory techniques. Information on the environment of the study area constitute the secondary data used in the study and was obtained from library sources, although such information were supplemented with field observations and assessments.

3.13 Methods and Procedures of Data Collection

3.13.1 Reconnaissance survey

A preliminary survey of Abuja Metropolitan Area was first carried out in May, 2012, as a base for data collection. The purpose of the preliminary survey was threefold. First, for the researcher to get acquainted with the environment, in particular, the spots where urban farming is on- going. Second, to conduct preliminary interview with selected urban farmers, whose farms offer promising site for this study, on the management history of their farms. Third, to select the plots to be used for the detail field investigations.

3.13.2 Detailed fieldwork

The method of investigation adopted in this study is an inferential one, which involves sampling and comparing soils used for urban agriculture, and that not in use, simultaneously. Although such approach may be less desirable, as compared for example to the one involving monitoring of soil change over an established plot, which has been widely used by researchers and has the advantage of minimizing cost and time (Aweto, 1981 and Aweto& Areola, 1979).

3.13.3 Selection of plots

Five plots under urban cropping, and an additional one that is not in use for any form of cropping was selected for the study, making six plots. The size of the plots selected ranged between 0.8 ha and 1.2 ha. The selection of the plots was as a matter of necessity constrained by two major factors. One was availability of reliable information on the management history of plots in the area, obtained from the farmers. The other was the need to keep, as much as possible, all other environmental conditions at the sites similar, in order to minimize the likelihood of error arising from initial soil spatial variability. The six plots were located along different road arteries in the city. All are underlain by similar geology, granite gneiss, and because they are all confined within a single drainage basin, they can be assumed to experience the same climatological condition. All the sample sites are far away from point pollution sources (such as landfill regions, gas station and factories) other than line pollution sources of rivers and roads. All sites were located with GPS for possible follow up investigation in the future. Investigation results of the sample plots' surrounding environment, such as geographical and geological conditions, hydrological distributions, and neighbouring pollution sources, were recorded. The soil management conditions including the cultivation time, fertilization frequencies and quantities were also investigated.

The vegetation cover of the non-farm plot, which presumably represents the vegetation cover of the all sites prior to inception of urban farming on the plots, consist of mixture of grasses and remnants of a dry forest. The morphology of the grasses varies with the water depth and soil condition, but are composed of various combinations of species, including *Echinochloapyramidalis,Phragmitesmautritianus, Saccharumspontaneum, Oryzabarthiiand Vetiverionigritana.*Widely scattered species of low tree such as *Mitragynainermis, Syzigiumguineense and Terminaliaglaucescens*often dot the community. The tree species of the dry forests are mostly*Khayasenegalensis, Syzigiumguineense, Vitexdoniana, Anthocleistavogeli, and Albiziazygia.*

The history of land use over the vegetable plots was also roughly similar. The farmer opens up an area otherwise used extensively for livestock grazing during the dry seasons by clearing and burning of slash materials, usually in windrow.This is followed by flat tillage and sowing of crops. Soil fertility is maintained by use of farm yard manure (FYM) and chemical fertilizers, all applied at low rates. Irrigation water is applied as when necessary, but usually twice in a week (Plates 1a – 1d).

Table 3.2 shows the GPS readings of the centre of the respective sites selected for the study:

S/No.	Site location	Name of location	Coordinates
1	Site A	Wuse-Zone 4	Easting 0333632 Northing 1001900
2	Site B	Central Area	Easting 0333070 Northing 1001463
3	Site C	Jabi Lake	Easting 0327492 Northing 1002487
4	Site D	National Mosque	Easting 0333998 Northing 1001987
5	Site E	Wuse 2	Easting 0332134 Northing 1001987
6	Site F	Wuse-Zone 6	Easting 0330164 Northing 1002668

3.13.4 Soil sampling

A combined systematic and random sampling method was used in the soil sampling. Over each plot selected for study, a quadrat of either 15m by 12m or 30m by 6m was first demarcated. Each was subsequently subdivided into 20, (of 3m by 3m) subquadrats of which 5 wererandomly selected for soil sampling. Soil samples were taken at the four corners and the centre of each selected subquadrat. The samples were bulked to give a sample per subquadrat. Thus in all, five (5) bulked samples per plot, giving a total 30, were collected for laboratory analysis.

To further minimize the problem of soil spatial variability, all samples were taken over sites where the slope gradient did not exceed two degrees. The samples were taken with the aid ofhand trowel at the surface horizon (0-10cm), after an initial clearing aside of the coveringplant

a. Jabi Lake site

b. The uncultivated site, Zone 6

c. Central area site

d. Site at Zone 4

Plate 1: Some of the selected study sites in Abuja metropolis

debris. Soil samples were collected in plastic bags preserving the natural moisture content. In the laboratory, the soil samples were stored at room temperature until chemical analysis.

3.13.5 Laboratory analysis of soil samples

Table 3.3 summarizes the soilparameter and heavy metals determined and the analytical method employed.

The bulked soil samples drawn from the field were air dried, crushed lightly, and then passed through a 2mm sieve. It was these <2mm fraction that were used subsequently in all analyses performed, using standard methods. These methods are described briefly in the preceding subsections.

Table 3.3: Summary of soil properties determined

S/No	Parameter	Determination method
1	Particle size distribution	Pipette and sieving
2	Bulk density	Cylindrical core method
3	Moisture content	Cylindrical core method
4	Organic matter content	Walkey –black digestion method
5	Exchangeable Ca, Mg, Na K	1N ammonia acetate extraction
6	CEC	1N ammonia acetate extraction/AAS
7	Total metal (Cu, Fe, Mn, Zn, Pb)	Tanary acid method/AAS
8	Available metal(Cu, Fe, Mn, Zn, Pb)	Double acid/AAS
9	pH	pH meter

3.13.6 Particle size distribution

The particle size distribution of selected soil samples were determined using a hydrometer following the procedures given by Bowles (1992). A standard hydrometer (ASTM 152H) was used. This hydrometer is directly calibrated to the mass of suspended soil present in a 1000 ml soil-water suspension. Owing to the high silt and clay rich soil, un-sieved soil samples were used in the hydrometer analysis for determination of silt and clay fraction. The sand content was obtained after the hydrometer analysis by wet sieving the soil through No. 200 mesh (0.075 mm).

For the hydrometer test, a sub-sample of soil (about 60 grams) was soaked in a 0.5% sodium hexametaphosphate solution for 24 hours to disperse soil particles and to avoid clay flocculation.This thoroughly soaked soil sample was stirred vigorously by a commercial grinder for one minute. Longer grinding times were avoided to minimize the mechanical breakdown of soil grains. After the mechanical dispersion of soil in water, this suspension was poured into a cylinder and distilled-deionized (DD) water was added to a volume of 1000 ml. Prior to starting the hydrometer test, the cylinder containing the soil-water suspension was shaken several times for one minute to mix the soil homogeneously in the water. After shaking, the cylinder with the soil-water suspension was placed undisturbed for taking periodic temperature and hydrometer readings.

Hydrometer and temperature readings were taken up to 3000 minutes. The initial readings were very frequent; however, later readings were taken with wide time span following Bowles (1992). After the temperature and other systematic error corrections, the hydrometer data were analyzed to get the proportions of clay and silt using simple Stockes' Law (Bowles, 1992).In general, particle size was divided into three classes: sand (>0.074 mm), silt (0.074-0.002 mm) and clay

(<0.002). Some rock fragments (larger than sand-size particles) were also included in the sand category.

3.13.7 Soil organic matter

This was determined by Walkey – Black digestion method. A 10g sub sample for the fine earth fraction prepared for laboratory analysis, was then taken to a 250ml conical flask and 10ml of potassium dichromate ($K_2Cr_2O_2$) solution was pipetted into 500ml conical flask and swirled gently to disperse the soil. From then, 20ml of concentrated tetraoxosulphate (VI) acid (H_2SO_4) was added and gently rotated for one minute, it was then allowed to stand on a sheet of abestos for 30 minutes in order to cool the mixture. The solution was diluted with 100ml of distilled water, orthophosphate acid, 0.2g sodium chloride (NaCl) and four drops of diphenylamine indicator. The solution was then titrated with ferrous ammonium sulphate solution in a burette. After this was done, a blank determination was then made in the same way but without the soil with a view to standardizing the dichromatic. The organic matter content was then estimated as follows:

% organic matter $10[1 – s/t] \times 1.3$

where s = blank titration.

3.13.8 pH

To determine soil pH, 20g of air-dried soil sample was taken into a 50ml beaker to which 20ml of distilled water was added. The suspension was then stirred several times for 30 minutes with a glass rod after which it was allowed to stand for 30 minutes in order to allow most of the suspended clay to settle down. Electrodes of pH meter were then inserted into the partly settled suspension and the pH was then measured. While taking the measurement, the suspension was not stirred and the electrodes were not allowed to touch the bottom of the beaker to avoid errors in measurement.

3.13.9 Heavy metals

Sequential extraction was carried out according to Emmerich et al. in Bryld (2003). After removing the saturation extract using a vacuum and a Buchner funnel, the soil sample was leached two to three times with 15-20 ml of deionized water to remove the soluble salts. Two grams of dry soil (on a 105°C basis) were placed in preweighed centrifuge tube (three replicates) and the following sequence was used.

1. Add 25 ml 0.5M KNO_3, shake for 16 h, centrifuge and filter the supernatant liquid.

2. Add 25 ml of deionized water, shake for 21 h, centrifuge and filter the supernatant liquid. Extraction with water on a number of samples showed that the concentration of heavy metals in the extract was below the sensitivity limit of the atomic absorption spectrometer, and therefore this step was omitted in the rest of the samples.

3. Add 25 ml 0.5M NaOH, shake for 16 h, centrifuge and filter.

4. Add 25 ml 0.05N Na_2EDTA, shake for 6 h, centrifuge and filter.

5. Add 23 ml 4M HNO_3 and heat for 16 h in a water bath at 70-80 °C. After cooling, the solution was filtered.

After each step, the centrifuge tube was weighed to estimate the quantity of the remaining extractant and to calculate the amount of heavy metal carried over to the next step. Heavy metal concentrations in all extracts were determined by atomic absorption spectrometry.

As far as soil pollution by heavy metals is concerned, it is important to identify the available and unavailable forms of the heavy metals to ensure that the soil is managed in such a way as to prevent the unavailable forms from becoming available. The most common and simple way to identify the forms in which heavy metals are found in soils is to use sequential extraction in which components loosely held by the soil are extracted first, followed by those more tightly bonded. The various forms of the heavy metals thus sequentially extracted can be classified as dissolved, exchangeable, organically-bound, or bound to oxides. As Beckett, (1989), pointed out, the fractionation of heavy metals into various forms on the basis of sequential extraction is only operational and cannot indicate a specific mechanism, since it is by no means certain that a given extract does not contain smaller quantities of another form, nor that the extractant would dissolve similar forms (e.g., carbonates) of different metals. Nevertheless, it is useful to attribute a specific fraction to each extractant. Thus, neutral salts like potassium nitrate (KNO_3) areassumed to take up exchangeable forms of heavy metals, sodium hydroxide (NaOH) organically-bound forms, Na_2EDTA forms associated with carbonate salts, while strong acids like nitric acid (HNO_3) take up chiefly that fraction which is a structural component of mineral lattices and surfaces.

Beckett (1989), in his extensive review suggested that it is preferable to classify the metal by its extract, e.g., EDTA extract, and to describe the experimental method exactly. However, this approach would ignore the purpose of sequential extraction, which is to investigate the chemistry of various forms of heavy metals in the soil. It would be preferable to find extractants that will actually distinguish between the various metal forms based on their chemistry. Earlier studies in the wider area of the Bursa plain have shown by sequential extraction that heavy metals exist in the soils at various sites (Aydinalp, 1996).

3.14 Analysis of Data

Three major statistical techniques were employed in the analysis of data. These are one-way analysis of variance, t-test and simple regression and correlation analysis. The analysis of variance was used to test for any significant differences amongst the different sites used for the study, while the t-test was used to test for the soil properties which differ significantly between pairs of plots.While analysis of variance will only indicate any significance differences amongst the different locations, it will not indicate the sources of such differences, hence the need for t-test, as a supplementary test. The regression and correlation analysis was used for the establishment of the extent of dependency of the heavy metals on the measured soil physicochemical properties. All tests were performed at the 0.05and 0.01 level.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion of the study. It first examines the level of the soil properties and heavy metals. This is followed by examination of the variation of the properties over the study area and the relation of the soil heavy metals to the soil properties. Lastly, it examines the toxicity levels of the heavy metals by comparison to the EU regulatory standard, and the discussion of the results.

4.2 Status and Variability of Soil Properties and Heavy Metals

Tables 4.1 and 4.2 show the status and variation of the various soil properties and heavy metals considered over the different sites. It also incorporates the result of the analysis of variance employed to test for significant differences in the properties amongst the different sites. Tables 5.3 and 5.4 on the other hand show the result of t-test employed to test for significant differences between pairs of location.

4.3 Soil Properties

4.3.1 Texture

The sand content shows significantly different mean values amongst the different sites. The value ranged between 76.60g/kg^{-1}in soils at site C, through about 72.00g/kg^{-1}, 57.64 g/kg^{-1} and 56.6g/kg^{-1} over sites E, A and B, and 53.76g/kg^{-1} over D. Consequently, analysis of variance revealed significant differences amongst the various sites at the 0.05 level. On the whole, all sites show comparatively homogenous values as depicted by relatively low CV%; less than 32%.

Table 4.1: Variation of soil properties over different sites studied

Soil Property	Stats	SITES						ANOVA	
		A	B	C	D	E	F		
SAND %	X	57.64	56.60	76.60	53.76	72.00	63.70	3.578	*
	SD	6.96	7.67	12.32	17.55	10.68	4.94		
	CV%	12.1	13.5	16.1	32.6	14.8	7.8		
SILT %	X	17.36	16.50	16.00	30.84	17.40	15.70	2.024	
	SD	4.82	4.77	12.33	14.59	8.53	4.99		
	CV%	27.8	28.9	77.1	47.3	49.0	31.8		
CLAY %	X	25.00	26.90	7.40	15.40	10.60	20.60	16.617	**
	SD	3.74	8.95	1.67	2.97	2.19	0.89		
	CV%	15.0	33.3	22.6	19.3	20.7	4.3		
TEXTURE		SCL	SCL	LS	SL	SL	SL		
pH H_2O	X	6.34	6.32	6.18	6.58	6.74	6.28	19.177	**
	SD	0.09	0.11	0.13	0.13	0.05	0.11		
	CV%	1.4	1.7	2.1	2.0	0.8	1.7		
Organic. Carbon	X	9.10	7.33	5.34	8.44	6.12	8.38	1.750	
	SD	2.48	1.54	1.93	3.18	2.22	3.12		
	CV%	27.3	20.9	36.1	37.6	36.3	37.2		
Avail. P	X	520.20	264.36	477.32	516.21	452.59	457.97	.159	
	SD	217.41	52.14	733.19	711.36	745.26	174.66		
	CV%	41.8	19.7	153.6	137.8	164.7	38.1		
Ca	X	4.86	3.42	2.98	3.82	3.82	3.64	4.097	**
	SD	0.72	0.72	0.83	0.38	0.88	0.48		
	CV%	14.8	20.9	27.7	9.9	23.1	13.1		
Mg	X	0.88	0.74	0.74	1.14	1.15	0.81	3.529	*
	SD	0.22	0.11	0.26	0.10	0.25	0.32		
	CV%	24.6	15.4	35.6	8.7	21.7	39.6		
K	X	0.18	0.15	0.05	0.19	0.21	0.11	4.595	**
	SD	0.10	0.06	0.04	0.08	0.06	0.02		
	CV%	55.2	38.0	82.2	39.9	29.7	17.8		
Na	X	0.36	0.31	0.20	0.42	0.34	0.46	2.211	
	SD	0.06	0.08	0.07	0.20	0.11	0.21		
	CV%	17.7	26.5	35.2	48.3	31.1	44.9		
CEC	X	8.18	6.66	5.78	6.68	6.84	7.02	4.712	**
	SD	0.90	0.95	0.75	0.54	0.98	0.54		

CV%	11.0	14.2	13.0	8.1	14.3	7.8

Level of Significance: * < 0.05; ** < 0.01

A = Wuse-Zone 4, **B** = Central Area, **C** = Jabi Lake, **D** = National Mosque, **E** = Wuse 2, **F** = Wuse-Zone 6

X = Mean, **SD** = Standard Deviation, **CV%** = Coefficient of Variation percent

Table 4.2: Variation of soil heavy metals over different sites studied

Heavy Metals	Stats	SITES						ANOVA	EU REGULATORY STANDARD
		A	B	C	D	E	F		
Avail. Zn	X	17.70	15.81	7.36	9.12	5.66	11.05	.620	300
	SD	27.11	16.73	2.61	3.23	0.81	2.95		
	CV%	153.2	105.8	35.4	35.5	14.3	26.7		
Total Zn	X	43.82	59.80	60.49	73.50	93.16	107.09	.454	
	SD	12.56	12.45	107.43	38.09	124.03	79.44		
	CV%	28.7	20.8	177.6	51.8	133.1	74.2		
Avail. Cu	X	1.65	1.60	0.52	1.62	1.89	2.56	7.039 **	3O
	SD	0.71	0.16	0.15	0.45	0.57	0.85		
	CV%	42.9	10.0	29.3	27.7	30.0	33.4		
Total Cu	X	13.95	4.67	2.35	16.30	3.44	27.41	6.474 **	
	SD	7.34	1.73	0.59	10.87	0.67	15.64		
	CV%	52.6	37.0	25.1	66.7	19.4	57.1		
Avail. Mn	X	84.82	73.59	83.35	195.52	115.00	152.87	3.302 *	1500
	SD	14.01	30.73	65.71	78.94	47.45	62.52		
	CV%	16.5	41.8	78.8	40.4	41.3	40.9		
Total Mn	X	816.76	1009.92	555.83	1613.56	741.36	1315.72	3.018 *	
	SD	319.10	96.70	262.95	826.98	292.97	640.55		
	CV%	39.1	9.6	47.3	51.3	39.5	48.7		
Avail. Fe	X	26.19	31.75	53.96	76.43	125.36	75.95	7.469 **	1500
	SD	3.54	18.10	23.55	44.25	34.63	32.08		
	CV%	13.5	57.0	43.6	57.9	27.6	42.2		
Total Fe	X	21759.72	27857.15	4560.86	42346.06	11071.41	30212.91	3.233 *	
	SD	15304.96	14032.41	3613.01	25698.02	12990.61	23142.02		
	CV%	70.3	50.4	79.2	60.7	117.3	76.6		
Avail. Pb	X	2.26	1.38	0.19	0.19	0.09	3.06	16.175 **	–
	SD	1.16	0.70	0.18	0.05	0.01	0.93		
	CV%	51.4	50.8	91.8	27.9	11.1	30.2		
Total Pb	X	3.62	3.72	0.69	0.45	0.35	5.85	20.503 **	
	SD	1.66	1.19	0.47	0.24	0.25	1.60		
	CV%	45.8	31.9	67.8	54.3	73.7	27.4		

Level of Significance: * < 0.05; ** < 0.01

Table 4.3: t-TEST RESULT FOR DIFFERENCES IN MEAN OF SOIL PROPERTIES BETWEEN PAIR OF SITES

	Soil Properties										
	Sand*%*	**Silt***%*	**Clay** *%*	**pHH_2O** *1:2.5*	**OC***g/kg^{-1}*	**AvP** *mg/kg*	**Ca***cmol/kg^{-1}*	**Mg** *cmol/kg^{-1}*	**K** *cmol/kg^{-1}*	**Na** *cmol/kg^{-1}*	**CEC** *cmol/kg^{-1}*
A/B	0.23	0.28	-0.44	0.312	1.35	2.56*	3.17*	1.28	0.69	1.11	2.60*
A/C	-3.00*	0.23	9.60**	2.26	2.67*	0.13	3.84**	0.92	2.85*	3.85**	4.57**
A/D	0.46	-1.96	4.50**	-3.39**	0.36	0.01	2.86*	-2.44*	-0.11	-0.61	3.19*
A/E	-2.52*	-0.01	7.43**	-8.53**	2.00	0.20	2.04	-1.82	-0.52	0.36	2.25
A/F	-1.59	0.54	2.56*	0.95	0.40	0.50	3.16*	0.40	1.64	-0.98	2.46*
B/C	-3.08*	0.09	4.79**	1.84	1.81	-0.65	0.90	0.00	3.36*	2.31*	1.63
B/D	0.33	-2.09	2.73*	-3.41**	-0.70	-0.79	-1.11	-5.90**	-0.99	-1.12	-0.04
B/E	-2.62*	-0.21	3.96 **	-7.67**	1.01	-0.56	-0.79	-3.34*	-1.69	-0.53	-0.30
B/F	-1.74	0.26	1.57	0.58	-0.67	-2.38*	-0.57	-0.46	1.50	-1.47	-0.74
C/D	2.38*	-1.74	-5.25**	-4.85**	-1.87	-0.09	-2.07	-3.18*	-3.80**	-2.30	-2.17
C/E	0.63	-0.21	-2.60*	-8.85**	-0.59	0.05	-1.55	-2.53*	-5.05**	-2.52*	-1.92
C/F	2.17	0.05	-15.56**	-1.31	-1.85	0.06	-1.55	-0.38	-3.27*	-2.65*	-2.98*
D/E	-1.99	1.78	2.91*	-2.53*	1.34	0.14	0.00	-0.08	-0.50	0.76	-0.32
D/F	-1.21	2.20	-3.75**	3.94**	0.03	0.18	0.66	2.20	2.34*	-0.28	-0.99
E/F	1.58	0.38	-9.45**	8.40**	-1.32	-0.02	0.40	1.87	3.53**	-1.10	-0.36

Level of Significance: * < 0.05; ** < 0.01

Table 4.4: t-TEST RESULT FOR DIFFERENCES IN MEAN OF HEAVY METALS BETWEEN PAIR OF SITES

Pair of Sites	Heavy Metals(ppm)									
	Available					Total				
	Zn	Cu	Mn	Fe	Pb	Zn	Cu	Mn	Fe	Pb
A/B	0.13	0.15	0.74	-0.67	1.46	-2.02	2.75*	-1.30	-0.66	-0.11
A/C	0.85	3.50**	0.05	-2.61*	3.94**	-0.35	3.52**	1.41	2.45*	3.80**
A/D	0.73	-0.11	-3.12*	-2.54*	3.51*	-1.96	-0.33	-1.81	-0.97	4.28**
A/E	0.99	-0.61	-1.36	-6.37**	4.18**	-0.89	3.19*	0.39	1.19	4.36**
A/F	0.55	-1.84	-2.38*	-3.45**	-1.20	-1.76	-1.74	-1.56	-0.68	-2.16
B/C	1.12	10.99**	-0.30	-1.67	3.67**	-0.01	2.84*	3.62**	3.60**	5.29**
B/D	0.91	-0.41	-3.25*	-2.10	3.34*	-1.07	-2.27	-1.41	-0.53	6.10**
B/E	1.36	-1.12	-1.64	-5.36**	4.11**	-0.60	1.48	1.95	1.96	6.21**
B/F	0.63	-2.47*	-2.55*	-2.68*	-3.25*	-1.32	-3.23*	-1.06	-0.20	-2.39*
C/D	-0.80	-5.53**	-2.47*	-1.01	0.02	-0.36	-2.78*	-2.52*	-2.60*	1.20
C/E	1.39	-5.25**	-0.87	-3.81**	1.29	-0.45	-2.75*	-1.05	-1.08	1.45
C/F	-2.09	-5.26**	-1.71	-1.24	-6.81**	-0.78	-3.58**	-2.45*	-2.45*	-6.90**
D/E	2.13	-0.64	1.98	-1.94	4.20**	-0.25	2.55*	2.02	1.84	0.41
D/F	-1.12	-2.02	0.97	0.03	-6.11**	-0.72	-1.36	0.47	0.30	-7.50**
E/F	-3.93**	-1.45	-1.08	2.34*	-7.18**	-0.21	-3.42**	-1.82	-1.61	-7.58**

Level of Significance: * < 0.05; ** < 0.01

When the values of the sand content for each pair of plots were subjected to t-test, the results obtained show that pair of plots A/C, A/E, B/C, B/E and /CD are statistically significant at 0.05 level, while the rest are not.

Unlike the sand content, ANOVA did not reveal significant differences in the silt content amongst the different sites. The value varies between about 17.40g/kg^{-1} over A and E, through 16.5g/kg^{-1} and 15.7g/kg^{-1} over B and F, respectively, and 30.84g/kg^{-1} over D. Unlike the sand content however, the CV% is generally above 32%, except over A and B. This implies that the fraction is more uneven within each location. The result of t-test between pair of plots does not show any statistical significant differences.

Similar to the sand content, the clay content show significantly different mean values amongst the various study locations. The value is highest over B (26.90g/kg^{-1}) and lowest over C (7.40g/kg^{-1}), while values over the remaining locations are intermediate. While the CV% is greater than 19% over sites D, E, B and C, it is lower than 15% over sites A and F. The t-test values for pair of plots suggest that the clay content is statistically different at 0.01 level for plots A/C, A/D, A/E, B/C, B/E, C/D, C/F, D/F and E/F and at 0.05 for plots A/F, B/D, C/E and D/E, while plots A/B and B/F are not statistically significant.

Overall, all groups of soils are sandy which may be due mainly to the coarse textured nature of the parent rock over which the soil was formed (Jaiyeoba, 1986). Other factors that could account for the sandy nature of the soils could be the elluviation of finer particles from the top horizon and illuviation in the lower horizon and also, the selective removal of finer particles in wash processes (Young, 1976; Jaiyeoba, 1986).

4.3.2 Organic carbon and available P

The soil organic carbon did not reveal significant differences amongst the different sites. However, values over sites A, D and F are slightly higher than those over C and E. When the pair of plots were subjected to t-test, the t-test values obtained were also very low and therefore, not statistically significant. The only exception however, is pair of plot A/C which shows some significant difference. Similarly, as revealed by the CV%, the values within each sites are relatively similar (CV% > 36%). The only exceptions are sites A and B with CV% less than 27%. The lack of significant differences in the mean organic carbon content and the generally low values of CV%, is a reflection presumably, of intensive anthropogenic influence and therefore, low organic matter (Young, 1976 and Jaiyeoba, 1988).

Similar to the soil organic carbon content, the mean values of Available P are not significantly different amongst the various sites. It varies from 264.36ppm over B, through 520.2ppm and 457.97ppm over A and F respectively, to 516.21ppm over D. Unlike the soil organic carbon content, however, the element show considerable variability within most of the respective sites as depicted by relatively high CV%. However, the t-test values over pair of plots depict statistical significance for pair of plots A/B and B/F at 0.05 significant level, while the rest are not statistically significant. The comparatively low Available P over the different sites is a reflection of the low organic carbon content. This is because Available P and Organic Carbon occur in organic combination and therefore, a reduction in one would lead to the reduction in the other and vice versa (Brady and Weil, 1999).

4.3.3 Exchangeable cations

The values of the exchangeable Ca show relatively similar values over the sites with the exception of plot A having the highest value of 4.86cmol/kg^{-1}. The CV% however, varies between about 14.8% over plot A, over 20% over plots B, C and E, 9.9% and 13.10% over plots D and F, respectively. This implies an uneven distribution of exchangeable Ca within the plots. The t-test show significant differences between pair of plots A/B, A/D and A/F at 0.05 and A/C at 0.01 significant levels, respectively.

The result of t-test show that the exchangeable Mg between pair of plots A/D, B/E, C/D and C/E are statistically significant at 0.05 while only B/D is statistically significant at 0.01 level. Similarly, exchangeable Mg show significantly different mean values by ANOVA amongst the various study locations. The value is highest over E (1.15cmol/kg^{-1}) and lowest over B and C (0.74 cmol/kg^{-1}). The CV% varies between 8.7% over plot D, about 24.6% over plot A and 39.6% and 35.6% over plots F and C.

Exchangeable K did not reveal significant differences amongst the different sites. By ANOVA however, values over sites A, B, D and E are higher than those over C and F. The CV% shows considerable variability amongst the different sites. The values vary from about 82% over C, 55% over A, 29% over E, 38% and 39.9% over B and D and 17.8% over F. Student t-test between pair of plots however, shows considerable statistical significance between C/D, C/E and E/F at 0.01, and AC, B/C, C/F and D/F at 0.05 significant levels.

The t-test did not show statistically significant differences in the exchangeable Na between the pair of plots. The only exceptions are pair of plots A/C (at 0.01), B/C, C/E and C/F at (0.05). The CV% varies greatly among the plots, with the highest over plot D (48.3%) and the lowest over plot A (17.7%). Unlike the CV%, the mean values depict less variations among the different sites. The value ranged between 0.20cmol/kg^{-1} over C and 0.46cmol/kg^{-1} over F. Consequently, ANOVA did not reveal significant differences amongst the various sites.

Overall, the relatively low values of exchangeable cations may be a reflection of losses through either cultivation, harvesting or leaching (Wilson & Kent, 1983). This phenomenon could also be as a result of greater mobilization by plants or greater weathering and release of the elements within the soil (Fitzpatrick, 1980).

4.3.4 pH and CEC

The soil pH values vary little over different plots, with values ranging between 6.18 and 6.74. However, ANOVA revealed significant differences amongst the different sites. Similarly, as suggested by the CV%, the values of the different sites are fairly similar. The highest value occurs over plot C (2.1%) and the lowest over plot E (0.8%). When the value for the pair of plots were subjected to t-test, the result obtained shows that there is significant differences for plots A/D, A/E, B/D, B/E, C/D, C/E, D/F and E/F at 0.01 significant level and for D/E at 0.05 significant level.

The soil cation exchange capacity (CEC) show considerable variability over the different sites. The value is lowest over site C (5.78cmol/kg^{-1}) and highest over site A (8.18cmol/kg^{-1}) while those over B (6.66cmol/kg^{-1}) and F (7.02cmol/kg^{-1}) are intermediate. Analysis of variance thus, shows highly statistical significant differences amongst the various sites. As suggested by the relatively low CV% values, there is considerable homogeneity in the CEC of the respective sites. The t-test result shows that the CEC value is statistically significant at 0.01 level for pair of plots A/C and at 0.05 level for A/B, A/D, A/F and C/F.

In all, all groups of soils are low in CEC. The comparatively smaller CEC values of the various plots reflects lower organic carbon content of the different sites or it may be that the clay mineralogy of the soil is predominantly the chemically less active Kaolinite type (Fitzpatrick, 1980).

4.4 Heavy Metals

4.4.1 Zinc (Zn)

The values of available Zn vary among the various plots. They vary from 17.7 ppmover plot A to 5.66 ppmover plot E. When values of each plot were paired and subjected to t-test, results obtained show that only E/F is significantly different at 0.01 level. The CV% ranges in values between 153 % over plot A and 14% over plot E.

The pattern of the total Zn differ somewhat from that of the available Zn. The mean value is highest over site F (107.09ppm) and lowest over site A (43.82ppm). However, similar to available Zn, ANOVA did not reveal significant differences amongst the different sites.

4.4.2 Copper (Cu)

The available Cu vary little among the plots with plot F having the highest value of 2.56ppm and plot C having the lowest value of 0.52ppm. The CV% ranged between 42% over plot A, through 33% and 30% over plots F and E respectively, to 10% over plot B. When subjected to t-test, the result obtained show significant differences between the pair of plots A/C, B/C, B/F, C/D, C/E and C/F.

Similar to the available Cu, the soil total Cu reveal highly significant differences amongst the different sites. Furthermore, the variation of the total Cu is somewhat similar to that of the available Cu, with the lowest value recorded over site C (2.35ppm) and highest value over site F (27.41ppm).

4.4.3 Manganese (Mn)

The available Mn shows higher significant differences amongst the different sites. The value is highest over site D (195.5ppm) and lowest over site B (73.59ppm). The t-test results between pair of plots revealed significant differences for sites A/D, A/F, B/D, B/F and C/D.

Similar to the available Mn, the differences in the total Mn is significant at the 0.05 level. However, the variation of mean value differ somewhat from that of available Mn. The value ranged between 1613.56ppm over site D, through 1009.92ppm and 816.76ppm over B and A, respectively, and 741.36ppm over site E.

4.4.4 Iron (Fe)

Available Fe is lowest over plot A with a value of about 26ppm. This is followed by values over plots B, C, F and D, with about 31ppm, 53ppm, 75ppm and 76ppm respectively. The highest value on the other hand is 125ppm and this occurs over plot E. The CV% shows that the measured Fe values over plots A and E, are relatively homogenous, compared to the rest of the sites. When the results were subjected to t-test, the result obtained shows that there are significant differences between pair of plots A/C, A/D, A/E, A/F, B/E, B/F, C/E and E/F.

The total Fe shows less significant differences amongst the various sites compared to the available Fe. Similarly, the variation over the different sites is also different. Unlike the pattern of available Fe, the total Fe is highest over D (42346ppm) and lowest over C (4560ppm), while the values over the other sites are intermediate.

4.4.5 Lead (Pb)

The result of t-test show significant differences in the available Pb between most pair of plots. Consequently, ANOVA show highly significant differences amongst the different sites. The mean value s ranged between 0.9ppm over site E, through 2.26ppm and 0.19ppm over site A and B respectively, and 3.06ppm over site F. As suggested by the CV%, the values over sites C, D and E are relatively homogenous, compared to those over sites A, B and F.

Similar to the available Pb, the total Pb shows highly significant differences amongst the various sites. The pattern of the mean value over the different sites is however slightly different.

It is noteworthy, that both the available and total heavy metal content of soils studied; show some level of significant differences amongst the different sites. The only exception is Zn. Despite that, the pattern of variation of both available and total heavy metals over the different sites differs considerably. Another important point of note is that both the level of available and total Fe and Mn, are considerably higher than those of the rest of heavy metals.

It is worth pointing out from the above analysis that while the hypothesis that there are no significant differences in the levels of the examined soil properties and heavy metals in soils under vegetable cropping at different locations in the study area cannot be rejected with respect to the soil organic matter, available P and pH. The hypothesis, however, is rejected with respect to most available and total heavy metal content studied.

4.5 Correlation of available and total heavy metal content of soils

Table 6 shows the correlation coefficient values of the soil total and available heavy metals. The value vary considerably, but on the whole, it does point to the fact that not all the amount of nutrient elements in soils are available for plant growth or participate in specific soil processes.

4.6 Relationship of heavy metals with soil properties

Figure 4.1 shows the scatterdiagram of the soil heavy metal content and soil properties for the combined sites, while Table 4.6 show the breakdown of the results according to the different locations

Table 4.5: Correlation matrix for Available and Total Heavy metals of all Sites

	Av. Zn	Av. Cu	Av. Mn	Av. Fe	Av. Pb	T. Zn	T. Cu	T. Mn	T. Fe	T. Pb
Av.Zn	1.00									
Av.Cu	.153	1.00								
Av.Mn	-.078	.448*	1.00							
Av.Fe	-.228	.415*	.552**	1.00						
Av.Pb	.335	.597**	.093	-.237	1.00					
T. Zn	-.066	.246	.485**	.363*	.023	1.00				
T. Cu	.065	.590**	.605**	.122	.661**	.008	1.00			
T. Mn	.088	.556**	.676**	.360	.319	.107	.624**	1.00		
T. Fe	-.037	.471**	.488**	.039	.388*	-.013	.595**	.712**	1.00	
T. Pb	.274	.547**	-.004	-.284	.955**	.038	.580**	.293	.402*	1.00

Level of Significance: * < 0.05; ** < 0.01

4.6.1 Heavy metals and soil texture

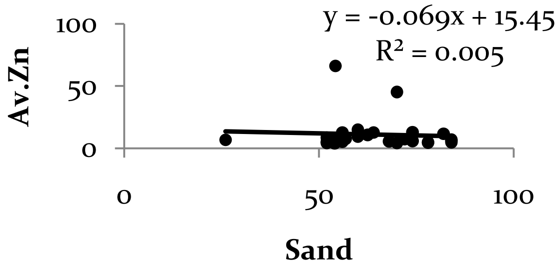
The available and total heavy metal content of the soils, show negative relationship with the sand content. The only exception is available Fe that shows a positive relationship. However, the relationship is only significant, statistically, with respect to available Mn and total Cu, Mn and Fe.

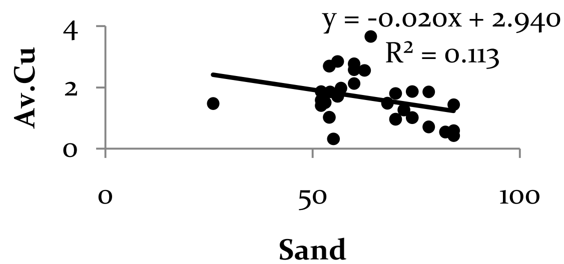
Unlike the trend with the sand %, the available and total heavy metal content of the soils, show positive relationship with the respective silt and clay content of the soil. The only exceptions are Pb (available and total) for silt, and available Mn and Fe for clay. However, similar to the variation with the sand content, the correlation coefficient values are only significant for available Mn and total Cu for silt, and Pb (available and total) and total Fe for clay.

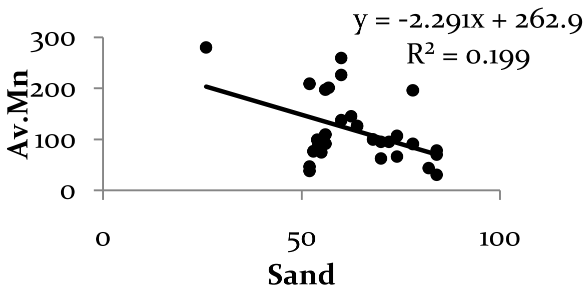
Thus, on the whole, while the sand content of the soil show negative relationship with the respective heavy metals (available and total), the silt and the clay content show positive relationships.

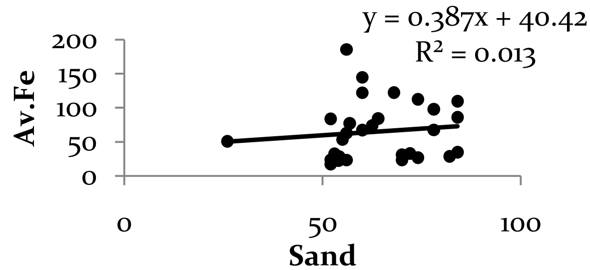
The result obtained when the data is split into different locations is rather similar to the overall pattern (Table 4.6). The only exception is over site B. Here, while the sand content reveals mostly positive relationship with the heavy metals, the silt and clay revealed negative correlation. Most of the relationships however, are insignificant statistically. This is understandable, considering that the silt and clay fraction of the soils are more reactive than the sand fraction.

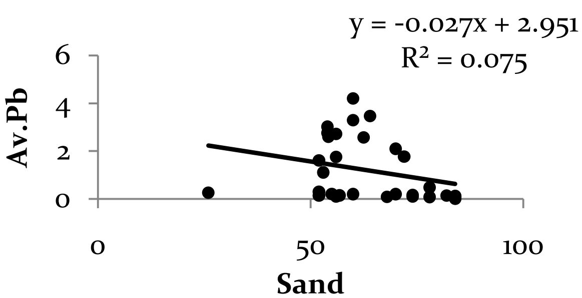
SCATTER PLOT FOR SAND

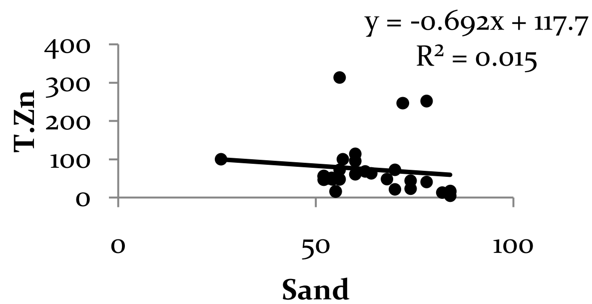


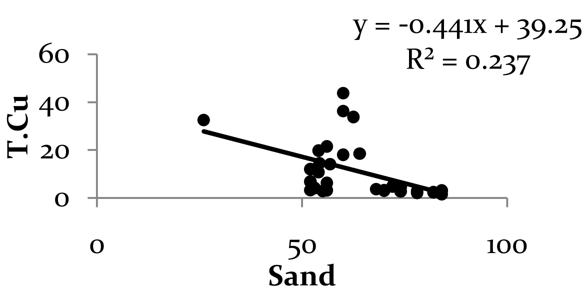


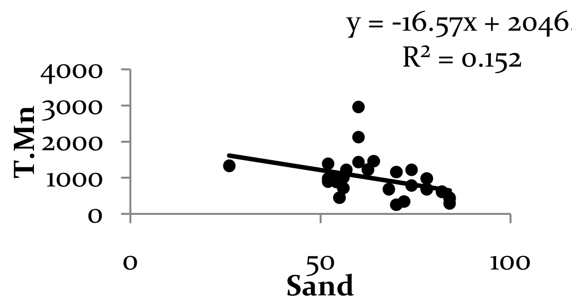


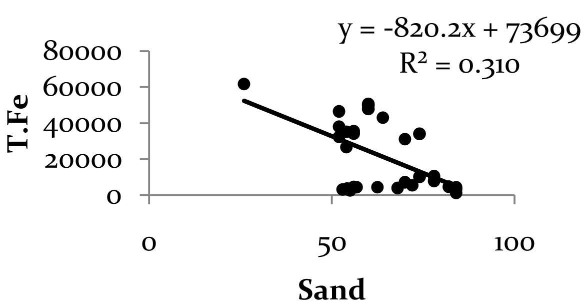


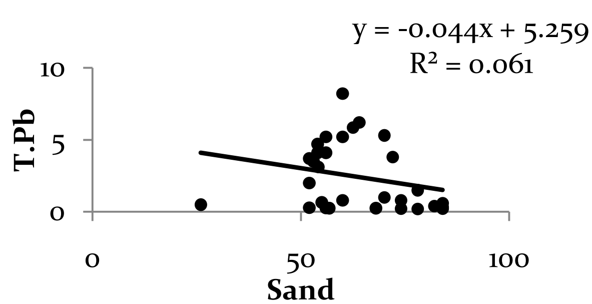




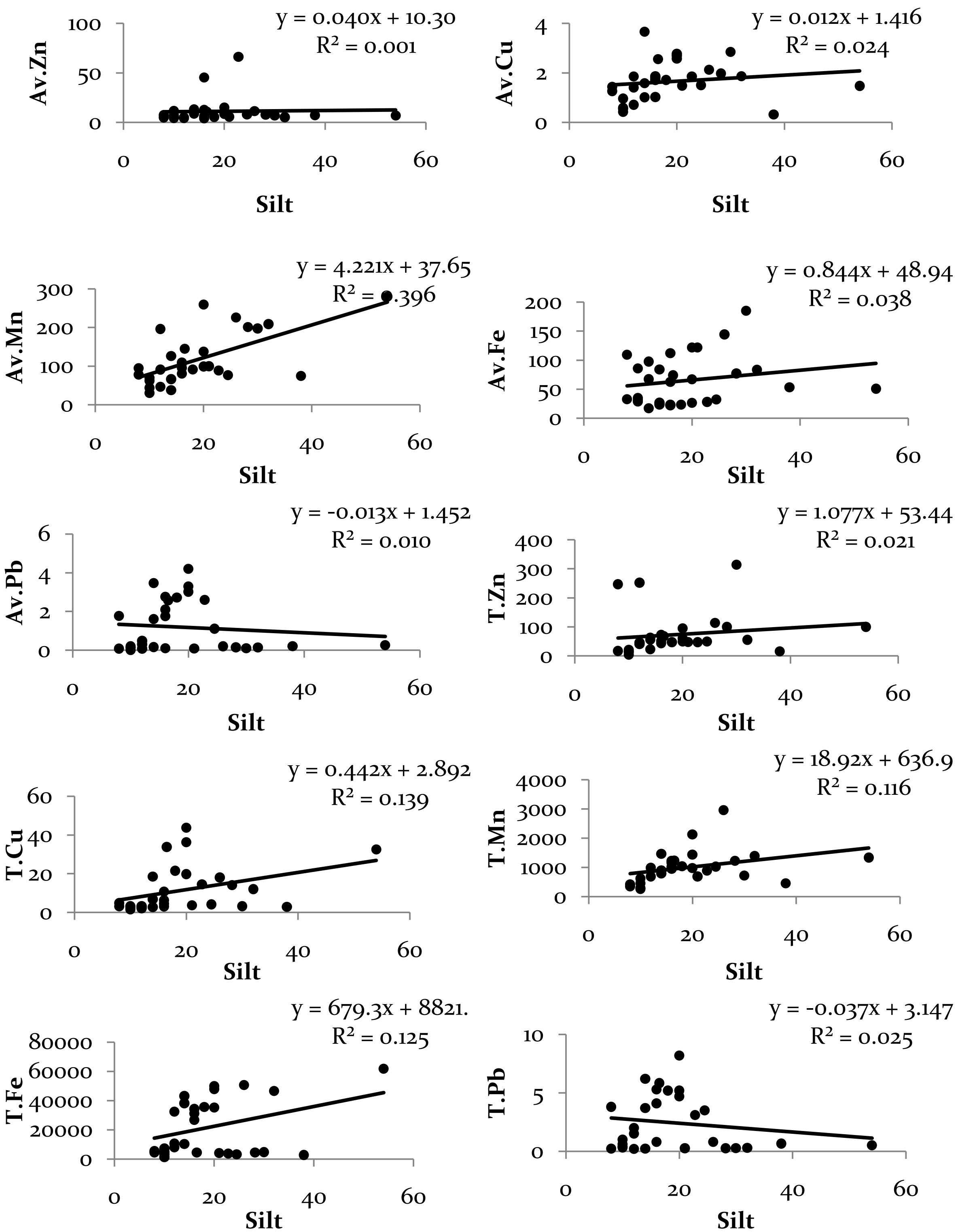




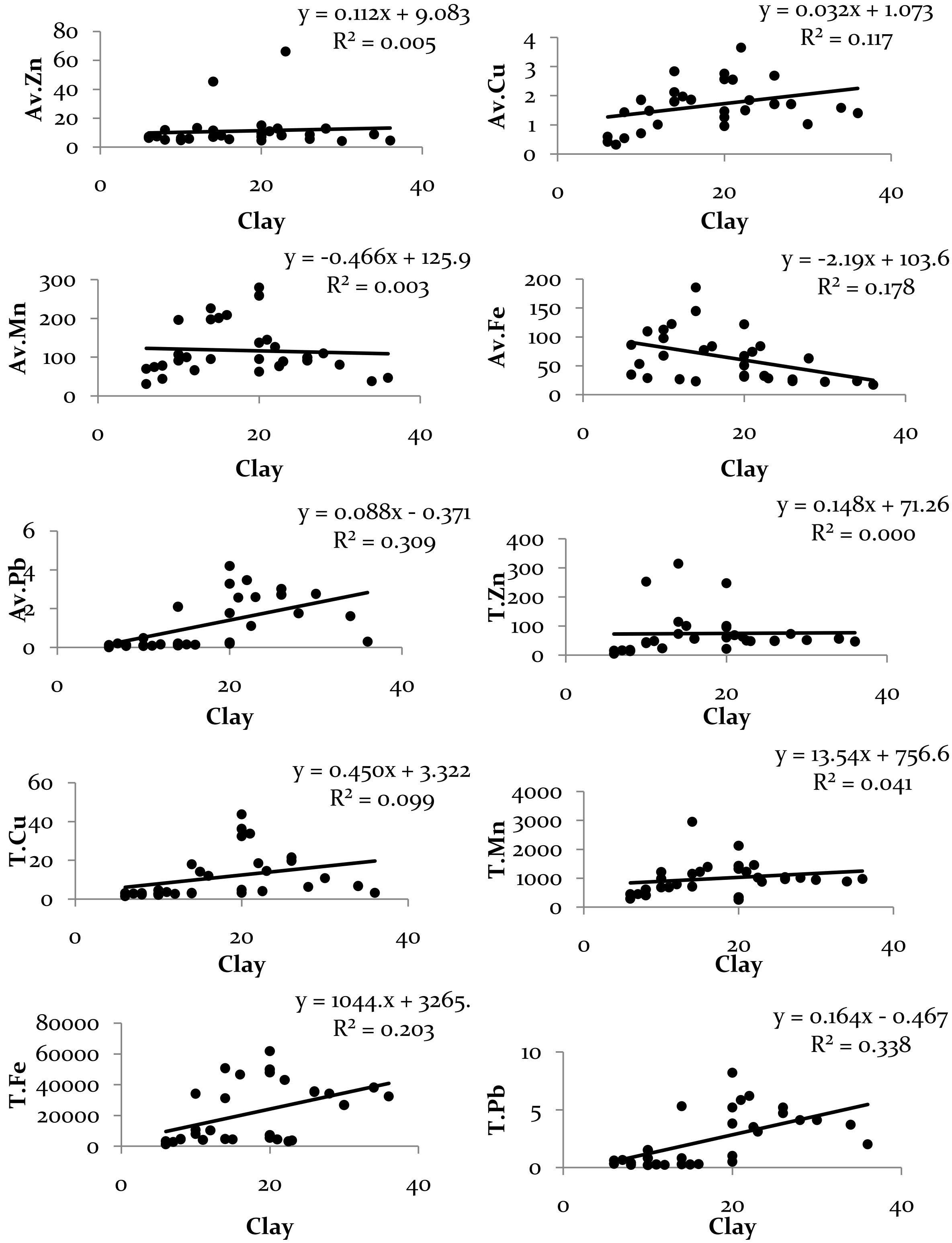




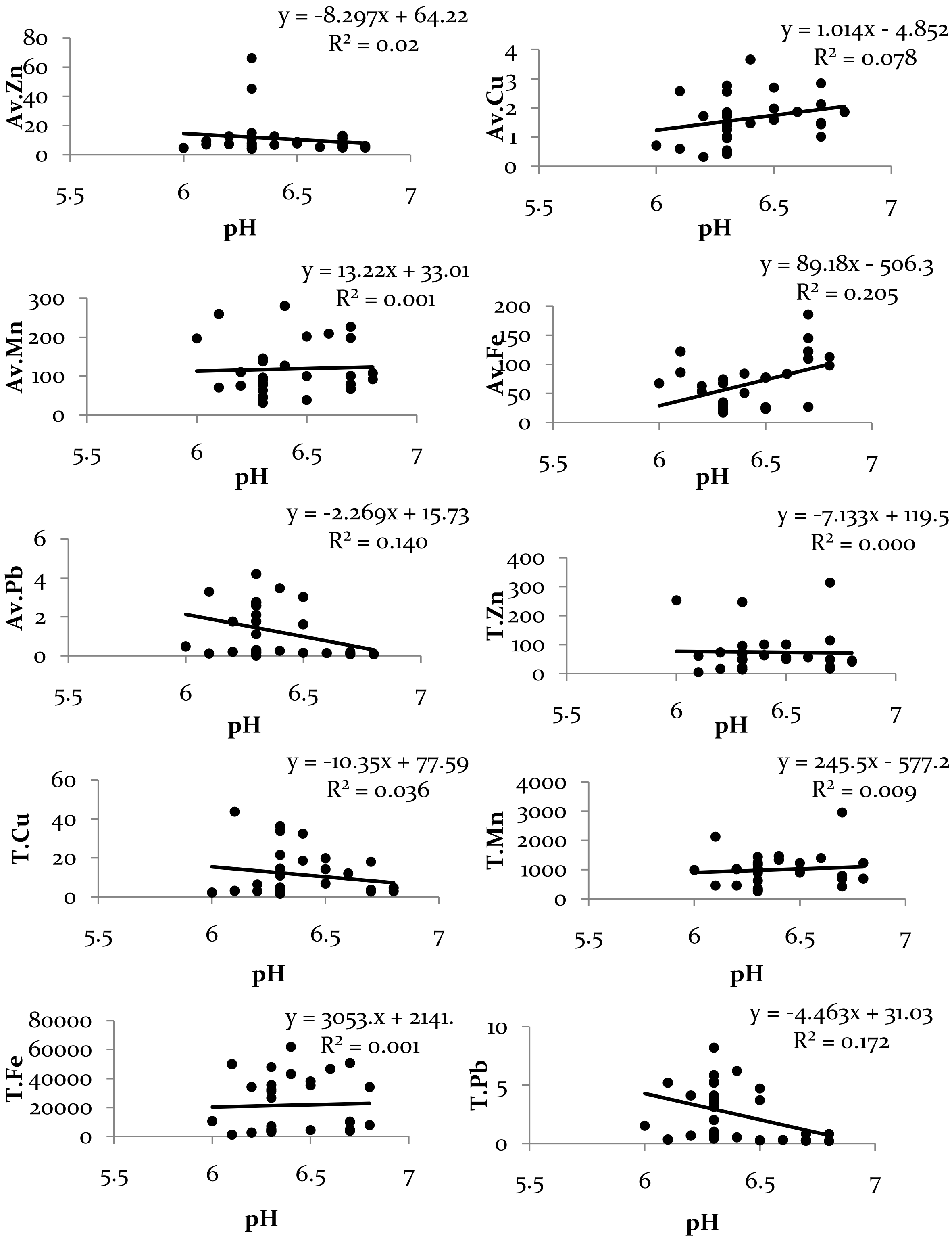
SCATTER PLOT FOR SILT



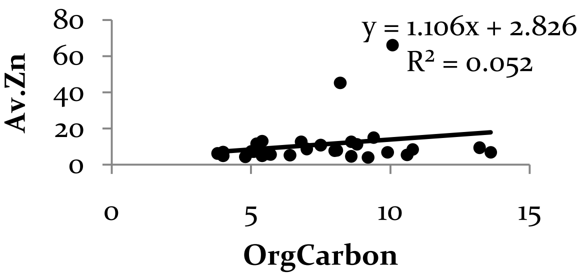
SCATTER PLOT FOR CLAY

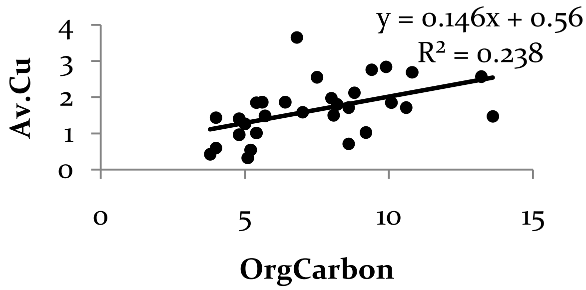


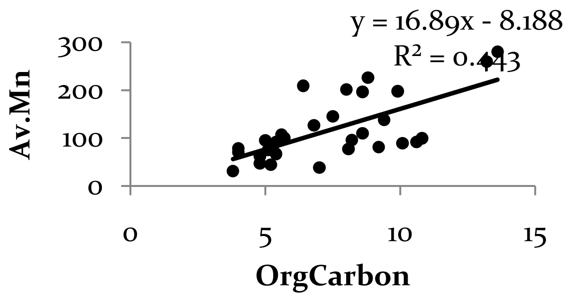
SCATTER PLOT FOR pH

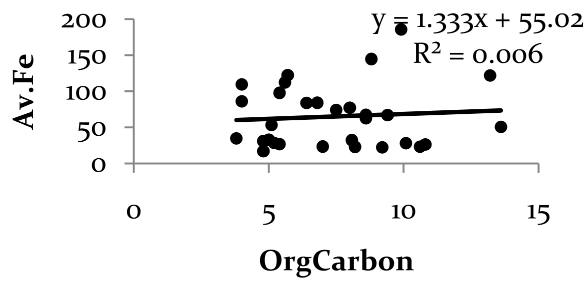


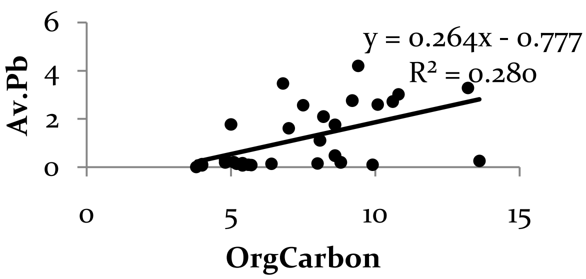
SCATTER PLOT FOR ORGANIC CARBON

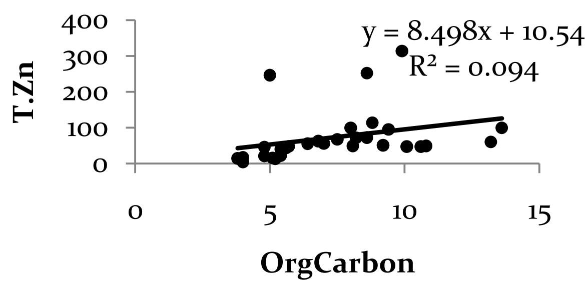


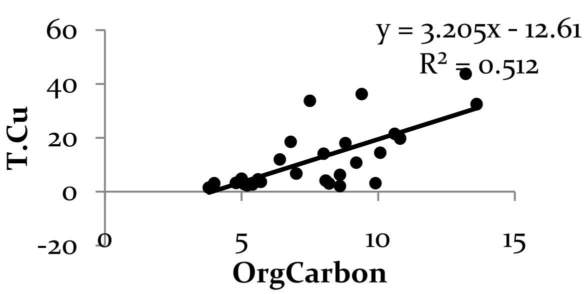


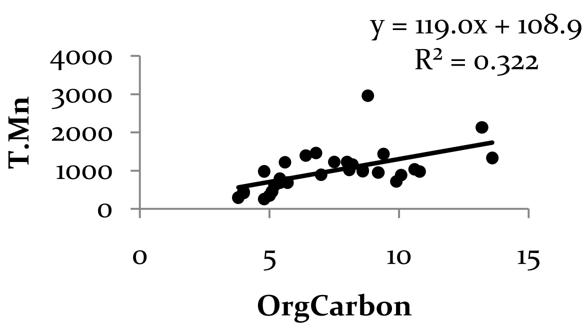


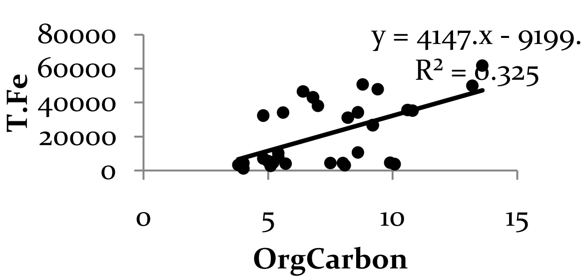


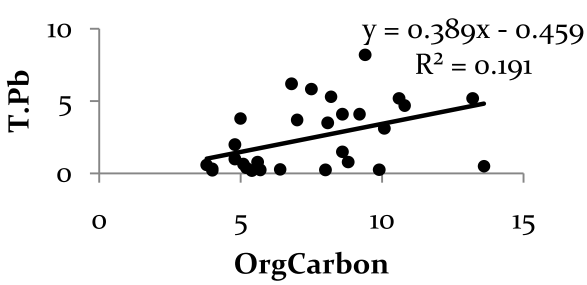




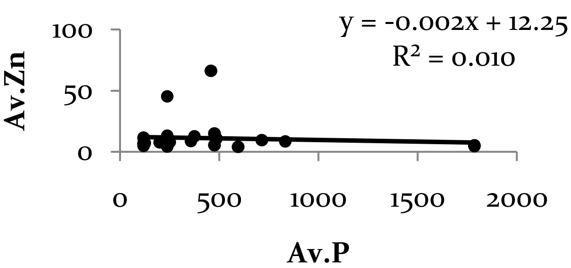


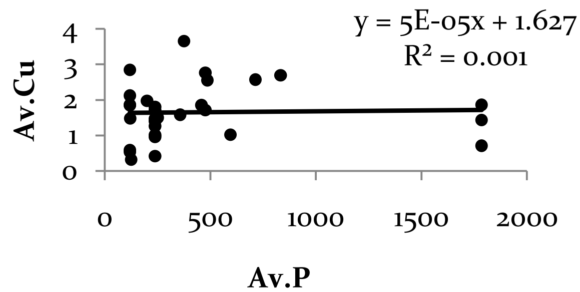


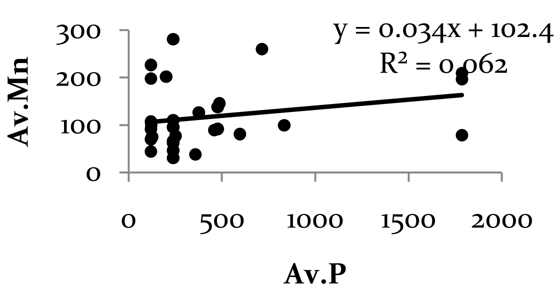


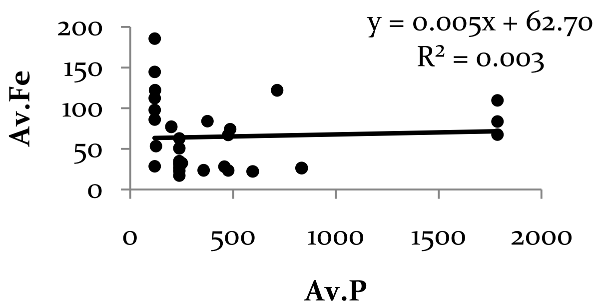


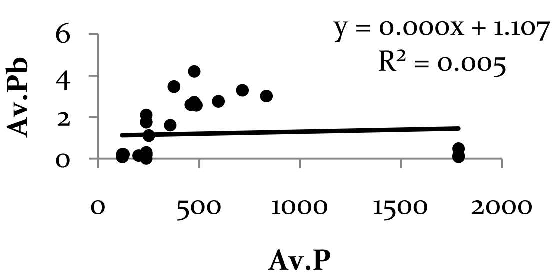
SCATTER PLOT FOR AVAILABLE P

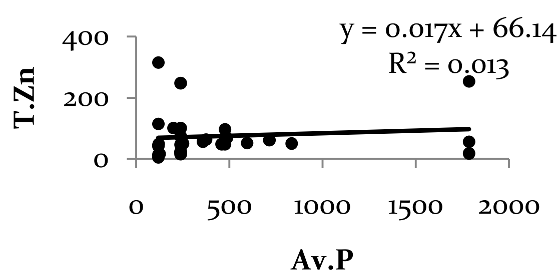


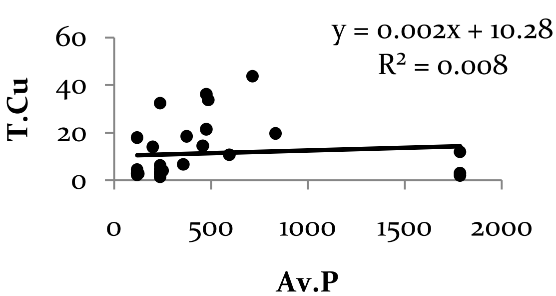


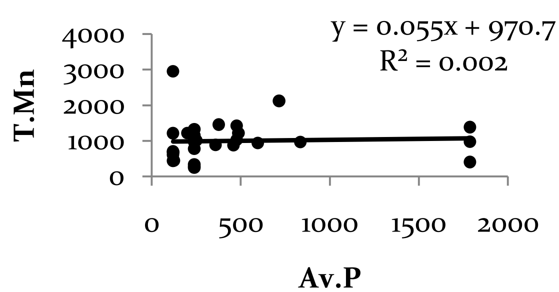


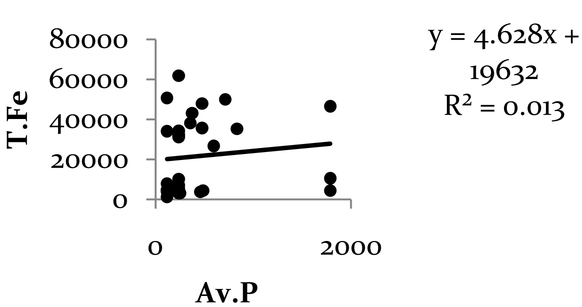


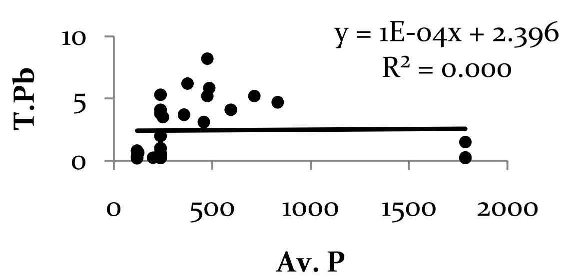




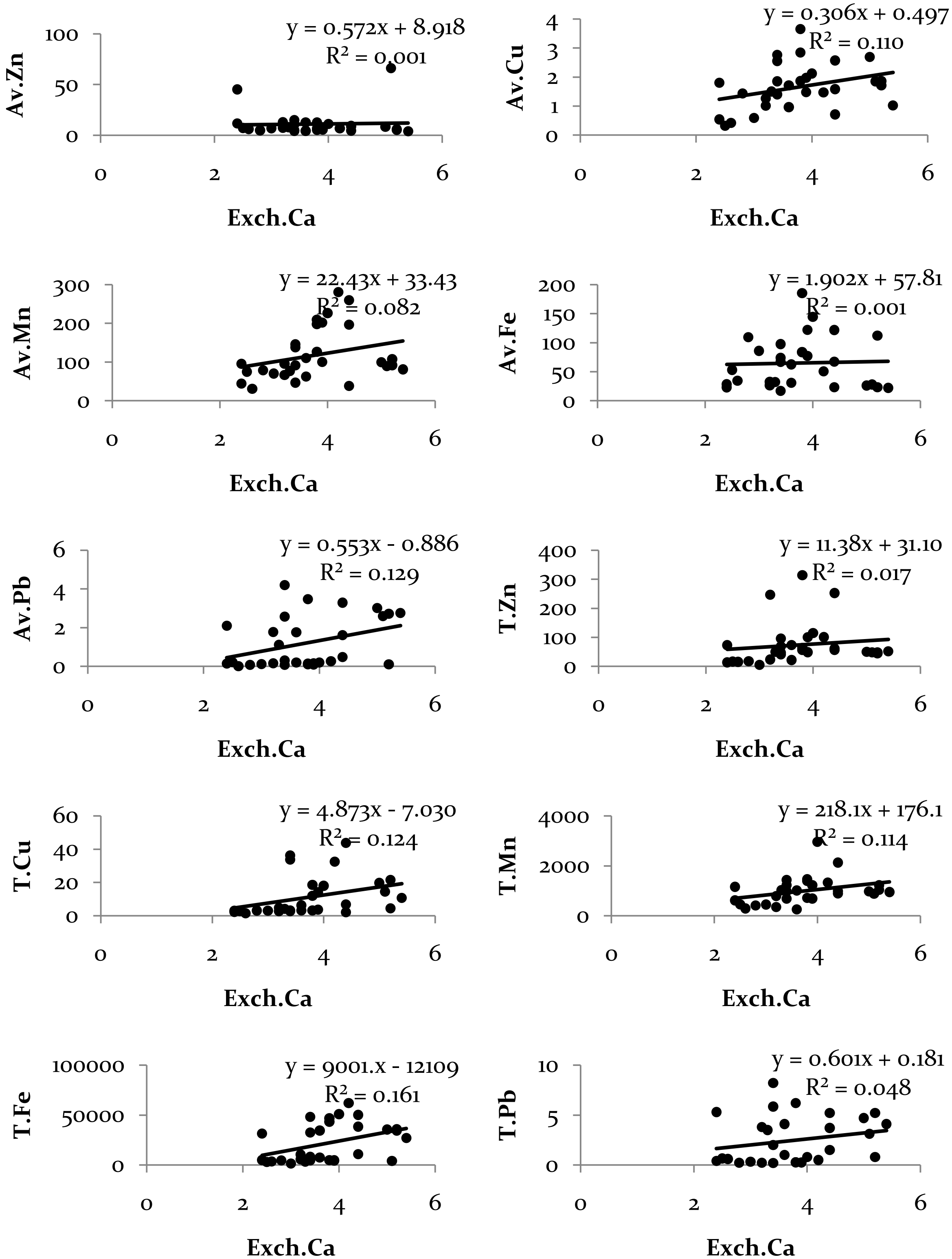








SCATTER PLOT FOR EXCHANGEABLE Ca



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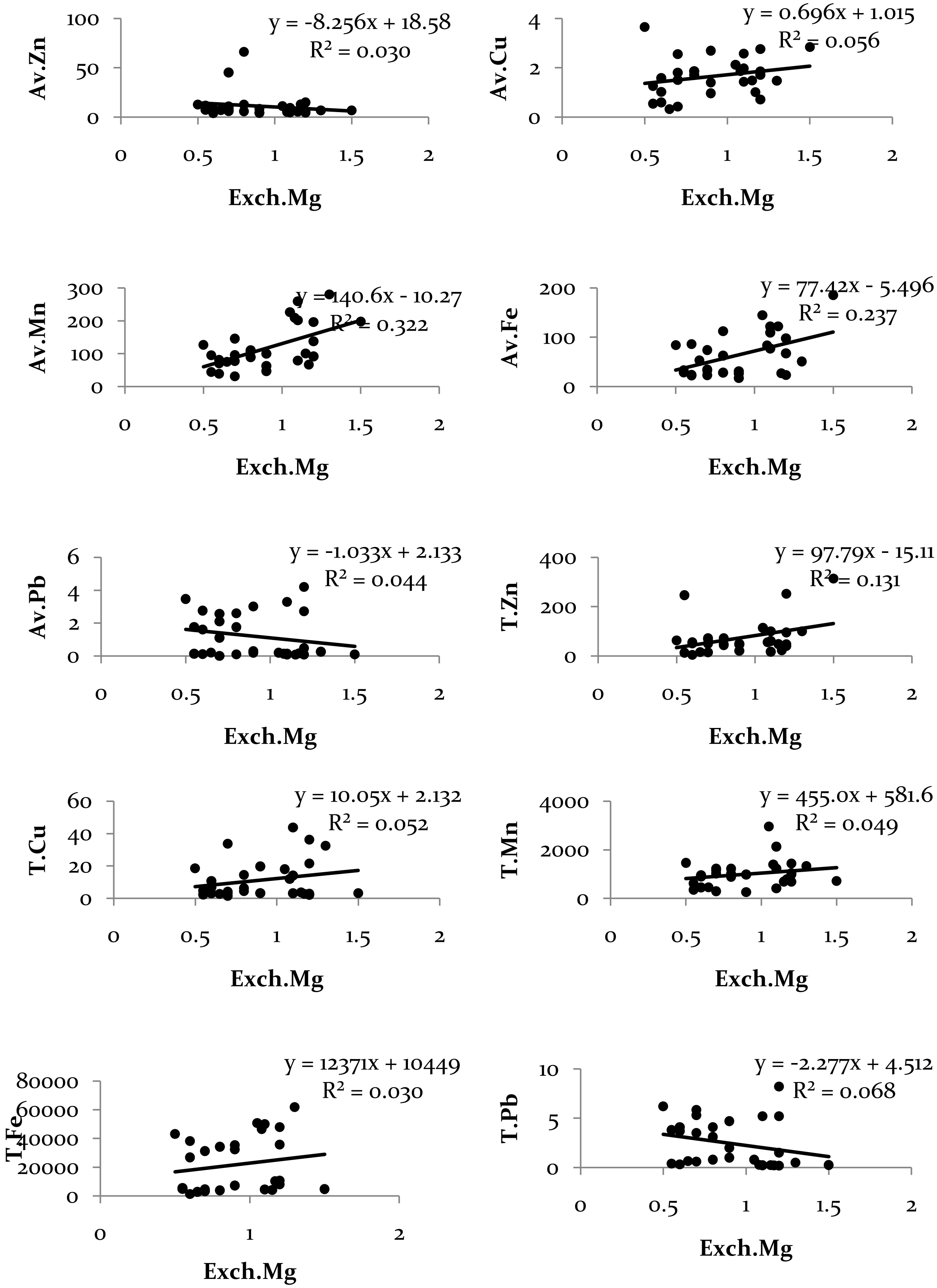
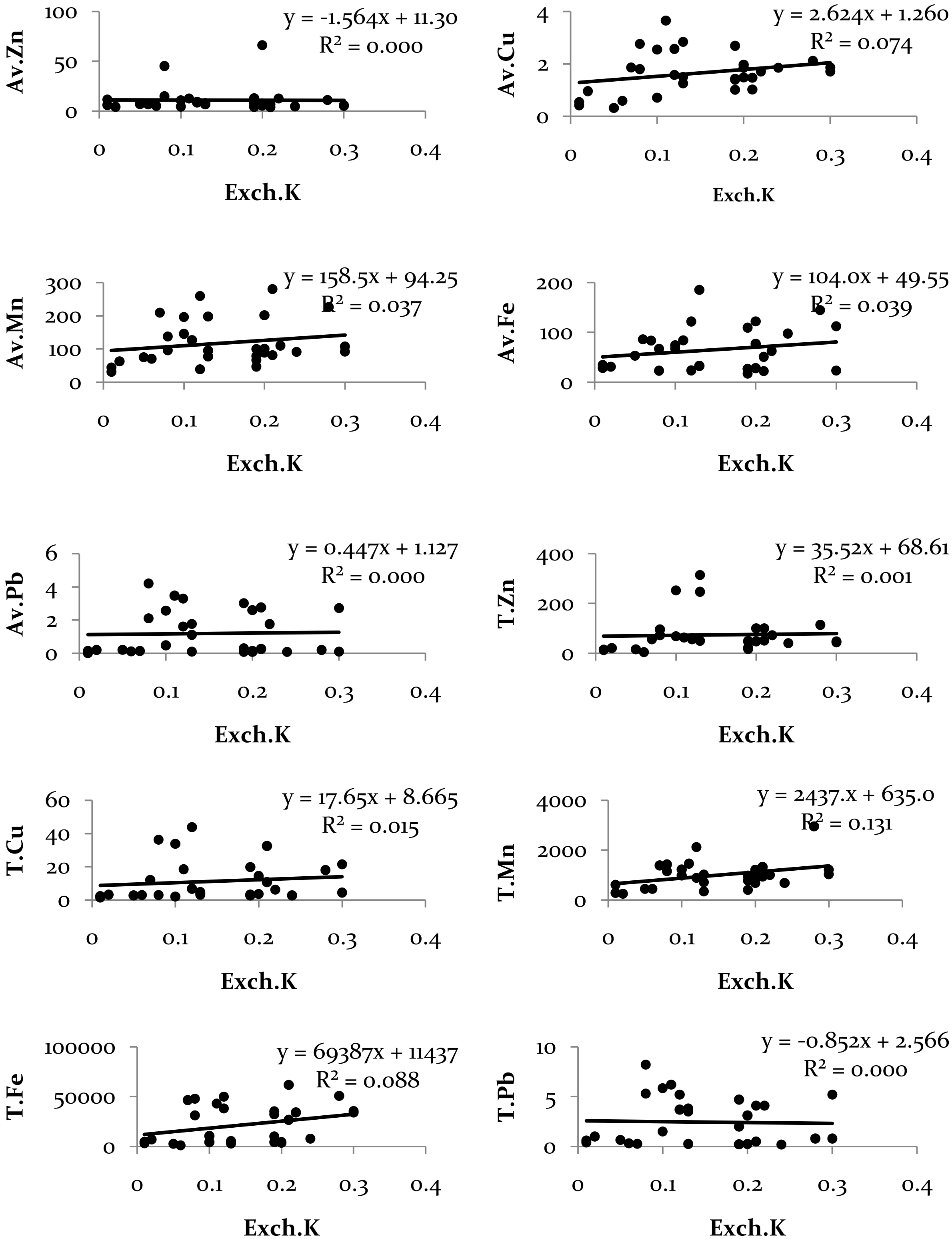
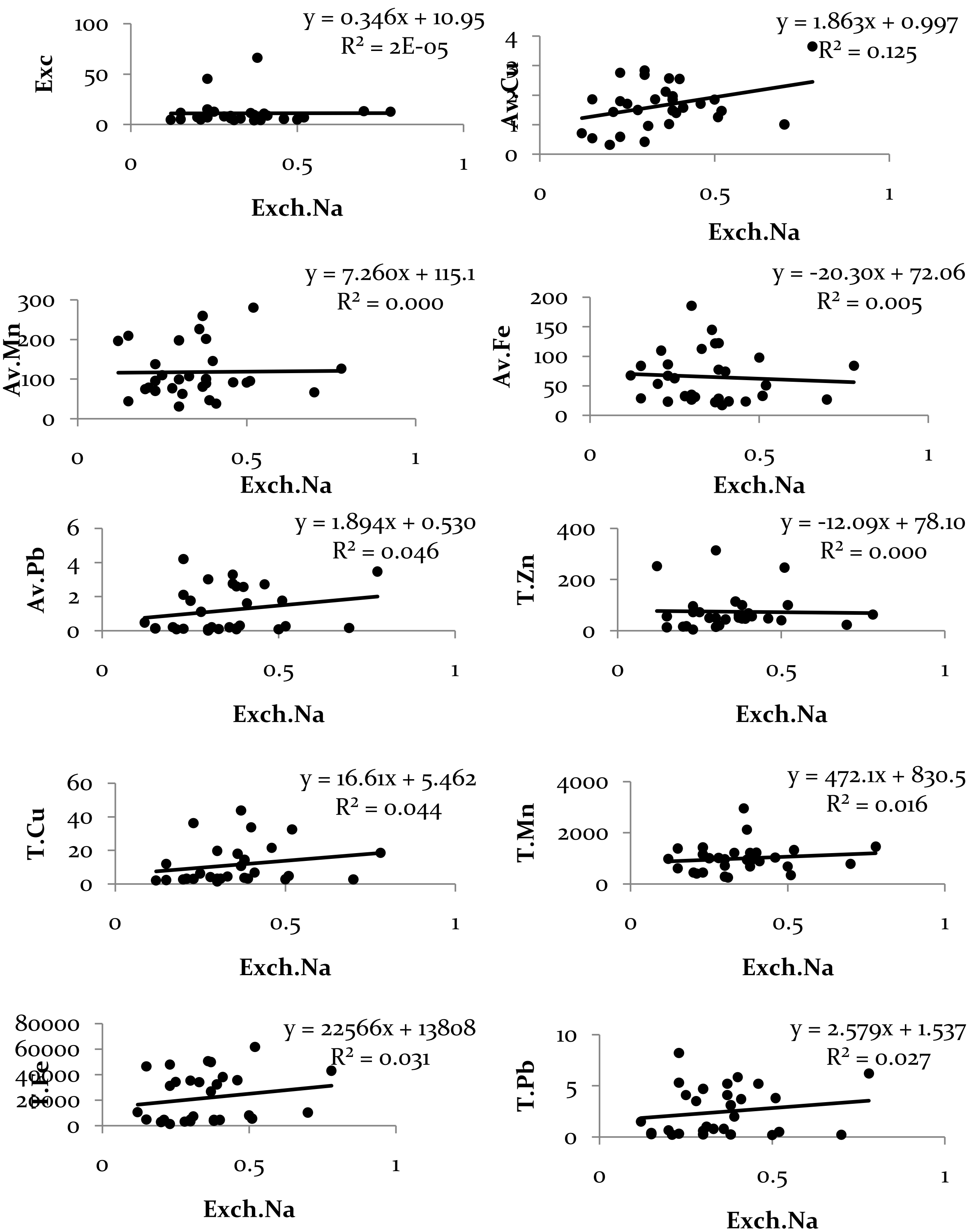


SCATTER PLOT FOR EXCHANGEABLE K



SCATTER PLOT FOR EXCHANGEABLE Na



SCATTER PLOT FOR CEC

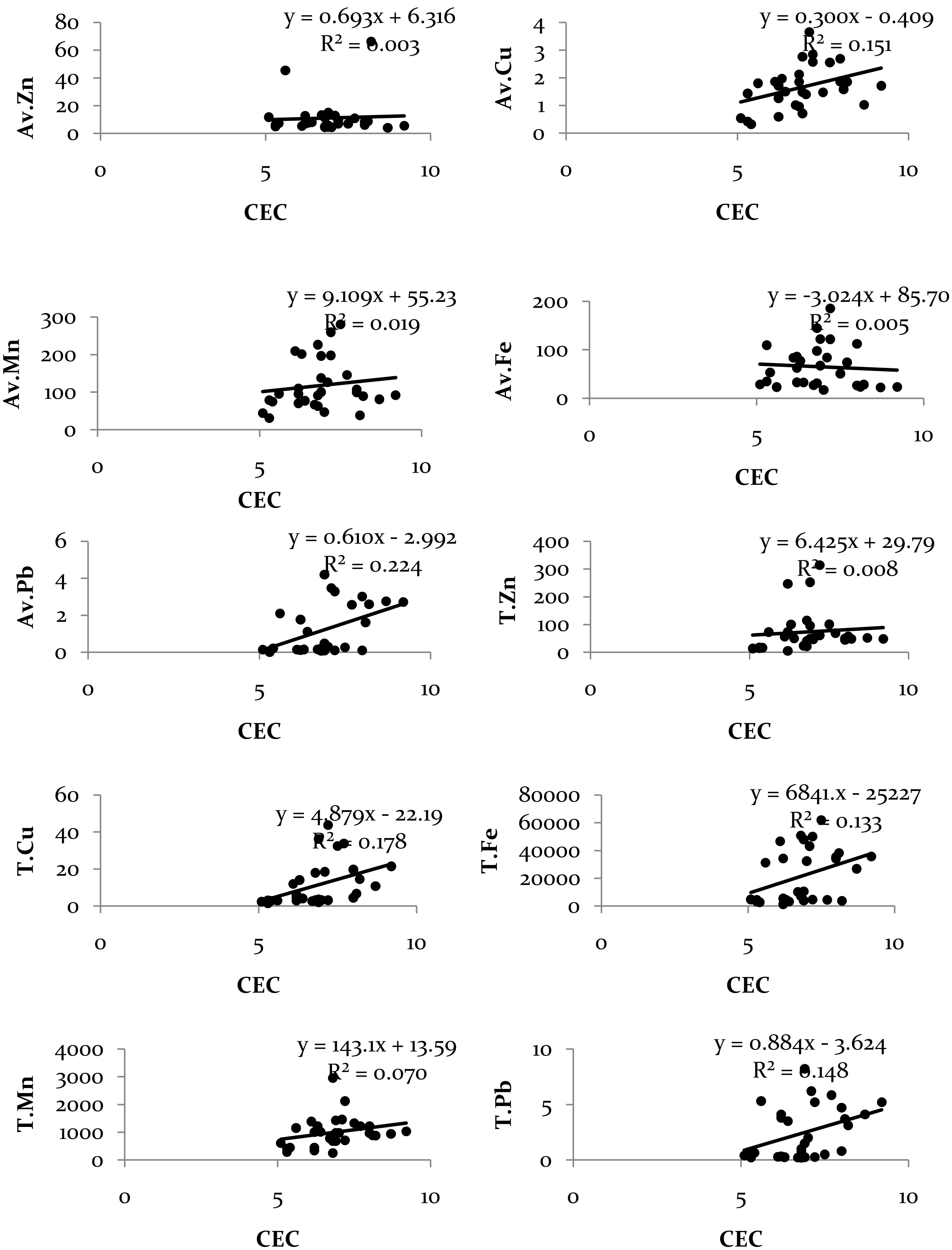


Table 4.6

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (All Sites)

Soil Properties	Heavy Metals(ppm)									
	Available					***Total***				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	-0.07	-0.34	-0.45**	0.12	-0.29	-0.12	-0.49**	-0.39*	-0.56**	-0.25
Silt %	0.02	0.16	0.63**	0.20	-0.08	0.15	0.37*	0.34	0.35	-0.16
Clay %	0.07	0.34	-0.06	-0.42	0.56**	0.02	0.32	0.20	0.45*	0.58**
pHH_2O 1:2.5	-0.14	0.28	0.04	0.45*	-0.37*	-0.02	-0.19	0.10	0.04	-0.42*
OC g/kg^{-1}	0.23	0.48*	0.67**	0.08	0.54*	0.31	0.72**	0.57**	0.57**	0.44*
AvP mg/kg	-0.10	0.03	0.25	0.06	0.06	0.14	0.09	0.05	0.12	0.02
Exch. Cacmol/kg^{-1}	0.04	0.33	0.29	0.04	0.37*	0.13	0.35	0.34	0.40*	0.22
Exch. Mg cmol/kg^{-1}	-0.17	0.24	0.57**	0.49**	-0.20	0.36*	0.23	0.22	0.17	-0.26
Exch. K cmol/kg^{-1}	-0.01	0.27	0.20	0.20	0.05	0.04	0.12	0.36*	0.30	-0.03
Exch. Na cmol/kg^{-1}	0.00	0.35	0.02	-0.07	0.22	-0.03	0.21	0.13	0.18	0.17
CEC cmol/kg^{-1}	0.06	0.39*	0.14	-0.07	0.47**	0.09	0.42*	0.27	0.37*	0.39*

Level of Significance: * < 0.05; ** < 0.01

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (Site A)

Soil Properties	Heavy Metals(ppm)									
	Available					Total				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	-0.30	-0.55	-0.87	0.72	-0.99**	-1.00**	-0.76	-0.96**	-0.49	-0.84
Silt %	0.66	0.72	0.87	-0.31	0.83	0.81	0.75	0.79	0.16	0.62
Clay %	-0.30	0.10	0.50	-0.95*	0.77	0.81	0.45	0.78	0.70	0.77
pHH_2O 1:2.5	-0.19	0.83	0.59	0.02	0.37	0.28	0.44	0.27	0.50	0.36
OC g/kg^{-1}	0.26	0.71	0.97**	-0.66	0.97**	0.95*	0.93*	0.97**	0.59	0.91*
AvP mg/kg	-0.11	0.75	0.82	-0.52	0.81	0.77	0.66	0.73	0.69	0.75
Exch. Cacmol/kg^{-1}	0.20	0.37	0.78	-0.85	1.96**	0.98**	0.72	0.97**	0.53	0.86
Exch. Mg cmol/kg^{-1}	-0.19	0.30	0.23	0.04	-0.05	-0.14	0.50	0.07	0.34	0.27
Exch. K cmol/kg^{-1}	0.10	0.40	0.79	-0.83	0.88	0.87	0.87	0.95*	0.63	0.92*
Exch. Na cmol/kg^{-1}	0.12	-0.13	0.27	-0.59	0.39	0.41	0.49	0.52	0.25	0.51
CEC cmol/kg^{-1}	0.01	0.20	0.65	-0.91*	0.82	0.84	0.75	0.90*	0.62	0.88*

Level of Significance: * < 0.05; ** < 0.01

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (Site B)

Soil Properties	Heavy Metals(ppm)									
	Available					Total				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	0.99**	0.81	0.58	-0.06	0.67	0.72	-0.46	0.89*	0.14	0.82
Silt %	-0.02	-0.00	0.35	0.23	0.12	-0.10	-0.10	0.24	-0.93*	0.22
Clay %	-0.84	-0.70	-0.68	-0.07	-0.64	-0.57	0.45	-0.89*	0.37	-0.82
pHH_2O 1:2.5	-0.15	-0.21	-0.79	-0.60	0.03	-0.36	0.34	-0.57	0.23	-0.08
OC g/kg^{-1}	0.46	0.76	0.78	0.65	0.83	0.72	0.29	0.43	-0.26	0.83
AvP mg/kg	-0.27	-0.10	-0.65	-0.26	0.17	-0.20	0.67	-0.71	0.32	-0.02
Exch. Cacmol/kg^{-1}	-0.76	-0.41	-0.57	0.13	-0.20	-0.35	0.83	-0.97**	0.27	-0.44
Exch. Mg cmol/kg^{-1}	-0.25	-0.36	0.13	0.12	-0.63	-0.17	-0.42	0.13	0.08	-0.56
Exch. K cmol/kg^{-1}	-0.63	-0.33	0.13	0.59	-0.44	-0.08	0.31	-0.37	0.18	-0.55
Exch. Na cmol/kg^{-1}	-0.64	-0.71	-0.96*	-0.53	-0.59	-0.71	0.26	-0.84	0.32	-0.72
CEC cmol/kg^{-1}	-0.66	-0.55	-0.87	-0.32	-0.34	-0.56	0.57	-0.94*	0.31	-0.53

Level of Significance: * < 0.05; ** < 0.01

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (Site C)

Soil Properties	Heavy Metals(ppm)									
	Available					Total				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	0.09	0.60	-0.11	-0.01	-0.25	0.04	-0.38	0.03	0.08	-0.13
Silt %	-0.07	-0.68	-0.00	0.01	0.12	-0.16	0.40	-0.16	-0.21	0.02
Clay %	-0.13	0.62	0.83	0.01	0.91*	0.88	-0.14	0.97**	0.95*	0.82
pHH_2O 1:2.5	0.66	-0.68	-0.89*	-0.84	-0.80	-0.75	-0.33	-0.69	-0.53	-0.66
OC g/kg^{-1}	-0.36	0.62	0.94*	0.19	0.97**	0.95*	-0.11	0.96**	0.95*	0.92*
AvP mg/kg	-0.60	0.70	0.95*	0.29	0.89*	1.00**	-0.29	0.87	0.94*	0.97**
Exch. Cacmol/kg^{-1}	-0.68	0.79	0.95*	0.54	0.86	0.95*	-0.12	0.83	0.82	0.88
Exch. Mg cmol/kg^{-1}	-0.71	0.60	0.93*	0.30	0.85	0.98**	-0.34	0.79	0.90*	0.98**
Exch. K cmol/kg^{-1}	-0.67	0.58	0.92*	0.78	0.86	0.78	0.31	0.72	0.57	0.73
Exch. Na cmol/kg^{-1}	-0.17	-0.57	-0.69	-0.12	-0.82	-0.64	-0.27	-0.90*	-0.71	-0.53
CEC cmol/kg^{-1}	-0.70	0.78	0.89*	0.78	0.77	0.81	0.13	0.71	0.60	0.71

Level of Significance: * < 0.05; ** < 0.01

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (Site D)

Soil Properties	Heavy Metals(ppm)									
	Available					Total				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	0.70	-0.14	-0.86	0.04	-0.75	-0.52	-0.94*	-0.02	-0.70	-0.24
Silt %	-0.69	0.14	0.86	-0.03	0.76	0.53	0.94*	0.03	0.70	0.26
Clay %	-0.74	0.13	0.84	-0.08	0.70	0.48	0.91*	-0.04	0.67	0.17
pHH_2O 1:2.5	0.69	-0.04	-0.66	0.30	-0.71	-0.43	-0.75	0.32	-0.24	0.14
OC g/kg^{-1}	-0.35	0.11	0.81	0.05	0.96*	0.68	0.98**	0.21	0.64	0.49
AvP mg/kg	-0.63	0.16	0.07	0.02	-0.62	-0.37	-0.20	-0.16	0.24	-0.35
Exch. Cacmol/kg^{-1}	-0.60	0.64	0.99**	0.50	0.70	0.89*	0.90*	0.50	0.66	0.58
Exch. Mg cmol/kg^{-1}	-0.11	-0.65	0.19	-0.69	0.70	-0.06	0.55	-0.49	0.26	-0.13
Exch. K cmol/kg^{-1}	0.61	0.12	0.12	0.36	0.60	0.57	0.29	0.55	0.03	0.69
Exch. Na cmol/kg^{-1}	0.71	-0.81	-0.52	-0.63	0.31	-0.33	-0.12	-0.39	-0.34	-0.13
CEC cmol/kg^{-19}	0.19	-0.36	0.35	-0.19	0.96*	0.32	0.70	0.11	0.51	0.48

Level of Significance: * < 0.05; ** < 0.01

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (Site E)

Soil Properties	Heavy Metals(ppm)									
	Available					***Total***				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	-0.92*	-0.80	-0.92*	-0.90*	-0.75	-0.88*	-0.07	-0.22	0.14	0.03
Silt %	0.92*	0.78	0.91*	0.90*	0.76	0.87	0.10	0.22	-0.13	-0.01
Clay %[1]	0.88	0.87	0.94*	0.88*	0.69	0.91*	-0.05	0.19	-0.17	-0.08
pHH_2O 1:2.5	-0.26	-0.06	-0.30	-0.54	0.00	-0.37	0.29	0.65	0.70	0.55
OC g/kg^{-1}	0.90*	0.95*	0.99**	0.94*	0.69	0.98**	-0.09	0.16	-0.15	-0.07
AvP mg/kg	-0.50	-0.46	-0.43	-0.26	-0.56	-0.34	-0.28	-0.63	-0.29	-0.28
Exch. Cacmol/kg^{-1}	0.50	0.20	0.20	0.07	0.79	0.05	0.89*	0.98**	0.86	0.90*
Exch. Mg cmol/kg^{-1}	0.39	0.64	0.68	0.72	0.00	0.77	-0.73	-0.55	-0.78	-0.75
Exch. K cmol/kg^{-1}	-0.38	-0.47	-0.60	-0.74	0.00	-0.69	0.62	0.68	0.82	0.73
Exch. Na cmol/kg^{-1}	-0.23	-0.00	-0.14	-0.32	-0.19	-0.16	-0.17	0.22	0.02	-0.11
CEC cmol/kg^{-1}	0.61	0.45	0.41	0.23	0.79	0.29	0.65	0.91*	0.67	0.69

Level of Significance: * < 0.05; ** < 0.01

Pearson's Product Moment Correlation (PPMC) Analysis for Soil Properties and Heavy Metals (Site F)

Soil Properties	Heavy Metals(ppm)									
	Available					***Total***				
	Zn	*Cu*	*Mn*	*Fe*	*Pb*	*Zn*	*Cu*	*Mn*	*Fe*	*Pb*
Sand %	-0.67	-0.67	-0.66	-0.77	-0.82	0.90*	-0.94*	-0.89*	-0.68	-0.73
Silt %	0.61	0.53	0.70	0.74	0.80	-0.81	0.97**	0.87	0.67	0.70
Clay %	0.30	0.71	-0.27	0.12	0.10	-0.44	-0.20	0.08	0.00	0.12
pHH_2O 1:2.5	0.38	0.29	-0.87	-0.60	-0.01	0.14	-0.61	-0.53	-0.26	0.24
OC g/kg^{-1}	0.18	0.28	0.95*	0.87	0.56	-0.61	0.89*	0.90*	0.69	0.28
AvP mg/kg	0.17	0.34	0.95*	0.91*	0.49	-0.73	0.94*	0.91*	0.56	0.27
Exch. Cacmol/kg^{-1}	-0.03	0.43	0.90*	0.94*	0.37	-0.60	0.58	0.87	0.68	-0.03
Exch. Mg cmol/kg^{-1}	0.41	0.08	0.61	0.46	0.65	-0.36	0.80	0.61	0.60	0.56
Exch. K cmol/kg^{-1}	-0.91*	-0.48	0.09	-0.05	-0.74	0.50	-0.51	-0.28	-0.32	-0.96*
Exch. Na cmol/kg^{-1}	-0.16	0.34	-0.33	-0.06	-0.25	0.03	-0.61	-0.18	-0.07	-0.36
CEC cmol/kg^{-1}	0.36	0.60	0.45	0.63	0.33	-0.88	0.71	0.63	0.10	0.37

Level of Significance: * < 0.05; ** < 0.01

4.6.2 Heavy metals and organic carbon and available P

All the examined heavy metals (available and total) reveal positive relationship with the soil organic carbon content. Similarly, nearly all the relationships are significant at the 0.05 level. Similar to the trend with the organic carbon, the soil heavy metals (available and total) show positive relationship with the soil available P, except available Zn. Unlike the trend with organic carbon, however, none of the relationship is statistically significant. When the data was split into the different locations, the result obtained over locations A, C and F are similar to the overall pattern. The results obtained over sites B, D and E are slightly different in that, the relationship between available P and the heavy metals are mostly negative.

The positive correlation between the soil heavy metals and organic carbon and available P, reflect greater adsorption of cations with increase in soil organic matter content.

4.6.3 Heavy metals and exchangeable cations

The exchangeable Ca shows a positive relationship with the heavy metals (available and total). However, only available Pb and total Fe show a statistically significant relationship with exchangeable Ca.

The soil available Zn and Pb (available and total), show negative correlation with the exchangeable Mg of the soil, while the rest of the heavy metals show positive correlation. However, the relationship shows statistical significance with respect to availableMn, available Fe and total Zn.

All the examined heavy metals (available and total) reveal positive relationship with the exchangeable K, with the exception of available Zn and total Pb. Unlike the trend with exchangeable Mg, only total Mn show a statistically significant relationship with the exchangeable K. When the data was split into the different locations, the results obtained show considerable variation, both in terms of the trend of relationship and the strength of relationshipof theheavy metals, with the exchangeable cations. However, the general picture is still that of positive correlations.

Similar to the trend with the exchangeable Mg, the soil heavy metals (available and total) show positive correlation with the exchangeable Na, with the exception of available Fe and total Zn. Unlike the relationship between heavy metals and exchangeable Mg and exchangeable K, there is no statistically significant relationship between the soil heavy metals and exchangeable Na.

Thus, the general trend of the soil heavy metals with the exchangeable cations, is one of an increase over all sites and this can be explained by the fact that all of them occur in organic or inorganic combination in soils (Brady and Weil,1999).

4.6.4 Heavy metals and pH and CEC

The soil Zn, Pb and Cu (available and total), show negative correlation with the soil pH while the Mn and Fe (available and total), show positive correlation. The correlation coefficient values are however, significant only for available Fe and Pb (available and total). The generally lack of significant relationship between most of the soil pH probably is as a result of generally acidic condition of the soils.

The heavy metal contents show positive correlation with the soil CEC. The only exception is the available Fe. The trend is significant for Cu and Pb (available and total) and for total Fe.When the data was broken down according to the different locations, the result obtained again, is quite similar to the overall picture. The only exception is over site B where the correlation coefficient values of the heavy metals and the CEC are mostly negative.

From the above analysis, it is clear that the hypothesis that there are no significant relationships between the physico-chemical properties and heavy metal content of soils studied cannot be rejected with respect to the soil particle size fraction, available P and pH, and the soil heavy metals. The hypothesis, however, is rejected with respect to the soil organic carbon and CEC, and most of the heavy metals.

4.7 Comparison of measured heavy metals with EU regulatory standard

Regulatory standard for phenomena such as heavy metal content in soils are region specific. Unfortunately, such standards are yet to be set for African countries, including Nigeria. A comparison of the measured value in this study seems to suggest that the level of heavy metals in soils of the study area is obviously not threatening yet. For all the examined heavy metals, none has a mean value near the EU regulatory standard (Table 5.1). Result of t-test shows a significantly lower level than the EU regulatory standard. Thus, the hypothesis that the level of heavy metal content in the soils studied are not significantly greater than the level specified by the EU Regulatory Agency cannot be rejected. As indicated earlier, however, such a conclusion must be taken with caution, given the differences in environmental conditions and environmental impact assessment regulatory standard.

4.8 DISCUSSION

4.8.1 Soil properties

The results of the soil properties determined in this investigation confirm the domineering influence of lithology, climate and anthropogenic factors in tropical soil formation. All soils studied are sandy, rarely heavier than a sandy clay loam. They are also generally low in organic matter, total nitrogen, and are acidic. The soil exchangeable cations are low to moderate. The generally sand texture and acid reaction of all soil groups can be explained in terms of the mineralogical composition of the soil parent materials. All soils are alluvial and have been formed from granitic lithology, which by definition,is made up predominantly of quartz minerals which upon decomposition give rise to sandy texture and acidic soils. Other factors that could contribute to the acidic condition of the soils are the poor quality water being used for irrigation in the area during the dry season. The condition could also be partly due to intensive leaching in the soil because of the sandy texture. The relatively low organic matter and nitrogen content of all soil groups is a reflection of intensive use of these soils and the rapid mineralization of humus under savanna climate.

4.8.2 Soil heavy metals

Even though contamination of soils by the examined heavy metals is a reality over the study area, the level of contamination is still generally low and is within permissible limit for urban agricultural soils. It is worthy of emphasising in respect of the DTPA-extractable heavy metals that there are no available international standards or documented critical limits in the literature. The documented standards till now are mostly based on the total contents of heavy metals, therefore, the evaluation of soil contamination with heavy metals in this study was based on the total content in the soil. A comparison of values obtained with result obtained in several countries indicated that, soils of the study area generally have low concentrations of most of the heavy metals studied. For example, levels of Pb concentration in soil ranging from 25.0 to 1198.0 µg/g have been reported on roadside soil in England, 0.00 to 50.10 µg/g in India, 78.4 to 832 µg/g in Tanzania 9.27 ± 0.23 to 45.92± 22.06 µg/g and 47-151 µg/g on major highway in Lagos, Nigeria (Akbar et al., 2006; Atayese et al., 2008; Luilo and Othman, 2006; Sharma and Prasade, 2010; Othman et al., 1997). Cu is usually present in soils within the range of 0 to 250 µg/g (Akbar et al., 2006). The observed level in this study is lower than 15.5-240.0 µg/g reported in roadside soil of England (Akbar et al., 2006). Normal concentrations of zinc in soil range from 1 to 900 µg/g (Akbar et al., 2006). The observed level in this study is lower than Zn 56.7- 480.0 µg/g, reported in roadside soil of England.

The building up of the heavy metals in the present study area reflects the pollution sources existing in the surrounding area. Heavy metals are ubiquitous in the environment, because of both natural and anthropogenic activities, and humans are exposed to them through various pathways (Wilson and Pyatt, 2007). Wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals. In the absence of any major industry in the sampling sites, the levels of several of the soil heavy metals in the present study area could be due primarily to nature of the parent materials, road traffic, fertilization, pesticide application and use of polluted water for irrigation.

Use of effluent polluted waters for irrigation is a widespread practice in the world and recently a number of articles have been published on wastewater-irrigated soils contaminated with heavy metals (Liu et al., 2005; Mapanda et al., 2005; Rattan et al., 2005; Rothenberg et al., 2007). In general, wastewater or effluent polluted waters contain substantial amounts of beneficial nutrients and toxic heavy metals, which are creating opportunities and problems for agricultural production, respectively (Chen et al., 2005; Singh et al., 2004). Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety (Muchuwetis et al., 2006).

Because of continued agricultural development, population growth and economic development in Abuja, the water demand is constantly increasing but natural water resources are limited. Therefore, to remedy this water lack, especially for irrigation, which is one of the biggest water users in the town, there is recourse to polluted water sources of streamsnearby, which can have variable physicochemical parameters (pH, salinity and organic matter content). However, the nutriments and dissolved compound, in different waters, can result in some environmental and agronomic problems, due to salinization and increasing levels of toxic substances as heavy metal pollutants in soil. The recreational parks surrounding agricultural zones in the city can be an important pollution source (Douay et al., 2007). In such areas, large quantities of solid and liquid waste that are regularly discharged into the surrounding cropping lands, improper waste disposal (among others, organic and heavy metal) in the city generally, can result in redistribution by wind onto agricultural surrounding areas.

Similarly, to improve agricultural production, many organic and inorganic compounds have been continuously used as a soil amendment (Moore et al., 1995). The widespread and repeated application and/or wind intake of chemicals can cause toxic element increase in soils (Calderon et al. 2003). Soil heavy metal content is not the only parameter for environmental risk estimation. The mobility, which usually depends on their chemical form, is an important factor for evaluating their distribution and toxicity degree, since complex forms are much less available than the free ions (Forstner, 1979). The chemical speciation is closely related to parameters as pH, which plays important role in the partition of an element between the dissolved and particle phase. The pH of water used for irrigation and the pH on soil-residual system are thus, often the most important chemical properties governing trace element sorption, precipitation, solubility and consequently, the bioaccumulation and availability of heavy metal pollutants (Kabala and Singh, 2001). The composition and salinity of different waters used for irrigation can play non-negligible role in the adsorption or fixing of the pollutants (Forstner, 1979). Different parameters of soil matrix, such as chemical composition, mineralogy, texture and organic matter yield, have an important bearing on the heavy metal bioactivity (Tam and Wong, 1999).

Long-term and excessive fertilization, especially in the case of P fertilization and organic manure use, can increase the risk for serious heavy metal pollution. Previous reports list the main sources of heavy metal pollution in agricultural soils as effluent of waste air, water, and residue from industry, auto exhaust, sewage irrigation, and the use of agrochemical materials. In this study, the selected farmlands were observed to not be specifically affected by residue from industry and sewage sources, as no sewage irrigation and industries were found within the surrounding of the studied sites. Since heavy metals can naturally occur within some P fertilizers, and relatively high contents of Cu, Zn, and other heavy metals occur in organic manures, continuous and combined use of these nutrient sources at high application rates are presumably, the major cause of accumulation of heavy metals in the soils studied. Application rates of fertilizers (e.g. N, P_2O_5, and K_2O) and manures in the area vary considerably with each cropping system and farmer, but were noted to be much higher in the selected open vegetable fields compared with grain crop fields.

Atmospheric emissions tend to be of great concern because of the quantity, wide spread dispersion potential and their invisible nature. Environmental pollution of heavy metals from road traffic emissions has attracted much attention in the recent past. Several studies have proved that heavy metals such as Pb, Cd, Cu, and Zn are released into the atmosphere during different operations of the road transport (Zhang et al., 2012; Akbar et al., 2006; Sharma and Prasade, 2010; Atayese et al., 2008). Studies on some heavy metals in scalp hair of traffic wardens in Benin City, Nigeria, for example, is reported to be due to emissions from motor vehicle exhausts and vehicle component wear, which they are exposed to (Eruyogho et al., 2007).

The use of leaded gasoline in cars is one of the major sources of Pb pollution in cities around the world (Luilo and Othman, 2006). According to Irami et al. (2009) road traffic is responsible for over a thousand tonnes of Pb each year, as a result of lead additives in petrol. Other sources of heavy metals to roadside environments are vehicle component wear, engine oil consumption and corrosion of batteries and other vehicle metallic parts. The average Pb and Cd contents of dry cell batteries imported into Nigeria between 1980 and 1998 were 1051 and 107.7 mg/kg^{-1} respectively (Nnorom and Osibanjo, 2006). Studies by Hjortenkrans (2003) gave brake linings and tyres as contributing more than 85% of the total Cu and Pb emissions while Zn contributes more than 85% of the emissions from tyres. Zhang et al. (2012) reported engine oil consumption as the largest emission for Cd, tyres wear for Zn, and brake wear for Cu and Pb. In furtherance bitumen and mineral filler materials in asphalt road surfaces have also been reported to contain different metal species, including Cu, Zn, Cd, and Pb.

There are reports, for example, on the use of Pb as an anti-knocking agent in gasoline which results in its release during emissions from fossil combustion (Oztas and Ata, 2002; Akbar et al., 2006; Onder et al., 2007; Sharma and Prasade, 2010). The Pb content of leaded gasoline in

Nigeria has been reported to be as high as between 0.60 to 0.80 g/l (Kakulu, 2003). In addition, wearing down of vehicle tyres can also introduce Pb to the roadside soil (Sharma and Prasade, 2010; Zhang et al., 2012). Its distribution is dependent on wind direction, the oxidation of parent material and sulphide ores, anthropogenic materials and deposition due to alkalinity of soil (El-Gamal, 2000; Oztas and Ata, 2002; Iorfa, et al., 2011). Break dust have been recognized as a carrier of Cu, which is used in brakes to control heat transport (Manno et al., 2006; Hjortenkrans, 2003; Zhang et al., 2012). Zn is used in brake linings, because of their heat conducting properties, and as such released during mechanical abrasion of vehicles, and from engine oil combustion and tyres of motor vehicle (El-Gamal, 2000; Hjortenkrans, 2003;Akbar et al., 2006;Manno et al., 2006).

The nature of the soil plays an important role in influencing soil heavy metal concentration. (Kalavrouziotis, etal., 2007). According to Haktanir (1983) and Redondo et al. (2009), the amount of organic matter, pH, $CaCO_3$ % and texture of soil, affects the heavy metal accumulation.Heavy metals tend to form complexes with organic matter in the soil (humic and fulvic acids), which are different for each metal. Organic matter and clay fractions, which form the soil colloidal complex, play an important role not only in forming complexes, but also in re-taining heavy metals in an exchangeable form (Ghimire, 1994). These two properties affect each heavy metal differently. For example, Cu is bound and rendered unavailable chiefly through the formation of complexes (Cheraghi et al., 2009), while Cd is retained in an exchangeable form and is more readily available (Singh et al., 2004).

Heavy metals in soil may be found in one or more forms: (a) dissolved (in soil solution), (b) exchangeable (in organic and inorganic components), (c) as structural components of the lattices of soil minerals, (d) as insoluble precipitates with other soil components (Brady and Weil, 1999).

The first two forms are available to the plants while the other two are potentially available in the longer term. In general, the concentration of an element in the soil solution is believed to depend on the equilibrium between the soil solution and solid phase, with pH playing the decisive role (Buchholz, 1998). The soil's ability to immobilize heavy metals increases with rising pH and peaks under mildly alkaline conditions. Heavy metal mobility is related to their immobilization in the solid phase. Fakayode(2005), in discussing the relatively high mobility of heavy metals with regard to pH, considered that in acid soils (pH 4.2-6.6) the elements Cd, Ni, and Zn are highly mobile, Cr is moderately mobile, and Cu and Pbare practically immobile, and in neutral to alkaline (pH 6.7-7.8), Cr is highly mobile, Cd and Zn are moderately mobile and Ni is immobile.

Apart from pH and organic matter, other soil properties, such as cation exchange capacity (CEC), quantity and type of clay minerals, the content of the oxides of iron (Fe), aluminum (Al), and manganese (Mn), and the redox potential, determine the soil's ability to retain and immobilize heavy metals. When this ability is exceeded, the quantities of heavy metals available to plants increase, resulting in the appearance of toxicity phenomena. The CEC of a soil depends upon its organic matter and clay content. In general, the higher the CEC, the greater the ability to retain heavy metals. The type and quantity of clay determines the CEC, which increases with clay content, particularly when it contains a high proportion of 2:1 lattice-type minerals (e.g., montmorillonite). The specific soil surface is also closely related to clay content and type. Campbell and Davidson (1983), reported that the soil's ability to retain heavy metals is more closely tied to the specific surface than to the soil CEC.

CHAPTER FIVE

SUMMARY AND CONCLUSION

5.1 Summary

The study examined the level of contamination by heavy metals in soils used for vegetable cropping in Abuja metropolitan area.

For the purpose of soil sampling, five plots under urban agriculture and an additional one not in use for any form of cropping were selected for the study. The size of the plots selected ranged between 0.8 and 1.2 ha^{-1}. All sites were located with GPS. Each plot was further sub-divided into 3m by 3m sub-quadrats of which 5 were randomly selected. In all, a total of 30 bulked samples were collected for laboratory analysis.

The soil samples were analysed in the laboratory using the standard procedure: texture by the pipette and sieving method; bulk density by the cylindrical core method; organic matter content by the Walkey-Black digestion method; exchangeable cations by the 1N ammonia acetate extraction; CEC by the ammonia acetate extraction; pH by pH meter. Total content of heavy metals in soil was analysed by digestion with hydrofluoric (HF), perchloric ($HClO_4$) and hydrochloric (HCl) acids (Jackson, 1979), after which the saturation extract was removed and the heavy metal concentrations in all extracts determined by atomic absorption spectrometry. The available forms of the heavy metals were extracted using diethylenetriaminepenta acetic acid (DTPA) at pH 7.3 according to Lindsay and Norvell (1969) and determined with atomic absorption spectrophotometer.

Three statistical methods were employed in the analysis of the quantitative soil data generated, namely, one-way analysis of variance (ANOVA), t-test and simple regression and correlation; to test for significant differences amongst the different sites, significant differences of soil properties between pair of plots, and to establish the extent of dependency of heavy metals on the measured physicochemical properties, respectively.

The results obtained show that the texture of the soils is generally sandy. All the sites show comparatively homogenous values for sand%. The silt% did not reveal any significant differences amongst the different sites, while the clay shows statistical significantdifferences amongst the sites. The sandy nature of the soils was thought to be due mainly to the coarse textured nature of the parent rock over which the soil was formed and possibly, the elluviation of finer particles from the top horizon and illuviation in the lower horizon.

The organic matter content of the soils is generally low and characterized by relatively low values of CV%, a reflection presumably, of intensive anthropogenic influence. Because available P tends to occur mainly in organic combination, the value too is generally low over the study area.

The exchangeable cations depict relatively low values throughout all the sites. Most, however, showed significant differences amongst the different sites, and so the difference between pairs of sites. The values of the pH also showed significant differences amongst the different sites, so is the CEC.

With respect to the heavy metals, nearly all showed significantly different amount amongst the different sites by analysis of variance. The t-test also showed varying degree of statistical significance between pair of sites. Most of the metals also showed negative correlation with the sand %, and positive with the silt %, clay %, organic matter %, available P, and the cation exchange capacity. Most of the relationships, however, are insignificant, statistically. There is also considerable variation, both in terms of the trend of relationship and the strength of relationship,of theheavy metals with the respective exchangeable cations. However, the general trend is that of positive correlations, with many of the relationships showing no statistical significance. A comparison of the measured value in this study seems to suggest that the level of heavy metals in soils of the study area is obviously not threatening yet. Result of t-test shows a significantly lower level than the EU regulatory standard.

5.2 Conclusion

The following are the major conclusions of the study:

i. Of all the metals analyzed, the best represented are iron, and manganese. The least are lead and copper.
ii. The total heavy metal contents of the investigated soils were generally lower than the comparative levels reported in the literature for similar soils.
iii. The exchangeable forms of these metals were relatively low, indicating that under the present conditions, the availability of these metals to plants would be minimal.
iv. The major factors for the soil heavy metal accumulation in the study area are probably the chemical agricultural products utilized, the irrigation water used and road traffic in the area.
v. The heavy metals of Cu, Fe, Mn, Zn, andPb in the soils studied are still under the permissible threshold. By comparison to the European Union Regulatory Agency the heavy metal content of the soils are still below the limits of toxicity.

5.3 Recommendation

In general it is very difficult to eliminate heavy metals from the environment because they do not degrade like carbon-based (organic) molecules, mercury and selenium, which can be transformed and volatilized by microorganisms. Once they are introduced and they contaminate the environment, they will remain. While some treatments are available for metal contamination in soils, such as high temperature treatments (produce a vitrified, granular, non-leachable material), use of solidifying agents (produce cement-like material) and washing process (leaches out contaminants), they are extremely expensive and cost prohibitive when large areas of soils are involved (Brady and Weil, 1999). Best management practices for soils with elevated levels of heavy metals aim not at removing the heavy metal contaminants, but immobilizing them in the soil and reducing the potential for adverse effects from the metals (Baker and Brooks, 1989, McGrath, 1998). Brady and Weil (1999) have summarized these methods thus:

a) Increasing the soil pH to 6.5 or higher: Cationic metals are more soluble at lower pH levels, so increasing the pH makes them less available to plants and therefore less likely to be incorporated in their tissues and ingested by humans.
b) Draining wet soils: Drainage improves soil aeration and will allow metals to oxidize and thus make them less soluble, and therefore less available for plant uptake.
c) Applying phosphate: Heavy phosphate applications reduce the availability of cationic metals, but have the opposite effect on anionic compounds like arsenic.
d) Carefully selecting plants for use on metal-contaminated soils: Plants translocate larger quantities of metals to their leaves than to their fruits or seeds. The greatest risk of food chain contamination is in leafy vegetables like lettuce or spinach. Phytoremediation is a general term for using plants to remove, degrade, or contain soil pollutants such as heavy metals, pesticides, solvents, crude oil, polyaromatic hydrocarbons, and landfill.
e) leacheates.

It is recommended that urban farmers in the Abuja city should be encouraged to use organic manure, which may equally help to improve the water holding capacity of the soils, increase pH level, thereby reducing the solubility and availability of the heavy metals to crops. The farmers should also avoid direct use of the contaminated water for irrigation or use of sludge as manure Finally, more research is recommended for the study area, more so because this study considered only the surface soil and is limited to mere six locations within the city.

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Appendix 1: Result of laboratory analysis of the soil properties

S/No.	Sites	Sand	Silt	Clay	Textural Class USDA	pH H_2O (1:2:5)	Org. Carbon (g/kg^{-1})	Avail. P (mg/kg)	Ca	Mg	K	Na	CEC
		←---- (%) ----→							←---------- (g/kg^{-1})------------→				

1.	A I	560	180	260	SCL	6.30	10.60	476.20	5.20	1.20	0.30	0.46	9.20
2.	A II	540	200	260	SCL	6.50	10.80	833.35	5.00	0.90	0.19	0.30	8.00
3.	A III	540	160	300	SCL	6.30	9.20	595.25	5.40	0.60	0.21	0.37	8.70
4.	A IV	700	100	200	SCL	6.30	4.80	238.10	3.60	0.90	0.02	0.31	6.80
5	A V	542	228	230	SCL	6.30	10.08	458.09	5.10	0.80	0.20	0.38	8.20
6.	B I	560	160	280	SL	6.20	8.60	238.10	3.60	0.80	0.22	0.25	6.20
7.	B II	700	160	140	SC	6.30	8.20	238.10	2.40	0.70	0.08	0.23	5.60
8.	B III	520	120	360	SCL	6.30	4.80	238.10	3.40	0.90	0.19	0.39	7.00
9.	B IV	520	140	340	LS	6.50	7.00	357.15	4.40	0.60	0.12	0.41	8.10
10.	B V	530	245	225	SC	6.30	8.08	250.33	3.30	0.70	0.13	0.28	6.40
11.	C I	840	100	60	LS	6.30	3.80	238.10	2.60	0.70	0.01	0.30	5.30
12.	C II	820	100	80	LS	6.30	5.20	119.05	2.40	0.55	0.01	0.15	5.10
13.	C III	840	100	60	LS	6.10	4.00	119.05	3.00	0.60	0.06	0.23	6.20
14.	C IV	780	120	100	SL	6.00	8.60	1785.75	4.40	1.20	0.10	0.12	6.90
15.	C V	550	380	070	LS	6.20	5.10	124.66	2.50	0.65	0.05	0.20	5.40
16.	D I	260	540	200	SL	6.40	13.60	238.10	4.20	1.30	0.21	0.52	7.50
17.	D II	600	260	140	SL	6.70	8.80	119.05	4.00	1.05	0.28	0.36	6.80
18.	D III	520	320	160	SL	6.60	6.40	1785.75	3.80	1.08	0.07	0.15	6.10
19.	D IV	740	140	120	SL	6.70	5.40	238.10	3.20	1.17	0.19	0.70	6.70
20	D V	568	282	150	SL	6.50	8.00	200.05	3.90	1.10	0.20	0.38	6.30
21.	E I	740	160	100	SL	6.80	5.60	119.05	5.20	0.80	0.30	0.33	8.00
22.	E II	840	80	80	LS	6.70	4.00	1785.75	2.80	1.10	0.19	0.21	5.30
23.	E III	780	120	100	SL	6.80	5.40	119.05	3.40	1.20	0.24	0.50	6.80
24.	E IV	560	300	140	SL	6.70	9.90	119.05	3.80	1.50	0.13	0.30	7.20
25.	E V	680	210	110	SL	6.70	5.70	120.04	3.90	1.15	0.20	0.38	6.90
26.	F I	600	200	200	SCL	6.10	13.20	714.30	4.40	1.10	0.12	0.37	7.20
27.	F II	600	200	200	SCL	6.30	9.40	476.20	3.40	1.20	0.08	0.23	6.90
28.	F III	720	80	200	SCL	6.30	5.00	238.10	3.20	0.55	0.13	0.51	6.20
29.	F IV	640	140	220	SCL	6.40	6.80	375.15	3.80	0.50	0.11	0.78	7.10
30	F V	625	165	210	SCL	6.30	7.50	486.08	3.40	0.70	0.10	0.40	7.70

Appendix 2: Result of laboratory analysis of the heavy metals

S/No.	Sites	Available Heavy Metals					Total Heavy M		
		Zn	Cu	Mn	Fe	Pb	Zn	Cu	Mn
		←---------------------------- ppm ------------------------→					←------------------------------- ppm --		
1	A I	5.42	1.71	91.76	23.31	2.72	48.00	21.50	1033.00
2	A II	8.46	2.69	99.45	26.33	3.02	50.00	19.75	971.50
3	A III	4.07	1.02	80.97	22.26	2.76	51.50	10.75	945.25
4	A IV	4.43	0.96	62.70	30.96	0.20	21.50	3.25	254.50
5	A V	66.10	1.85	89.20	28.09	2.60	48.10	14.50	879.56
6	B I	12.71	1.71	110.03	62.64	1.76	73.00	6.25	1009.25
7	B II	45.27	1.80	95.61	23.07	2.10	72.75	3.00	1156.25
8	B III	4.40	1.40	46.85	17.16	0.30	46.75	3.25	977.50
9	B IV	8.72	1.58	38.42	23.51	1.61	56.50	6.75	888.00
10	B V	7.96	1.50	77.06	32.37	1.11	49.98	4.09	1018.62
11	C I	6.24	0.42	31.07	34.70	0.01	15.25	1.50	290.00
12	C II	11.67	0.54	44.18	28.59	0.14	13.50	2.35	612.25
13	C III	7.01	0.59	70.31	85.96	0.12	5.00	3.00	447.25
14	C IV	4.67	0.71	196.32	67.35	0.48	252.50	2.10	979.75
15	C V	7.22	0.32	74.85	53.22	0.21	16.21	2.78	449.90
16	D I	6.90	1.47	280.11	50.76	0.26	100.50	32.50	1328.00
17	D II	11.27	2.12	226.22	144.59	0.20	114.25	18.00	2952.75
18	D III	5.24	1.86	209.12	83.66	0.14	56.00	12.00	1388.50
19	D IV	13.08	1.01	66.62	26.69	0.16	23.25	2.70	785.00
20	D V	7.73	1.97	201.44	77.09	0,15	100.45	14.08	1220.72
21	E I	5.96	1.86	107.15	112.25	0.10	44.50	4.50	1216.50
22	E II	4.94	1.43	78.54	109.44	0.08	17.75	3.10	409.50
23	E III	4.91	1.85	91.40	97.68	0.08	41.01	2.80	683.25
24	E IV	6.86	2.84	197.70	185.31	0.10	314.00	3.15	713.50
25	E V	5.65	1.48	100.21	122.10	0.09	48.53	3.64	684.03
26	F I	9.44	2.57	259.37	121.85	3.29	61.00	43.75	2124.25
27	F II	14.96	2.76	137.69	67.07	4.20	95.75	36.25	1429.75
28	F III	7.29	1.26	95.28	32.81	1.77	247.00	4.75	343.50
29	F IV	12.72	3.65	126.56	84.00	3.47	63.25	18.50	1459.00
30	F V	10.82	2.55	145.45	74.00	2.57	68.43	33.80	1222.08

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