IMPACT OF CHARCOAL PRODUCTION ON SOIL PROPERTIES AND VEGETATION IN THE CENTRAL GONJA DISTRICT OF THE NORTHERN REGION, GHANA

BY

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DECLARATION

This thesis is the result of research work undertaken by Salifu Wahabu in the Environmental Science Programme, University of Ghana, under the supervision of Prof. Frank K. Nyame and Dr. Benedicta Y. Fosu-Mensah. It has never been submitted in whole or in part for any degree in this University or elsewhere. References to other people's work have been duly acknowledged.

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DEDICATION

I dedicate this work to the memory of my late father, Salifu Azindow.

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ABSTRACT

This study assessed the impact of charcoal production on soil properties, vegetation and the perception of charcoal producers on the environmental impacts of their activities in the Central Gonja District of the Northern Region, Ghana. Data acquired suggest significant differences in the proportions (or fractions) of clay and sand in soils sampled within 0-30 cm depth at sites of charcoal production referred to simply (as burnt sites) and sites with no observable indications of charcoal production (or unburnt sites). Soil silt fractions from 0-30 cm and 30-60 cm depths were, however, quite similar at both burnt and unburnt sites. The hydraulic conductivity of soils from 0-30 cm and 30-60 cm depths at burnt and unburnt sites also exhibited distinct differences ($P < 0.001$) and ($P < 0.029$) respectively. Soil chemical properties such as potassium ($P < 0.002$) and magnesium ($P < 0.011$) showed significant difference at 0-30 cm between burnt and unburnt. There was, however, no significant difference between burnt and unburnt sites within the 30-60 cm for same soil chemical properties, potassium ($P < 0.274$) and magnesium ($P < 0.076$). In terms of land use and (land) cover change in the Central Gonja District, analysis and interpretation of Remote Sensing and GIS data from Landsat TM images of 1990, 2000 and 2010 suggest reduction in the pristine or original guinea savannah (woody) vegetation of the area from 22,662 to 11,739 ha over the twenty-year period from 1990 to 2010, with grass/herbaceous and built-up areas increased from 23,088 to 95,148 ha and 6,355 to 81,702 ha, respectively. Even though charcoal production and marketing/trade are important economic activities for people in the district, providing income to the charcoal producers especially women, it appears to have had several environmental challenges in terms of deforestation, impact on soil parameters especially at burnt sites, bushfires and soil erosion.

Keywords: Charcoal production; environment; land degradation; soil properties.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
BSU	Built Up Areas
CBD	Convention on Biological Diversity
CLHEE	Candlelight for Health, Education and Environment
CSW	Closed Savannah Woodland/Dense Cover
CGDA	Central Gonja District Assembly
DHG	Dense Herbaceous Grass
ELC	Environmental Literacy Council
EC	Energy Commission
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organisation
FGD	Focus Group Discussion
GEMP	Ghana Environmental Management Project
GHC	Grass Herbaceous Cover
GIS	Geographical Information System
GPS	Global Position System
IPCC	Intergovernmental Panel on Climate Change
IWASH	Integrated Water, Sanitation and Health
LPG	Liquefied Petroleum Gas
NS	Not Significant
OSW	Open Savannah Woodland
RWA	Resource Watch Agency

SPSS	Statistical Package for Social Sciences
S.D	Standard Deviation
SD	Significantly Different
SWALIM	Somalia Water and Land Information Management
TM	Thematic Mapper
UN	United Nations
UNNICEF	United Nation International Children and Education Fund
UNU-LRT	United Nations University-Land Restoration Training
WB	World Bank
WBO	Water Body

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The environment, which is considered generally as a free gift of nature, has undergone serious transformation in the hands of man. This to a large extent is due to man's efforts to satisfy himself which leads to environmental degradation such as deforestation. The exploitation of the environment through farming, fishing, mining, lumbering, fuelwood, as well as charcoal production have socio-economic, environmental and policy implications to countries, especially when they are not well regulated (Nyame and Danso, 2006). These activities exert both short and long term impacts on the environment Mason (2009). Land degradation is one single mark of man's existence on earth since time immemorial, from simple tilling of the land with hoes and cutlasses, and hunting with bow and arrows to the present day sophisticated methods of exploiting the environment through ploughing, gaming, manufacturing, fishing, lumbering, and mining). Based on this, the human population has transformed the environment at different levels and at different places depending on available technology and policies (Kammen and Lew, 2005; Nyame and Blocher, 2010).

One area that has seen a dramatic transformation across the world as a result of human activities is the world vegetation, from its natural state to transitional zones and in many cases totally transformed. Areas which were in the past seriously forested have been converted into dry or desert lands and desert conditions keep on crippling into savannah areas and other vegetation zones. It is estimated that about 25% of the world's forest harvested for fuel is converted into charcoal for domestic and industrial purposes (FAO, 1987). The role of charcoal as a reliable energy source for the operation of industries such as metal smelting, chemical processing and other local craft industries in the developing countries besides being the major source of energy for domestic heating and cooking is huge (Msuya et al., 2011; Agyemah et al. 2012).

With high population growth in African countries including Ghana since independence, it is said that the energy requirement of these countries has doubled and in some cases tripled without the corresponding increase in alternative energy supply from the pre-independence fuelwood and charcoal use (Ikurekong et al., 2009; Kammen and Lew, 2005). As a result, the traditional energy source (fuelwood and charcoal) remains the most used (Malimbwi et al., 2004; World Bank, 1992). Besides being the most widely used energy source, charcoal production in most parts of Africa provides the desired income for households especially during the lean season when farming turns to provide little or no income for the support of families (Agyemah et al., 2012; Anang et al., 2011). Charcoal production continues to gain ground among the rural population because of the readily market from within and outside the local areas (Anang et al., 2011).

The use of charcoal as a source of energy by majority of people in Africa both in the rural and urban areas and elsewhere in the developing world has been attributed to its low cost, availability and the common knowledge of its use in most households compared to other energy sources like fossil fuel and Liquefied Petroleum Gas (LPG) (Mbilinyi et al., 2007). Although, there is an on-going effort to correct the deficiencies of the oldest method of charcoal production (i.e. carbonization) through modern kiln systems, practically the earth mound (kiln) remains the most popular method. Its common knowledge of production and use further makes it irresistible to most charcoal producers despite the associated environmental problems, such as incidence of bushfires, pollution, habitat destruction, and the poor conversion rate in most parts of the world (FAO, 1987).

There is evidence to the effect that high temperatures through charcoal burning have had noticeable effects on soil characteristics and mineralogy especially at the kiln site (Kettering et al., 2000 as cited in Oguntunde et al., 2004). Msuya et al. (2011) identified forest depletion and air pollution as some of the obvious environmental impacts of charcoal production. Msuya et al. (2011) estimated the combined effects of charcoal production and use at about 49,700,000, 9,830,000, 1,109,000 and 12,478,000 tons of carbon dioxide, Nitrogen oxide, Sulphur dioxide and Methane respectively in Tanzania. The impact of this on human health and the environment could be far reaching, including its contribution to the depletion of the ozone layer which many scientists have attributed to the global increase in diseases like catarrhs, skin cancers and the unpredictable weather patterns.

Msuya et al. (2011) categorized energy types largely used by households in Tanzania into traditional, intermediate and modern, out of which charcoal is most preferred in both rural and urban areas because of its relatively cheap cost. On the other hand, charcoal production has been identified as the cause of an estimated annual loss of 109,500 ha of forest in Tanzania. This loss in forest cover has a long term effect on soil fertility, water resources as well as wildlife habitat (Msuya et al., 2011).

In Somalia, commercial production of charcoal around the plateau areas where Acacia tress grows naturally resulted in the depletion of the Acacia woodland. This led to the country's parliament to pass a legislation against the exploitation of the Acacia trees for charcoal production and the commercial export of charcoal between 1969 and 1991 before the collapsed of central government following the country's civil war (FAO-CLHEE, 2006) . During this period, commercial production of charcoal resumed in Somalia defeating the objective of the legislation and further compounding the land degradation situation in the country (FAO-CLHEE, 2006).

From a high forest cover of about 8.2 million ha in 1900, Ghana's high forest is estimated at about 1.8 million hectares in the early part of (2000) and out of this only about 40,000 ha is outside the country's reserves (Mason, 2009). According to Mason (2009), the current deforestation rate of 2% is far beyond the global rate of 0.2% and also higher than Africa's average rate of 0.8% estimated between 1990 and 2000. Apart from the deforestation of the country's high forest, the savannah zones of the country are also under the threat of desertification (EPA-Ghana, 2012). According to Fosu-Mensah et al. (2012), farmer's observation of impact of environmental changes such as climate change on crop yield is very high although adaptation is still a big challenge among them.

The drivers of deforestation and desertification include activities of charcoal producers (Agyeman et al., 2012; Mason, 2009; Anang et al., 2004). In Ghana, it is estimated that about 71% of the country's energy supply comes from fuelwood and charcoal, and over 90% of household energy across the country use fuelwood and charcoal (Mason, 2009; Anang et al., 2011). Suddenly, there are incidences of charcoal producers encroaching into the few reserves dotted across the country as wood for charcoal production becomes scarce (Mason, 2009). The use of grasses and other forms of biomass as fuel when setting fire in kilns has exacerbated the depletion of the land cover (Anang, et al., 2011). Given the increasing level of charcoal production in Ghana, it's imperative to understand how it affects environmental resources especially soil, a resource upon which other elements of the environment are based.

1.2 Statement of the research problem

A significant number of Sub-Saharan African countries are bedevilled with environmental degradation such as desertification, deforestation and decreasing soil fertility. The causes of this land degradation, among others, include charcoal production. The impact of charcoal production on soil properties is critical since soil elements such as nitrogen and phosphorus have profound impact on maize yield (Fosu-Mensah, 2012). The results of low soil productivity due to these activities include widespread malnutrition especially among rural dwellers. Commercial charcoal burning is one of the major and emerging environmental problems in the Northern Region in particular and Ghana at large. The activity is predominantly practised in the savannah woodlands to meet the demands of rural folks and city dwellers who entirely depend on charcoal as a source of energy for cooking and other domestic needs.

In recent times, there is a growing belief that large scale charcoal production in the Northern Region is contributing to desertification which, to a large extent, impacts negatively on the vegetation cover and soil fertility of the area (Anang, et al., 2011). In 2005, Gonja traditional rulers under the leadership of the Yegbun-wura (the overlord of the Gonja traditional area) came out with a bye-law which prevented large scale production of charcoal in the traditional area including Central Gonja District. Despite the good intentions of the traditional rulers, trade in charcoal only stopped for a while and started again under their watch.

The failure of the District Assemblies, local systems and institutions in the Northern Region of Ghana to address the charcoal production problem could be attributed to a number of reasons such as lack of reliable information about the effects of charcoal production on soil characteristics and vegetation cover, the socio-economic benefits to households as well as the perceptions of local communities of the impacts of charcoal production. Studies of charcoal production have been conducted in the Upper West Region by Agyemah et al. (2012) and the southern sector by Oguntunde et al. (2008). Anang et al. (2012) studied the economic impacts of charcoal production, suggesting that the environmental impacts are still not clearly understood.

In addition, most of the studies conducted on charcoal production did not involve remote sensing. According to Lillesand et al. (2007), remote sensing as a tool is useful for environmental management, because of its large area coverage and its ability to capture huge information on single or multiple platforms for easy comparison and analysis. In view of the potential socio-economic and environmental impacts posed by commercial charcoal production, and the fact that there is limited reliable information about its impacts on soil characteristics and vegetation cover in the Northern Region of Ghana in general and the study area in particular, this study was conducted to provide requisite data as well as bridge the knowledge gap.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study was to assess the impact of charcoal production on soil properties and vegetation cover in the Central Gonja District.

1.3.2 Specific objectives

The specific objectives of this study were;

1. To determine the impact of charcoal production on soil properties in the Central Gonja District.
2. To assess land use and land cover change in the Central Gonja District from 1990 to 2010 using satellite imagery.
3. To assess charcoal producers' perception about the effects of charcoal production on both soil properties and vegetation in the Central Gonja District.

1.3.3 Hypotheses

This study was based on the following hypotheses:

H_1: Charcoal production has no significant impact on soil properties especially around the kiln site where burning takes place.

H_1: The land use of the study area has not resulted in significant land cover change of the vegetation of the area.

H_1: Although, most people are into charcoal production as source of their livelihood, they do not perceive it as having a negative impact on the environment.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter covers the relevant literature available in the area both published and unpublished which is reviewed based on the relevant sections such as method of charcoal production, environmental impacts of charcoal production (impact on air, soil and vegetation). It also covers, land use and cover change as well as the use of remote sensing and Geographical Information System (GIS) for change detection. While available literature on charcoal production cuts across a wide range of issues, this review will primarily focus on the environmental impact of charcoal production with special interest on its impact on soil properties and vegetation.

2.2 Theoretical framework

Like many other problems confronting human society today, the problem of environmental degradation has been explained in many theoretical works. From the days of Harman Daly, who condemned the unsustainable use of natural resources motivated by the traditional economic notion that natural resources are infinite Environmental Literacy Council (2007), various concepts have been developed some in opposing direction to explain what is likely to happen to our common heritage (the environment) if measures are not taken to protect it.

One person who has painted an infamous picture of how the individual in society can work in his/her self-interest to the detriment of the larger society by degrading the environment was Garret Hardin. In his famous concept of “The Tragedy of the Commons”, Hardin explained that the use of the “Commons” unlike lands belonging to the individuals in the society, is opened to unsustainable use due to human greed. More theories have been put forward to explain how individual greed and endless desire expressed in the way natural resources are exploited can bring misery to the larger society through environmental degradation (Environmental Literacy Council, 2007).

Hardin's "Tragedy of the Commons" has worn hearts especially when it comes to explaining how unregulated use of the world natural resources such as exploitation of natural wood for charcoal production have caused various forms of land degradation be it Europe, Asia, America or Africa, both in the past and present. He noted that, human beings by their nature would want to maximize their selfish interest by using more and more from the "commons" even though the impact of these actions would at long last haunt the larger society.

The tragedy of the commons in simple terms is saying that the environment would be degraded if laws are not made to regulate its use. Using common grazing pasture lands to illustrate his point, Garret Hardin said that the individuals acting on their own self-interest, will want to add to their stock, more animals and graze more which otherwise would have been avoided by this same individuals if they were grazing on their private pasture land. This in the long run will lead to the ultimate depletion of the shared limited resource, even though individuals know the obvious outcome of their greed and understand that it is not in anyone's long-term interest for this to happen.

In modern Ghanaian society, the attitude of charcoal producers in the rural areas who harvest wood for their trade leading to the depletion of the natural forest and woodlands can be explained in the context of Hardin's concept of "The tragedy of the common". The charcoal producer motivated by his/her individual greed continuous to cut down trees to burn charcoal degrading the soils and vegetation, knowing very well that their actions are detrimental to the lager society.

This theory provides bases for environmental regulation to protect the world most used but less protected commodity (vegetation) especially in Africa. Despite numerous conventions and treaties Africa countries, like Ghana, have signed into pledging to protect their environment from degradation, there is still a high rate of degradation going on in these countries.

2.3 Importance of charcoal

The importance of charcoal greatly lies in the numerous uses or application of charcoal since time immemorial, such as its application in gunpowder production, tool for artistic, treatment of diseases, medium of absorption and purification of liquid substances, domestic and industrial energy source among others. As one of the oldest means of energy, the importance of charcoal spans from its application from domestic to industrial use, especially in the developing World. In Ghana like most parts of Africa, charcoal is used as a means of providing energy needs for both rural and urban population (Anang et al., 2011 and Msuya et al., 2011). According to the Energy Commission (2010) charcoal and fuelwood constitute over 60% households energy supply in Ghana.

FAO (2000) measured the importance of charcoal in terms of households use in the urban Sub Saharan Africa by putting it at 54 to 71% and estimated that over 1 million families in Sub Saharan Africa use charcoal as their main source of energy in the urban area alone. Many writers have also tried to put market value on charcoal production considering the number of people engaged in the trade as a means of income for rural population that produce charcoal for sale. In 2000, the market price of charcoal produced in Sub Saharan Africa was estimated at US $60 million which FAO intimated that if the figures were translated into daily wages of US$1.50, that 80% of it would have created about 144,000 permanent employment earning more than twice the estimated average daily earnings of the region at the time (FAO, 2000).

While there is no much information on how much local and central government gets from collecting taxes from the charcoal trade in Ghana, Hibajene and Kalumiana (2003) listed four different types of tax levies (stumpage, conveyance, council and market fees) as taxes collected on charcoal in Zambia which forms a good tax component to the government.

Charcoal is a key energy source for many households in the developing world. In Ghana for example, it fuels small-scale industries (FAO, 1987 and Hibajene and Kalumiana, 2003). According to Ghana Energy Commission (2010) over 600,000 light to medium scale industries such as blacksmithing, and chop bars are been fuelled by charcoal.

2.4 Method of charcoal production

Charcoal is the general term for a range of carbonized materials, with varying combustion and dark properties (Amanor et al., 2002, cited in Stephen, 2011). The production of charcoal involves a skilful control of heat in a process called pyrolysis which leads to chemical breakdown. The product of this process, is a porous black substance of the burnt wood or material which weighs just about a fifth of the wood it is made from and has the ability to generate heat much more efficient when used compared to the material it's made from (Hibajene and Kalumiana, 2003; Kamemen and Lew, 2005; Stephen, 2011).

Methods of charcoal production vary from Mobile Kiln commonly used in advanced world such as Great Britain to the use of traditional earth clamp in most parts of Africa including Ghana (FAO, 1987; World Bank, 1992; Anang et al., 2011). One common practice in all these cases however, is the effort at regulating air circulation in the process leading to controlled combustion and eventually resulting into carbonation as charcoal is produced (Hibajene and Kalumiana, 2003).

According to Food and Agriculture Organisation-Somalia Water and Land Information Management FAO-SWALIM (2009) charcoal production in Africa is largely practiced using traditional methods with the pit and the earth clamp being the most widely practiced. The process involves felling of trees and cutting of the wood into stacks which are loaded into a pit or on the ground (the earth-mound kiln) and covered with materials before being ignited with fire starting the process of controlled combustion (Hibajene and Kalumiana, 2003). Hibajene and Kalumiana (2003) established that charcoal production as practised in developing countries involve steps such as; gathering of wood and chopping of the wood into manageable pieces, packing/arranging the pieces of wood into prepared kiln, putting materials such as soil on the kiln to regulate air circulation, setting fire to the buried wood to start burning, managing kiln leading to charcoal production and finally, taking out the carbonated wood for sale.

Charcoal burning as well as management of kiln benefits immensely from the expertise of the producer, access to the raw material and to a larger extent the number of people or workers that the producer has (Boutette and Karch, 1984, as cited by Hibajene and Kalumiana, 2003). Sustainable charcoal production requires that expertise of the charcoal producer is brought to bear on the management of his/her source of raw materials such as the forest. According to Hibajene and Kalumiana (2003), from the very point of felling a tree for charcoal production, charcoal producers ensures that the trees are cut in a manner to sustain the forest.

Materials for charcoal production are carefully selected to maximize yield. Apart from trees exempted from charcoal production for economic or religious beliefs the size and hardiness of a tress also influence the selection process (Pagama, 1993 as cited by Hibajene and Kalumiana, 2003). In an extensive work on charcoal production in Zambia, Hibajene and Kalumiana, 2003, explained that knowledge of kiln management such as selection of materials for kiln construction is very critical. They concluded that soil used in building a wall around the charcoal kiln needs to be carefully selected so as to avoid cracks on the walls as the soil is exposed to heat. The assertion is further buttressed by FAO (1987) when it made the point that because vertisols contracts and develop fissures when exposed to heat, it should not be used as soil lump to construct kiln walls. Wood carbonation is a critical part of charcoal production. Efficient management of the carbonization process in charcoal production not only ensures quality charcoal been produced but it also leads to high yield per kiln site.

2.5 Environmental impact of charcoal production

Charcoal production is believed to have a significant impact on all natural resources used in the process especially the local vegetation and soil. In addition, burning of charcoal impacts on the surrounding air due to excessive smoke that emanates from the controlled carbonization (Chidumayo, 2011). The use of fire to generate the desired heat in kilns, and the clearing of forest and woodland resources also contribute to land degradation. These practices seem to generate concerns about the impact of charcoal production in almost all the countries where commercial charcoal production takes place (Oguntunde et al., 2008; Hofstad et al., 2009).

Tree felling forms the basis for charcoal production, although it varies from country to country and even sites within each country depending on the method used. The method used depends on how complex charcoal production has taken root, as different working tools or machines such as cutlasses, axes and in some cases chainsaws are used. Depending on the tools or machines used, tree cutting has left dramatic impact on vegetation and soil in communities where charcoal production has taken place (Anang et al., 2011; Chimayo, 2011; Msuya et al., 2011). In most cases, charcoal production results into land cover change. One area where charcoal production has triggered concerns largely has to do with its impact on vegetative cover which has a direct relation to loss of subsoil nutrients, siltation of surface water bodies, flooding, and water shortages due to its impact on hydrology, it also causes depletion of biological diversity such as reduced fauna and fora richness (Oguntunde et al., 2008).

2.5.1 Impact on air quality

The processes involved in charcoal production leads to emission of gases into the atmosphere which contributes to air pollution (Baillis 2009; Gomes and Encarnacao, 2012; Msuya et al., 2011). Thus, apart from being one of the causes of land cover change in many communities where it is practised, commercial charcoal production is a major contributor to air pollution through emission of gases.

According to Kammen and Lew (2005), emission of greenhouse gases into the atmosphere across the world’s tropical ecosystems where charcoal production is prevalent is a major source of greenhouse gas from most developing countries where industrialisation other sources of greenhouse gas emissions are minimal or non-existent compared to the developed world. Chidumayo and Gumbo (2013) noted that because of the nature of charcoal production in developing countries, emission of greenhouse gas from charcoal burning due to mismanagement makes charcoal production a major greenhouse gas source compared to bushfire. Table 1 shows the emission rates of greenhouse gas across the world.

Table 1: Greenhouse gas emissions from charcoal production in tropical ecosystems of the world

Region	**Estimated charcoal production in 2009 (million tons)**	**Greenhouse gas emissions (million tons)**			
		Carbon dioxide	**Methane**	**Methane (CO_2 equivalent)**	**Total CO_2**
Africa	26.116	46.70	0.84	20.93	67.63
Asia	5.006	8.95	0.16	4.01	12.96
Central America	1.061	1.90	0.03	0.85	2.75
Oceania	0.012	0.02	0.00	0.01	0.03
South America	7.621	13.62	0.24	6.10	19.72
All regions	39.816	71.19	1.27	31.85	103.04

Source: Kammen & Lew (2005)

Methane, one of the major gasses emitted during charcoal production is considered short-lived in the atmosphere and has little or no impact on climate change according to the Intergovernmental Panel on Climate Change (IPCC, 2007). This however, seems not to be universally acceptable as many researchers including (Baillis, 2009 & Chidumayo, 2011) consider methane as greenhouse gas. Highlighting the contribution of charcoal production to greenhouse gas, Kammen and Lew (2005) concluded that emission during charcoal production is far more than what is emitted during charcoal use.

2.5.2 Deforestation

Charcoal production has been identified as one of the earliest major causes of deforestation in Europe especially in Britain during the Middle Ages (Armstrong, 1978, cited in Msuya et al., 2011). The disappearance of natural forest in many parts of Britain such as the Sussex

Downs, the New Forest and the Forest of Dean is said to be as a result of forest wood being cut to produce charcoal to fuel the new iron industry (Boutette and Karch, 1984). This account has been widely corroborated by many writers investigating deforestation in Europe around the same period. Account of charcoal production in many parts of the world especially in developing countries such as Brazil, Tanzania, Senegal, Somalia, Ghana and many others today paints a gloomy picture of unsustainable use of forest and savannah woodland resources (Chidumayo, 2011; Mason, 2009; Msuya, 2011; Baillis, 2009).

Deforestation is a major environmental problem associated with charcoal production across the world. According to Chidumayo and Gumbo (2013), estimates in 2009 put deforestation caused by charcoal production in various parts of the world at; Oceania 5.40 km^2, Central America 390 km^2, South America 2400 km^2, Asia 5100 km^2, and Africa 29,760 km^2. Africa appears to be leading when it comes to deforestation resulting from charcoal production with Tanzania being one of the heaviest hit as about 33.16% of its forest is depleted due to charcoal production.

Determination of deforestation attributable to charcoal production in the midst of many other human activities with varying potential impacts on the environment is based on estimation (Hibajene and Kalumiana, 2003). Hibajene and Kalumiana (2003), however, estimated deforestation caused by charcoal production using the formula;

$$Dc = \frac{Wp}{Sr}$$

Where;

D_c is annual deforestation, in hectares, arising out of charcoal production,

W_p is the quantity of wood, in tons, used to produce charcoal in a year, and

S_r is the stocking rate, in tons/ha, in this case the amount of usable wood for charcoal production.

According to FAO (2000), population increase coupled with increasing demand for land-based resources accounts for almost all the deforestation and land degradation in Sub-Saharan Africa. FAO (2000), maintained that as a result of unsustainable use of charcoal and fuel wood in this region, fuelwood and charcoal consumption is likely to move from estimated 15.9 million m^3 in 1998 to 20.6 million m^3 within ten years.

Many including (Ribot, 1999 and Tappan et al., 2004) believe that the impact of charcoal production on forests especially in West Africa has not been fully told, emphasising that charcoal production has not only caused deforestation but also degradation in most places. Writing on charcoal production in Senegal (Tappan et al., 2004) revealed how the activities of charcoal producers led to degradation of the Tambacounda region in the late 1980's. Tappan et al. (2004) concluded that charcoal production not only degraded the region's woodlands but also altered the biodiversity composition of the area.

In Ghana, the one-time cherished forest and savannah has since been declining as a result of human activities such as charcoal production. According to Resource Watch Agenda (2010), Ghana's forest cover loss is estimated at about 75 percent of her 8.2 million hectares. FAO (2001), described energy demand and supply in most areas in Ghana as imbalanced leading to heavy reliance on the natural forest especially in the three northern regions. The UN agency, explained that this has led to serious clearing of the savannah woodlands for fuelwood and charcoal production in the Brong Ahafo, Northern, Upper East and West regions of the country leaving the immediate surroundings of communities little or no vegetation.

2.5.3 Biodiversity loss

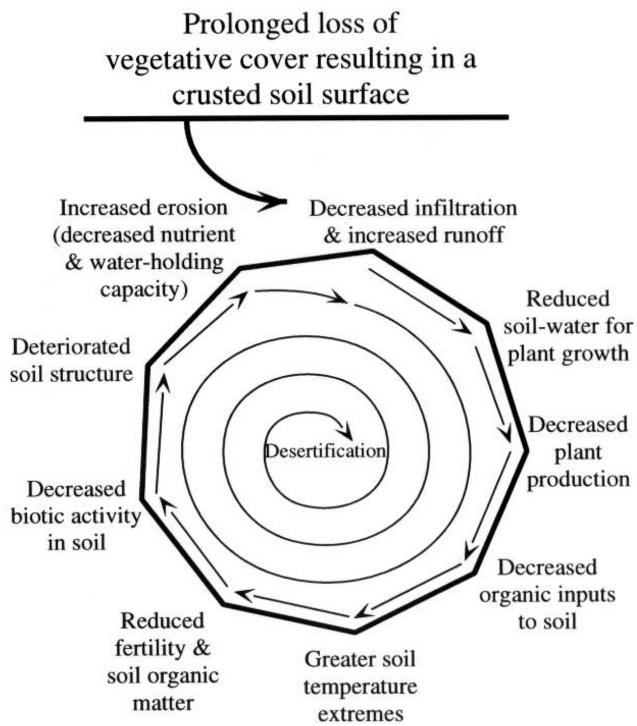
Concerns over biodiversity loss have been growing in the last few decades as more and more previously known species continue to reduce in numbers and in some cases disappeared entirely (Akingbogun et al., 2012). The human factor is by far considered as the most damaging because of the scale and the frequency it is taking place, as more and more areas are converted due to land use change destroying natural habitats (Akingbogun et al., 2012). According Akingbogun et al. (2012) biodiversity loss today is largely due to economic activities despite the numerous services human beings get from it. According to the Convention on Biological Diversity (1992), "Biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

The raw material for charcoal production in most parts of the world is wood harvested from the natural forest (Chidumayo, 2011). Mason (2009) emphasised that the cutting down of trees for charcoal production has led to disappearance of certain tree species as well as wild animals and micro-organisms in both the forest and savannah ecological zones in Ghana. Kindt et al., (2008) observed that the impacts of wood harvest and charcoal production when situated in the context of ecological damage tree-cutting brings about becomes much more revealing. They indicated that where charcoal production is based on selective wood harvesting in most cases leads to changes in species composition as the most harvested species tend to disappear leaving the less preferred species. Kindt et al. (2008) made their conclusion based on the study they conducted comparing national reserves and opened land and the species composition in Mali, Senegal and other countries in West Africa.

2.5.4 Impact on soil

Charcoal production involves tree-cutting which exposes the topsoil to other agents of erosion and at the same time it involves digging up the soil in the case of earth-based kilns for burying of wood which is then processed into charcoal (Hibajene and Kalumiana, 2003;Oguntunde et al., 2008). Oguntunde et al. (2008), in their study of the impact of charcoal production on soils in the forest zone of Ghana stated that the production of charcoal can impact on soil at both the kiln site as well as the surrounding area where wood is normally harvested.

Studies of soil condition using parameters like exchangeable cations (Ca^{2+}, Na^{+} and Mg^{2+}), total nitrogen, and others in both charcoal burning sites and adjacent field sites have revealed a significant variation where soil properties are the same indicating that charcoal burning impacts on the soil especially at the kiln site (Oguntunde et al., 2008; Ogundele et al., 2012; Alexis et al., 2007). The relationship between vegetation cover and soil condition has long been established in most parts of the world. Whisenant (1999) diagrammatically illustrated the impact of vegetation loss emanating from land use and the impact on soil condition from short to long term. Below is a diagram from Whisenant showing the relationship between vegetation cover and soil condition.



Source: **Whisenant (1999)**

Figure 1: Downward spiral of soil degradation due to vegetation loss

The above diagram illustrates impact of soil exposure due to vegetation loss in an area. It indicates how activities such as indiscriminate felling of trees for charcoal production will ultimately lead to reduction in vegetation cover and poor soil fertility without efforts at achieving sustainable land management. It shows that vegetation loss damages soil surface and that leads to acceleration of soil degradation by impacting of soil infiltration, soil fertility and in the long run, affects crop production.

2.5.4.1 Soil fertility and soil erosion

There is a correlation between deforestation and low agricultural productivity due to land degradation Whisenant (1999). The removal of vegetation through tree felling exposes the soil to run-off whenever it rains leading to the removal of the top soils which by far is known to contain most of the soil nutrients and thereby causing low agricultural productivity (Mason, 2009). As a result of over reliance on nature for energy needs of most people in Sub Saharan Africa through fuelwood and charcoal production, the vegetation cover of most countries have witnessed reduction over the years (Msuya et al., 2011). Apart from impacting on soil fertility, charcoal production due to its nature is noted for causing reservoir siltation, flooding, water shortages due to shifting ground water regimes due to vegetation loss in local or production areas (Oguntunde et al., 2008; Chimayo, 2011; Mason, 2009).

2.6 Geographical Information System (GIS) and Remote Sensing

Remote sensing since its use in the 1940s has been defined severally by many authors, one unique feature in the definition of remote sensing which however cuts across these definitions is the issue of information acquisition without being in touch with whatever is being investigated within a spatial setting (Tappan and Cushing, 2008; Ramachandran, 1993; Lillesand et al., 1994), GIS on the other hand is a tool for data analysis including information from landforms to demographics. Information or data for GIS can be acquired from various sources such as public data bases, map, aerial photos, satellite scans, etc.

The system uses electromagnetic radiation as a medium of communication between itself and the earth surface and as energy from the electromagnetic radiation is absorbed, transmitted, scattered and reflected based on the features of the object under investigation, the features of the objects are recorded as the "spectral signature" of the object which is useful for subsequent analysis (Lillesand et al., 2008). These features make the results of remote sensing suitable for the study and management of natural resources such as vegetation in modern day.

The ability to use GIS in decision making is made easier because of its geo-referencing capability which enhances data accuracy. GIS as a tool fills the enormous gap along the information chain as it is been used as a medium of storing information collected as well as serving as a good analytical tool for data processing. Many management decisions have be made in recent times based on information acquired from remote sensing and GIS technology especially when it comes to planning and natural resource management (Egeru et al., 2010; Rimal, 2005; Prenzel, 2003).

Researchers have taken advantage of the unique features that remote sensing presents by adopting it as an approach for understanding land degradation problems among others, since understanding the processes and products of interaction in the environments is very complicated. A careful assessment of changes that occur in the environments and in various ecosystems forms a major milestone for effective ecosystem management and leads to sustainable utilization of forests as well as savannah resources.

GIS works effectively based on reliable information which can be manipulated, this is achieved through scientific data. Remote sensing technology in recent years has been used to collect these data and proved to be reliable when it comes to acquiring data for effective resources management of any ecosystem (Ramachandran, 1993; Baillis, 2009). The use of GIS in analysing changes and trends that have occurred in different themes can influence the direction of policies and decision making at both local and national levels (Lillesand et al., 2008).

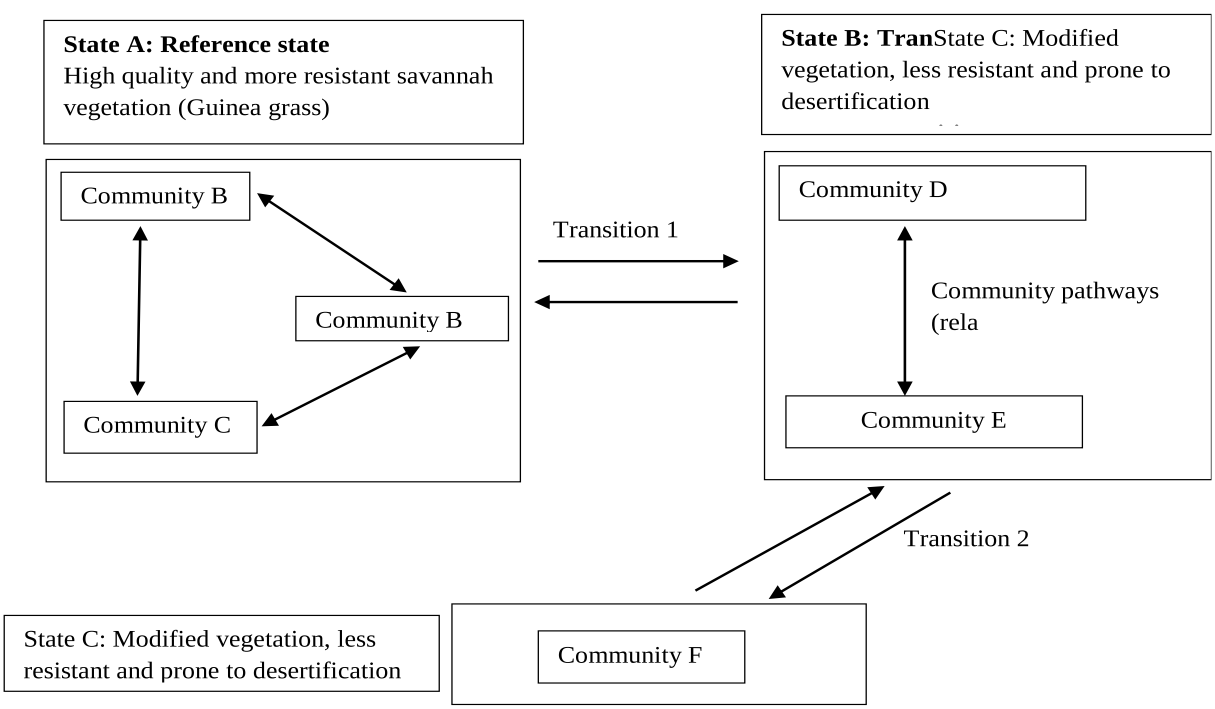
In their study of the changes in the woodlands of Tanzania between 1991 and 1998 taking into consideration both temporary and spatial factors in the eastern part of Tanzania, Mbilinyi et al. (2007) used remote sensing due to its synoptic nature, repetitive and uniform capability to facilitate the acquisition of information and for monitoring. Combined with GIS, the information acquired through remote sensing was easily extracted analysed taking advantage of both visual and digital image interpretation capability of this tool.

2.7 Impact of charcoal production on land use and land cover change

Land use and land cover are sometimes used as synonyms. According to Meyer and Turner II (1994), while land use looks at manipulation of land and land resouces or the purpose of a piece of land with the objective of getting something out of it, land cover on the other hand is concerned about what is on the surface of a piece of land, particularly the vegetation stand and may include, water and many others in most cases. Land use and land cover therefore, play different roles in understanding and managing land since different land uses could lead to varying land cover situation even if two pieces of land are influenced by the same conditions such as climate, vegetation as well as relief. Charcoal production is one land use situation that has an enomous impact on land cover (Msuya et al., 2011; Chidumayo, 2011; Alexis et al., 2007). The impact of charcoal production on land cover or vegetation cover is largerly due to the fact that vegetation mostly trees forms the main raw material for charcoal production and in many cases resulting in unsustainable use of trees.

Deforestation is a major environmental problem associated with charcoal production across the world. Pellant et al. (2005) demonstrated that land use practices such as charcoal production can influence land condition or land cover change, from a reversible degraded land condition when disturbance is minimal to a virtually transformed land condition (eg vegetation cover change) when disturbance increases. The original vegetation which in most case are more resistant can be replaced by less resistant vegetation due to new disturbances such as felling of trees for charcoal production. Below is a modified diagram from Pellant et al. (2005) demonstrating pathways for transition from guinea savannah vegetation to Sahel savannah vegetation and as the vegetation is degraded more, moves are towards desert conditions.

From figure 2: the transitional period of vegetative classes in State A: communities B & C (Guinea grass) which is more resilient to State B: and subsequently State C: which are both less resilient and prone to desertification demonstrates pathways of vegetative transformation from resilient to less resilient one.



Source: *Modified version of Pellant et al. (2005)*

Figure 2: *Land use and impact on vegetation change*

Land degradation in most parts of the world in the past according to Lambin et al. (2001), was largely due to increase in population. He concluded that technological development by man in the last century, in addition to population increase have worsened the situation. With the help of heavy machines, fewer people are now capable of depleting or change land surfaces than the past (Lambin et al., 2001).

2.8 Perception of charcoal producers

The human perception has been used as research tool for assessing the way people prefer to do certain things in a particular way and not the opposite. According to Little (1999) human perception can both be immediate which deals with the way people see their physical environment as well as one that comes in the form of informative (interpretative) perception. This perception has been identified as one of the many things that influence people understanding and the way people do things including how they treat their environment. Understanding individual or a group of people perception in a given area therefore plays a significant role when it comes to natural resource analysis and management (Little, 1999).

The way people act within their environment is therefore, said to be the outcome of their physical experience and the way they recognise things around them and their influence. Through the perceptual process, we gain information about properties and elements of the environment that are critical to our survival. Little (1999), maintained that among other things, our perception helps us to create picture of the world around us through our experience and enable humans to work within their environment. The immediate combined with the human psychology leads to interpretation which can be informative and this is useful when it comes to assessment of the way people act or do certain things. Therefore, charcoal producers were interviewed to understand their perception about charcoal production and the impact on their environment since perception can influence people way of using the natural resources.

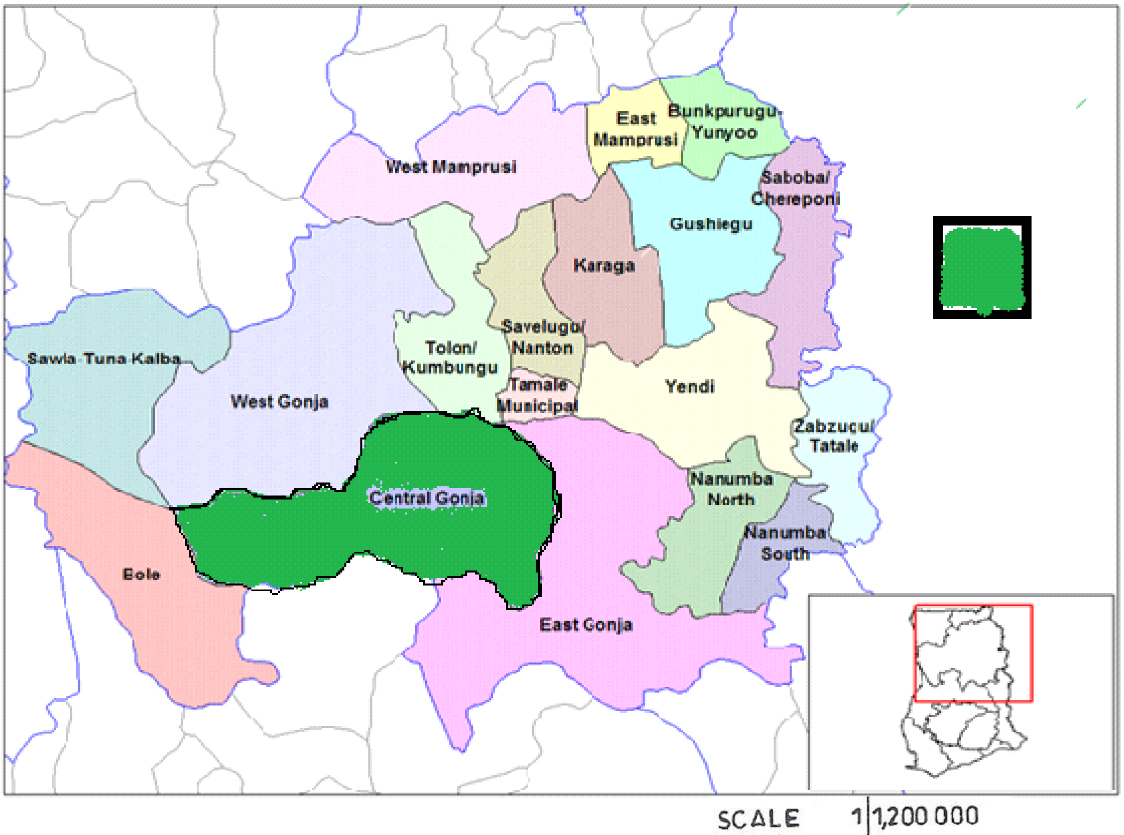
CHAPTER THREE

METHODOLOGY

This chapter outlines the techniques and procedures used in undertaking the study. The chapter therefore highlights the research design, data requirements and sources, data collection tools and methods, sampling techniques, study variables, and plan for data handling and processing data.

3.1 The study area

The Central Gonja District Assembly (CGDA) is one of the districts in the Northern Region of Ghana that were created in 2004. The district is an infant one but with vast human and natural resources. The district is located at the South Western part of the Northern Region of Ghana. The Central Gonja District Assembly (CGDA) lies within longitude 1˚5'and 2˚ 58' West and latitude 8˚32'and 10˚2' North. The district shares boundaries with the Kintampo District of the Brong Ahafo Region to the South, the West Gonja District to the West, the Tamale Metropolis to the North, the Tolon-Kumbungu District to the North West, and the East Gonja District to the East. The district is strategically located because it links the Northern Region to the rest of the Southern part of Ghana. The District covers approximately 8,353 km^2 which represent 12% of the total land area of the Northern Region.



Source: *Central Gonja District Assembly Document (2006)*

Figure 3*: Map of Ghana showing the Districts in Northern Region*

3.1.1 Relief and drainage

The topography is generally undulating with altitude of between 150-200 meters above sea level. The major rivers which drains the district are the White Volta and Black Volta which joins each other around Tuluwe and Mpaha. The confluence of the Black and White Volta Rivers is at Sheri which is a potential site for tourist attraction. Both the Black and White Volta haves good potential for small-scale irrigation schemes along their valleys. They also provide good waterways from Buipe and Yapei respectively to Akosombo via the Volta Lake in Yeji and have good potentials for fishing in the district. There is an inland harbour at Buipe on the Black Volta.

3.1.2 Climate

The district experiences extreme temperatures from November to March during the year. The daily temperatures range from 24^0C to 37^0C in the course of the year. The mean monthly temperature is 27˚C, and humidity is very low causing dry skin and cracked lips of humans. The district experiences the North East Trade Winds popularly known as the Harmattan, winds from December to February which are characterised with cold nights and dry winds during day time. The climate of the area is also influenced by the south west monsoon winds which blow from the April to October and causes rainfall leading the two seasons (dry and wet seasons). The mean annual rainfall is about 1144 mm. The rainfall pattern is erratic, beginning in late April to late October. June, July and August generally record the highest rainfall and also the highest number of rainy days. The rainfall is characterized by thunder storms or heavy showers. Soil erosion and floods are common due to the torrential nature of rains. The irregular distribution and short duration of the rainfall are a great limitation to crops and vegetative growth.

3.1.3 Soil and geology

The district is situated in an old geological area. The rocks are mainly of the Voltaian formation with isolated Cambrian rocks which contain valuable minerals such as gold and diamond. Limestone occurs between the lower and middle Voltaian formation around Buipe, the capital of the district. The soils are generally made up of savannah *ochrosols (oxisols, eutrustols, inceptisols)* as well as groundwater laterites, from the voltaian rock formation. These variations are as a result of the drainage system in the area (Asiamah et al., 1996). Generally, the soils in the district are said to be fertile for agriculture purposes.

3.1.4 Vegetation

The natural vegetation is guinea savannah dominated by *Butyrospermum parkii* (Shea), *Parkia clappertonniana*, (Dawadawa), *Adansonia dititata* (Baobab), *Acacia sp.* (Acacia), *Azadirachta indica* (Neem) and *Khaya senegalensis* (Ebony). These trees are scattered except in most valleys where isolated woodland or gallery forest are found. Most trees are deciduous, shedding their leaves during the dry season. Grass which grows in tussocks may reach 2.7 m during the rainy season. The original vegetation around settlements such as Buipe, Yapei, Mpaha and Kusawgu has been seriously impacted by human activities such as charcoal burning, fire wood harvesting, farming and also bush fires (Asiamah et al., 1996). One of the forest reserves in the district, the Yakumbo Forest Reserve located at the western part of the district capital is equally not spared these destructions.

3.1.5 Demographic characteristics

The district has about 69,665 people according to the 2000 population census but the recent population projection by the Ghana Statistical Service (2010) put the figure at 104,985. The population, though not evenly distributed according to the projection, has large concentration of people in a few large settlements such as Buipe (8,347), Yapei (4,044) and Mpaha (4,126). The population density of the district is 8.3 persons per sq. km which is below the regional density of 25.9 persons per sq. km. The district population growth rate of 3.1% is higher than the national at 2.8%. The sex ratio is 103 males to 100 females. The population is concentrated in a few accessible areas or settlements like Buipe, Yapei, and Mpaha. The age structure is typical of developing countries with over 50% between 15-60 years of age (Table 1).

Table 2: Age and sex structure

Age groups	Male (%)	Female (%)	Total (%)
0 – 4	7.4	7.3	14.7
5 - 9	7.2	7.5	14.7
10 – 14	5.9	6.2	12.1
15 – 19	4.8	2.9	7.7
20 - 24	4.2	2.6	6.8
25 - 29	4.4	3.6	8.0
30 – 34	2.8	4.0	6.8
35 – 39	3.4	5.1	8.5
40 – 44	2.3	2.3	4.6
45 – 49	2.0	1.9	3.9
50 – 54	1.6	1.5	3.1
55 – 59	0.9	1.0	1.9
60 – 64	1.0	0.9	1.9
65 +	2.8	2.5	5.3
	50.7	**49.3**	**100.0**

Source: 2008, United Nation International Children Education Fund/Integrated Water, Sanitation and Health UNICEF/IWASH

3.1.6 Economic activities

The main economic activity of the people is agriculture involving crop production and livestock farming. The land is fertile for farming which is done extensively. Crops cultivated include maize, sorghum, millet, groundnut, cowpea, soy beans, yam, rice, and cassava. Other economic activities undertaken in the district are charcoal production, small- scale agro-based industries such as shea butter processing, rice milling, groundnut oil extraction and gari processing. Shea-butter processing and charcoal production are some of the major commercial activities for Women. Fishing and livestock production are considered as supplementary activities to crop production. Large scale fishing is carried on at Yapei and Buipe on the White and Black Volta lakes. The major animals reared are cattle, sheep, goats, fowls, guinea fowls etc. The animals and birds are practically reared in every home, but large scale ranching is non-existence in the district.

3.2 Research design

This study involved determination of some soil physico-chemical parameters, vegetation dynamics and a social survey. Therefore both experimental and cross-sectional designs were used. The latter involved focus group discussions and interviews of some community members.

3.2.1 Selection of communities and respondents

Selection of respondents for this study was guided by purposive sampling technique. The goal of purposive sampling is not to randomly select units from a population, but rather the main aim of purposive sampling is to focus on particular characteristics of a population that are of interest, which will best enable the researcher to answer research questions.

Five communities where charcoal production is being carried out were selected for the study using purposive sampling (Figure 2). These communities were selected to correspond to the five local councils in the district. Each local council was represented by one community. The communities included; Juku in the Tuluwe local council, Jankura in the Yapei local council, Mankpam in Mpaha local council, Bouchipe in the Buipe local council, and Sankpala in the Kusawgu local council. Fifty charcoal producers were selected from each of the five (5) selected communities resulting in a total of 250 respondents. As part of the purposive sampling technique employed, charcoal producers in the research communities were identified during the pre-interview visits and targeted for the face-to-face interview. The individual interview was focused on the perception of charcoal producers about the environmental impacts of charcoal production in the area.

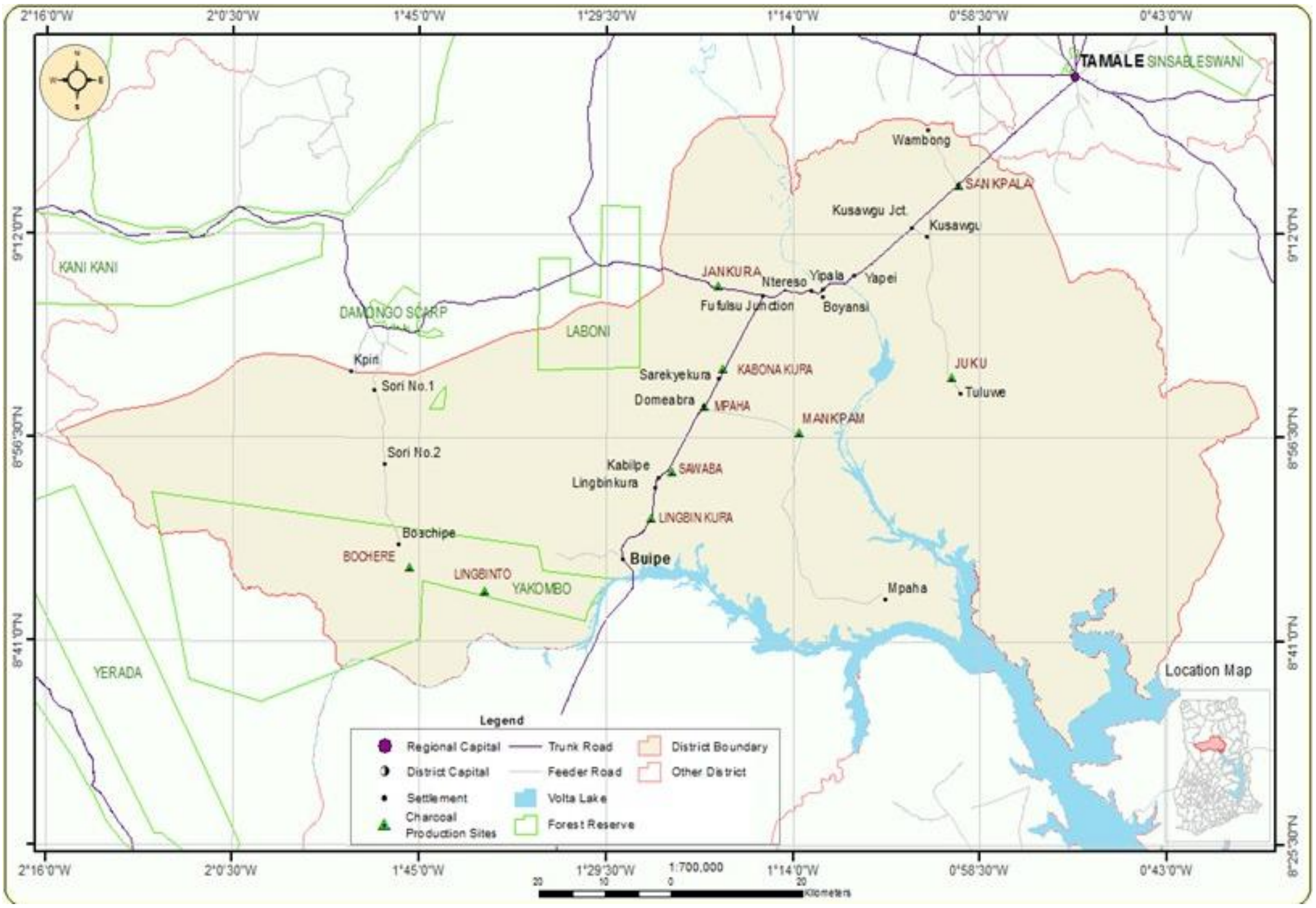


Figure 4: *Map of Central Gonja District (CGD) showing research communities (Source: produced by Tetteh, Dept of Geography, UG, 2013)*

3.3 Data collection

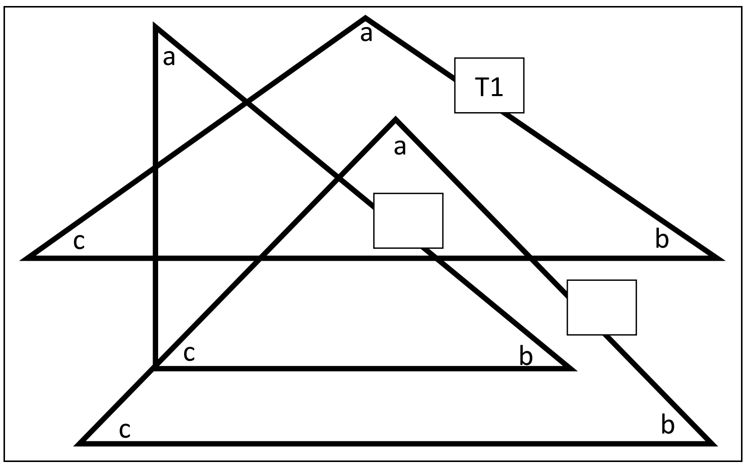
Data was obtained from primary and secondary sources. Secondary data concerning the geography as well as the socio-economic activities of the Central Gonja District was obtained from the District Assembly, Geography Department and the University of Ghana libraries, journal articles, Forestry Commission and Environmental Protection Agency (EPA), while primary source included social survey and soil and land use/land cover analysis.

The social survey involved face-to-face interviews using interview guide to obtain information from charcoal producers as respondents in the selected five communities in the study area. Also, two focus group discussions were held at Juku and Sankpala to solicit detail information on charcoal production from the community members. The interview guide was first developed and pre-tested before actual administration was done in the field.

3.3.1 Collection of soil samples

To evaluate the impact of charcoal production on soil properties and vegetation cover, soil samples were taken at two (2) sites each in all the five communities from October, 2012 to January, 2013. Site selection was based on evidence of charcoal production within the last six months and unburnt site of 150 meters away from each site with demonstrable evidence of charcoal production serving as the control sites. This was done to ensure that samples have been taken from the same place, and the only factor for potential variation during samples analysis could be attributable to charcoal burning. In all, six composite samples were taken from each site (0-30 cm and 30-60 cm depths) three composite samples at each level. Sampling was done randomly from each of the areas within the burnt and unburnt sites.

The soil samples were taken at two different levels from 0-30 cm and 30-60 cm at each sample point. At each site, three different triangles were constructed labelled T1, T2 and T3. In each triangle, samples were collected at the converging points of the lines (a, b and c; see figure 3), (Fosu-Mensah, Y. B., 2013, *personal communication*). The soil samples from each triangle from the same level were mixed and a composite sample taken leading to six composite samples of the two depths (0-30 cm and 30-60 cm) each for both the burnt and unburnt sites. The composite soil samples were taken by driving a soil auger into the soil taken at the different depth and placed into sampling bag. Samples were air-dried, ground and passed through a 2 mm sieve. The samples were kept in a polythene bag and labelled appropriately. Samples were taken to the Ecological Laboratory of the University of Ghana for physical and chemical analysis.



Source: *Author's construct 2013*

Figure 5: *Soil sampling procedure*

3.4 Soil analysis

3.4.1 Chemical analysis of soil

The soil properties assessed were particle size distribution, pH, carbon, total nitrogen, Organic carbon, exchangeable cations: K^+, Ca^{2+}, Na^+, Mg^{2+}, electrical conductivity and hydraulic conductivity. These measurements were done for both burnt and unburnt soil samples.

3.4.2 Determination of exchangeable potassium and sodium

Flame photometry method was used to determine potassium (K^+) and sodium (Na^+) in the soil extract. To determine K^+ and Na^+, standard solution of 0, 2, 4, 6 8 and 10 ppm K and Na were prepared by diluting appropriate volumes of 100 ppm K^+ and Na^+ in volumetric flask using distilled water (see Moss, 1961).

Ammonium acetate (1N NH_4OAc) 77.08g of NH_4OAc was dissolved into 800ml with water, then neutralised with concentrated NH_4-H to pH 7.0. The solution was then diluted to 1 liter. In terms of extraction proceduce, 10g of soil was weighed into extractable bottle and 100ml of 1N NH_4OAc solution added. This was placed in a bottle with content and then put in a shaking machine and shook for one hour. At the end of the shaking, the bottle was put in a centrifuge and centrifuged for about 20 minutes. The supernatant solution was finally filtered through No.42 whatman filter paper.

3.4.3 Determination of K^+ and Na^+

An aliquot of the extract was then taken and sprayed into the flame as directed and obtain the photometer reading. The milliequivalents of the exchangeables K was then calculated by reading the flame photometer for the standard solution, as this was done and standard curve constructed, potassium and sodium concentrations in the soil extract were read from the standard curve.

The calculations were as follows:

$$\text{Exchangeable K (cmol/kg soil)} = \frac{\text{Spec reading}}{\text{Mw } 39.1} \qquad (3.1)$$

Where: W = weight of air – dried sample soil in grams
39.1 = mole of potassium
23 = mole of sodium

3.4.4 Determination of soil pH, electrical conductivity and hydraulic conductivity

The pH and electrical conductivity of the soil were measured from reading (ratio 1:1) and (1:5 soil: distilled water) respectively on standardised meters and finally the hydraulic conductivity was measured in the laboratory using the falling-head method (*Klute* and *Dirksen*, 1986). The advantage to the falling-head method in determining hydraulic conductivity is that it can be used for both fine-grained and coarse-grained soils. The soil sample is first saturated under a specific head condition. The water is then allowed to flow through the soil without maintaining a constant pressure head.

3.4.5 Determination of exchangeable calcium and magnesium

To determine exchangeable Ca^{2+} and Mg^{2+}, 10 ml of the extract described in 3.4.3 for potassium and sodium determination was transferred to an Erlenmeyer flask and 5 ml of an ammonium chloride-ammonium hydroxide buffer solution was added followed by addition of 1 ml triethanolamine. A few drops of potassium cyanide and Eriochrome Black T solutions were then added. The mixture was then titrated with 0.02 *M* EDTA solution from a red to a blue end point.

3.4.6 Determination of soil carbon and organic matter content

To analyse the carbon and organic matter content of the soils, this was done by reducing the $Cr_20_7^{2-}$ ions by organic matter in which case the unreduced $Cr_20_7^{2-}$ is measured by titration. Organic forms of soil –C plus the carbonate forms of the element including HCO_{3-} and $CO_3^{2-}$of any soluble salts present, constitute the total-C present in soils. Values for the organic-C content of soils may be expressed as such or may be reported as total organic matter by multiplying the figure for organic-C by the conventional "Von Bemmlen" factor of 1.724. Finally, the organic matter was calculated by multiplying the percentage C by the factor 1.724 to convert to organic matter (Black, 1965; Wakley and Black, 1934), Potassium dichromate ($K_2Cr_20_2$) was dissolved in 49.04g of reagent grade $K_2Cr_20_2$ (dried at 105^0 C) in water and the solution diluted to the volume of 1000ml, then sulpuric acid (H_2S0_4) concentrated (not less than 69%). If the CI^- is present in the soil, 1.25g Ag_2SO_4 would be added to every 100ml of the concentrate. H_2S0_4 was employed as Orthophosphoric acid (H_3PO_4): 85%. At ferrous ammonium sulphate of (0.2N), 78.44g Fe $(NH_4)_2(SO_4)_2$ was dissolved in 500ml of water. With the addition of 20ml conc. and H_2SO_4 to get 1 litre barium diphnylamine sulphonate: 0.16% aqueous solution.

In terms of procedure, a representative sample of approximately 0.5g of soil was screened through 0.5mm sieve into a 250 Erlenmeyer flask. Then from a burette, exactly 10ml of dichromate solution was introduced followed by 20ml of concentration H_2S0_4. The flask was swirled keeping the solution in contact with all the particles of compost or soil. The flask and content was allowed to stand on an asbestos sheet for 30 minutes, after which 200ml of distilled water, 10ml of orthophosphoric acid and finally 2ml of barium diphenyamine sulphonate indicator were added. This was then titrated with the ferrous ammonium sulphate solution until the colour changes to blue then to a green end-point.

3.4.7 Calculation of percentage carbon (% C)

The following formula was used (reference/source?);

% carbon = $\underline{[10.0-(X\ N)\ X\ 0.3]}$

where X = ml of ferrous ammonium sulphate solution required for the titration

N = normally of ferrous ammonium sulphate solution and

W = weight of soil sample in gram.

3.4.8 Calculation of percent organic matter

The percentage of organic matter in soil samples was calculated by multiplying the percentage C by the factor 1.724 to convert to organic matter (Bremner and Mulvaney, 1982).

3.4.9 Determination of soil total nitrogen

Soil total nitrogen was determined using the micro Kjeldahl distillation and titration method (Bremner and Mulvaney, 1982). The modified Kjeldahl method permits the total nitrogen to be precisely determined in plants and in soil.

A 1 g soil sample was weighed into a digestion flask, 5 ml concentrated sulphuric acid and few drops of 30 % hydrogen peroxide were added with selenium to serve as catalyst. The entire content was then digested. The use of this method converts organic nitrogen to ammonium sulphate and the resultant solution made alkaline by the addition of 5 ml of 40 % sodium hydroxide and ammonia distilled into 2 % boric acid and titrated with standard hydrochloric acid. The digestion of organic converted organic nitrogen to NH_2^+-N (ammonium nitrogen), this was distillated to release NH3 into an absorbing medium and volumetric analysis of NH3 formed during digestion process.

Concentrated sulphuric acid (H_2SO_4), digestion accelerator: mixed together 10g $NaSO_4$, 1g CuSO4.5H20 and 0.1g selenium, Sodium hydroxides, 40% NaOH. Mixed indicator: 0.13g of methyl red + 0.066g of methylene blue dissolved in 100ml of 95% of ethanol. Hydrochloric acid 0.01m and boric acid (2%): 2g of H_3BO_3 in 100ml of distilled water.

In terms of procedure, a 1g of fine (2mm) composit soil was weighed into a 500ml Kjeldahl flask A 4ml of distilled water was added to the soil thoroughly. A scoop of digestion accelerator mixture was added to each tubeafter which 5ml of concentrate H_2SO_4 was added. The mixture was digested by heating in fume cupboard gently at first until vigorously effervescence subside. The heating (boiling) continued for 1 hour after the digest was turned white with no charried organic matter remaining. The digest was cooled and 20ml with distilled water and allowed the sand or compost to particles to settle, and decanted the supernatant solution into a 50ml volumetric flask. The process was repeated by washing the sand or compost particles and quantitatively transfering all the ammonium to the flask, this was done up to the mark.

An aliquot of 5ml was taken into a markham distillation apparatus, also, 5ml of the 40% NaOH and 100ml of distilled water were added. The mixture was distilled, collecting the distillate in 5ml of the 2% boric acid-indicator mixture.The distillate was subsequently titrated with 0.01m HCI from green to reddish end point and the titre value recorded.

3.5 Soil physical properties

Soil physically consists of three main components namely sand, silt and clay. The process of separating a soil into its particles, and then estimating the proportion of particles in the various size ranges, is usually referred to as Mechanical Analysis or Particle Size Analysis (Bouyoucos, 1962; Dietrich, 2005).

There are several methods of particle size analysis, but only two have wide acceptance Bouyoucos (1962): i) The Pipette Method and ii) The Bouyoucos Hydrometer Meter Method. The Hydrometer method was used in this study. This method quantitatively determines the physical proportions of the soil particles as determined by their settling rates in an aqueous solution using a hydrometer. The hydrometer method of estimating particle size analysis of sand, silt and clay content is based on the dispersion of soil aggregates using sodium hexametaphosphate solution and subsequent measurement based on changes in suspension density (see Dietrich, 2005).

Reagent, sodium hexametaphosphate, $Na(PO_3)_6$ (611.78) 99%**,** Sodium carbonate, Na_2CO_3(105.99)99.9% and deionised water. Preparation of calgon, in 1 litre flask, 35.7g of sodium hexametaphosphate was dissolved in 750ml of deionised water. Then 7.49g of sodium carbonate was added and made up to 1 litre with deionised water. This was vigorous shaken to dissolve the hexametaphosphate.

For the procedure, a 51g of air-dried soil (□ 2mm)was weighed and transfer into a 250ml beaker, the results was dispensed with 50ml of the calgon solution and 100ml of deionised water to the soil. The suspension was stirred vigorously for 1 minute using a glass rod and made to stand for 30 minutes. After that, the substance was transferred into the mixer and mixed for 15 minutes at a medium speed. After mixing, the suspension was transferred the into the sedimentation cylinder and made up to 1 litre with deionised water.

In terms of measurement, the suspension was mixed in the cylinder by several vertical movements of the plunger (1-2min), the cylinder was then placed on a flat surface and the time noted. The soil hydrometer was immediately placed into the suspension, sliding the hydrometer slowly into the suspension until it started floating. The first reading was taken on the hydrometer at 40 seconds after the cylinder was set on (H_1). The hydrometer was then removed and the temperature of the suspension measured with a thermometer (T_1 ^{0}F). Step 1-4 were repeated to take a duplicate reading after the first two hydrometer reading (H_1), the temperature of the suspension was taken (T_1 ^{0}F).

3.5.1 Calculation

Table 3: Formula for reading soil physical properties (Dietrich, 2005)

A	T_1	B	C	%SAND	D	E	F	%CLAY	G	%SILT
H_1	T_1 T_1	(T--68)×0.2	A+B-2	100-(2×C)	H_2	(T2--68)×0.2	D-2	F+E×2	SAND+CLAY	100-G

Using the above table, %sand=100-2×C, %clay=F+E×2 and %silt=100-G. As given in the above where H_1=average of first two hydrometer readings, T_1=average of first two temperature readings (^{0}F), H_2=second hydrometer reading and T_2=second temperature reading (^{0}F). The texture class was obtained for the soil using the texture triangle

3.6 Land use and land cover change

The land use and land cover change study of the area was carried out by acquiring and using satellite images of 1990, 2000 and 2010. The vegetation change due to land use of the Central Gonja District was established through systematic application of remote sensing and geographical information system (GIS).

3.6.1 Acquisition of raw satellite images

The data used in this study came from LANDSAT Thematic Mapper (TM) which has been widely used for similar studies because of its relative advantage such as low cost, availability and relative precision (high-resolution image per unit area), including Duadze (2004) study of land use and land cover change of the savannah ecosystem in the Upper West Region in Ghana.

The LANDSAT TM images were rectified by geo-referencing and projected onto a plane, making it conform to a map projection system. Then, already geo-referenced data were assigned map coordinates, since all map projection systems are associated with map coordinates. And this was done by assigning Ghana Coordinates to the image using ARCMAP.

3.6.2 Classification of images

In this study, unsupervised classification was used and validated by "ground truthing" using Global Positioning System (GPS) for the purpose of orientation in the field. Classification is the process of sorting pixels into a finite number of individual classes, or categories, of data based on their data file values. This was done by assigning pixels that satisfies a certain set of criteria to the class that corresponds to the criteria. There are two ways of classifying pixels into different categories.

- Supervised
- Unsupervised

Supervised classification is more closely controlled by the user than unsupervised classification. In this process, the user selects pixels that represent patterns you recognized or can identify with help from other sources. By identifying patterns in the imagery, the researcher can "train" the computer systems to identify pixels with similar characteristics. The researcher can then supervise the classification of pixels as they are assigned to a class value.

Unsupervised classification is more computer-automated. The unsupervised classification allows the researcher to specify parameters that the computer uses as guidelines to uncover statistical patterns in the data which are then used for a particular research purpose.

3.6.3 Recoding

New class value numbers were generated for all the classes and used to create a new thematic raster layer by recoding. Some of the classes were combined through this process. This was done using Erdas Imagine software.

After recoding, the raster attribute table was exported as data which was opened in excel and statistics where all the various classes were generated. Since the size of the pixels were known for example, the Landsat (30mx30m), the pixels were multiplied per class (30mx30m = 900m). And to get the total area in meters per class, this was divided by 10000 to get hectares, then divided by 100 to get sq km.

3.6.4 Map Composition

The land use and land cover units of the areas, such as built up areas, water bodies, vegetation types were generated and used to mask or subset the images and statistically generated before the final maps were composed in ARCMAP.

3.7 Data analysis

Soil chemical and physical properties were compared to test if there were difference between burnt and unburnt sites. For this purpose, t-test (test of Student) technique was carried out using Instat + v3.36 package (Dytham, 2011). Relationship between soils parameters for burnt and unburnt soils was tested using correlation of Pearson carried out in Minitab 16 (Dytham, 2011). Results from data analysis were interpreted using information from field interviews.

For quality control, of the data generated from interviews, results were checked in the field to ensure that the information collected was accurately recorded. Where some inconsistencies existed in the data due to mistakes by the respondent, it was detected and the interviewee concerned was contacted again for clarification in order to have the right information. This was possible and easy because the researcher assigned special identification codes to respondents. The interview data was introduced in Statistical Package for Social Science ver. 19 (SPSS ver. 19) for further analysis.

CHAPTER FOUR

RESULTS

4.1. Proportions of clay, sand and silt in soil from sites or areas of charcoal production (burnt sites) and sites with no evidence of charcoal production (unburnt sites)

4.1.1Clay

Table 4 shows data on the proportions of clay, sand and silt in soils taken from both charcoal producing (i.e. burnt) and non-charcoal producing (i.e. unburnt) sites during the study. The proportion of clay in soil at 0-30 cm depth at burnt site range from 6.0 to 22.0%, (mean 14.10 % and standard deviation 4.84) Clay in soil samples taken at similar depth (0-30 cm) at unburnt site range from 15.0-35.0% (mean and standard deviation 24.9 % and 12.0, respectively). Further analysis of the data using t-test showed that, within 0-30cm depth, the clay content in soil from unburnt site is significantly greater than at burnt site (t = 5.56, df = 28, $P < 0.001$).

Clay contents within 30-60 cm depth of soil at burnt site similarly range from 7.0-32.0% (mean 17.70 % and standard deviation 5.99) and at unburnt site from 15.0-33.0 % (mean 23.5 % and standard deviation 6.35) (see Table 4). The t-test showed that there is no significant difference in clay content at burnt and unburnt sites (t = 2.63, df = 28, $P < 0.014$).

4.1.2 Sand

Also in Table 4, the percentage of sand at the burnt site within 0-30 cm depth of soil range from 62 to 88%, (mean 75.2 % and standard deviation 8.06), and at the unburnt site from 44.0 to 80.0% (mean 60.73% and standard deviation 11.80). The t-test showed that sand content at burnt site is significantly greater than at the unburnt site (t = 3.92, df = 28, $P < 0.001$).

The sand content within the 30-60 cm depth of soil range from 54.0 to 80.0% (mean 69.70% and standard deviation 7.83) in the burnt site, and from 33.00 to 75.00% (mean 61.0% and standard deviation 10.74) in the unburnt site, as shown in Table 4. The t-test showed that the sand content at unburnt site is not different from the burnt site (t = 2.54, df = 28, P < 0.055).

4.1.3 Silt

In Table 4, the percentage of silt within the 0-30 cm depth at the burnt site range from 2.00 to 16.00% (mean 10.70% and standard deviation 4.67) and range from 3.00 to 30.00% (mean 14.40% and standard deviation 7.33%) at the unburnt site. The t-test showed that there is no difference in silt content between unburnt and burnt sites (t = 1.84, df = 28, P < 0.761).

In Table 4, the content of silt within the 30-60 cm depth at the burnt site range from 3.00 to 19.00% (mean 12.60% and standard deviation 4.99) and from 9.00 to 34.00% (mean 15.50% and standard deviation 6.15) at the unburnt site. The t-test showed that there is no difference in silt between the unburnt and the burnt sites (t = 1.47, df = 28, P < 0.154).

Table 4: Data on soil fractions within 0-30 and 30-60 cm at burnt and unburnt sites

		Burnt site (CPS)			**Control site (CS)**					
Property	**Depth (cm)**	**Mean ± S.D**	**Mini**	**Maxi**	**Mean ± S.D**	**Mini**	**Maxi**	***t*-value**	***P*-value**	***F* - probability**
Clay	0-30	14.10±4.8	6.0	22	24.87±6.1	15	35	5.56	0.001	**
	30-60	17.70±6.0	7.0	32	23.50±6.4	15	33	2.63	0.014	*
Sand	0-30	75.20±8.1	62	88	60.73±11.8	44	80	3.92	0.001	**
	30-60	69.70±7.8	54	80	61.00±10.7	33	75	2.54	0.055	NS
Silt	0-30	10.70±4.7	2.0	16	14.40±7.3	3.0	30	1.84	0.761	NS
	30-60	12.60±5.0	3.0	19	15.50±6.2	9.0	34	1.47	0.154	NS

S.D = Standard deviation, SD = Significantly Different, NS = Not significant

Sand, clay and silt fractions were measured in (%)

4.2 Soil physical properties at burnt and unburnt sites

4.2.1 Electrical conductivity, pH and hydraulic conductivity

4.2.2 Electrical conductivity (EC)

Table 5, shows the content of soil physical properties of sampled. Variations in electrical conductivity in soil taken from 0-30 cm at burnt site is from 94.0-650.0 µS/cm3 (mean 305.27 and standard deviation 149.8) and at unburnt site from 50.0-380.0 µS/cm3 (mean 172.0 and standard deviation 121.7) The t-test showed that there is no difference in electrical conductivity at burnt and unburnt sites (t = 2.67, df = 28, P < 0.012). Electrical conductivity within 30-60 cm at burnt sites vary from 80.0-400.0 µS/cm3 (mean178.0 and standard deviation 113.2) and at unburnt sites from 45.0-490.0 µS/cm3 (mean 209.3, standard deviation 157.2). The t-test showed that the electrical conductivity at unburnt site did not differ significantly from burnt site (t = 0.63, df = 28, P < 0.536).

4.2.3 Soil pH

The pH within the 0-30 cm depth of soil at burnt and unburnt sites, pH has a variation of 6.06 to 6.93 at the burnt site (mean and standard deviation, 6.41 and 0.26, respectively), and unburnt site, 4.84 to 7.48 (mean 6.31and standard deviation 0.83), see Table 5. The t-test showed that there is no significant difference in pH between the burnt and the unburnt sites (t = 0.46, df = 28, P < 0.659). The pH within the 30-60 cm depth of soil at the burnt site is 6.08 to 6.72 (mean and standard deviation 6.35 and 0.15, respectively) and 4.54 to 7.16, (Mean 6.33 and Standard deviation 0.81). The t-test showed that the pH of soil at unburnt site has no difference from the burnt site (t = 0.10, df = 28, P < 0.923).

4.2.4 Hydraulic conductivity

In Table 5, the hydraulic conductivity (0-30 cm) at the burnt site ranges from 0.63 to 3.9 (mean and standard deviation, 1.79 and 0.99 cm h^{-1} accordingly) and at the unburnt site 0.13 to 1.13 (mean and standard deviation 0.53 and 0.32 (cm h^{-1}), respectively). The t-test showed that the hydraulic conductivity at burnt site is significantly greater than in the unburnt site (t = 4.67, df = 28, $P < 0.001$). While hydraulic conductivity of soil within the 30-60 cm depth at the burnt site is between 0.18 to 3.11 (mean 1.19 (cm h^{-1}) and standard deviation 0.77) and at the unburnt 0.18 to 1.35 (mean 0.67 (cm h^{-1}) and standard deviation 0.44). The t-test showed that the hydraulic conductivity at unburnt site shows there is no difference from the burnt site (t = 2.29, df = 28, $P < 0.029$).

Table 5: Data on soil physical properties within 0-30 and 30-60 cm at burnt and unburnt sites

		Burnt site (CPS)			**Control site (CS)**					
Property	**Depth (cm)**	**Mean ± S.D**	**Mini**	**Maxi**	**Mean ± S.D**	**Mini**	**Maxi**	***t*-value**	***P-value***	***F - probability***
pH	0-30	6.4±0.3	6.1	7.0	6.3±0.8	4.8	7.5	0.46	0.659	NS
	30-60	6.4±0.2	6.1	6.7	6.3±0.8	4.5	7.2	0.1	0.923	NS
EC	0-30	305.3±149.8	94	650	172.0±121.7	50	380	2.67	0.012	*
	30-60	178.0±113.2	80	400	209.3±157.2	45	490	0.63	0.536	NS
HC	0-30	1.8±1.0	0.6	3.9	0.5±0.3	0.1	1.1	4.67	0.001	**
	30-60	1.2±0.8	0.2	3.1	0.7±0.4	0.2	1.4	2.29	0.029	*

S.D = Standard deviation, SD = Significantly Different, NS = Not significant

Measurement, electrical conductivity (µS/cm3) and hydraulic conductivity (cm h^{-1}).

4.3 Soil chemical properties at sites (or areas) of charcoal production and sites (or areas) with no evidence of charcoal production ("burnt" and "unburnt" sites)

4.3.1 K, Ca, Na, Mg, organic carbon, organic matter and total nitrogen contents

4.3.2 Potassium (K)

Data on soil chemical properties are presented in Table 6. The content of potassium at the burnt site ranges from 0.15 to 0.94, (mean 0.52 Cmol (+) kg^{-1} and standard deviation 0.21) and in the unburnt site is 0.12 to 0.59 (mean 0.29 Cmol (+) kg^{-1} and standard deviation 0.14). The t-test showed that the potassium content within the 0-30 cm depth of soil at the burnt site is significantly greater than in the unburnt site ($t = 3.35$, df = 28, $P < 0.002$).

Also potassium within 30-60 cm, in the burnt site had 0.08 to 0.80 (mean 0.36 Cmol (+) kg^{-1} and standard deviation 0.21) and at the unburnt site 0.10 to 0.49 (mean 0.29 Cmol (+) kg^{-1} and standard deviation 0.11). The t-test showed that there is no difference in the content of potassium within the 30-60 cm depth, between burnt and unburnt ($t = 1.12$, df = 28, $P < 0.274$). The results indicate that charcoal burning may have impact on top 0-30 cm potassium content in the soil but not on 30-60 cm.

4.3.3 Sodium (Na)

In Table 6, Sodium presence within the 0-30 cm depth of soil in burnt and unburnt sites, indicates a variation of sodium at the burnt site from 0.49 to 0.91 (mean and standard deviation 0.66 Cmol (+) kg^{-1} and 0.12, respectively) and at the unburnt site is 0.47 to 1.10 (mean and standard deviation 0.78 Cmol (+) kg^{-1} and 0.16, in that order). The t-test showed that the sodium content in burnt site is greater than in the unburnt site ($t = 2.32$, df = 28, $P < 0.028$). The content of sodium within the 30-60 cm depth of soil at the burnt site is 0.39 to 0.71 (mean and standard deviation, 0.54 Cmol (+) kg^{-1} and 0.10, respectively) and 0.57 to 0.940 (Mean 76 Cmol (+) kg^{-1} and Standard deviation 0.13) in the unburnt site. The t-test showed that there is significant difference between sodium content at unburnt burnt sites (t = 5.01, df = 28, P < 0.001), at the same time.

4.3.4 Magnesium (Mg)

Also in Table 6, magnesium content within (0-30 cm) at the burnt site ranges from 1.37 to 2.70 (mean 1.78 Cmol (+) kg^{-1} and standard deviation 0.36) and at the unburnt site 1.49 to 7.94 (mean 3.28 Cmol (+) kg^{-1} and standard deviation 1.96). The t-test showed significant difference in the magnesium content at unburnt and burnt sites (t = **2**.92, df = 28, P < 0.011). Magnesium (30-60 cm) at the burnt site had 1.01 to 3.86 (mean and standard deviation 1.71Cmol (+) kg^{-1} and 0.66, respectively), and in the unburnt site had 1.39 to 27.55 (Mean 5.26 Cmol (+) kg^{-1} and Standard deviation 7.14). The t-test shows there is no difference in magnesium content between unburnt site and burnt site (t = **1**.92, df = 28, P < 0.076).

Table 6: Analysis of soil chemical properties within the depths of 0-30 and 30-60cm at both burnt and unburnt sites

		Burnt site (CPS)			Control site (CS)					
Property	**Depth (cm)**	**Mean ± S.D**	**Mini**	**Maxi**	**Mean ± S.D**	**Mini**	**Maxi**	***t*-value**	***P-value***	***F - probability***
K	0-30	0.52±0.21	0.15	0.94	0.29±0.14	0.12	0.59	3.35	0.002	**
	30-60	0.36±0.21	0.08	0.80	0.29±0.11	0.10	049	1.12	0.274	NS
Ca	0-30	8.57±2.85	4.13	13.10	8.78±6.22	1.59	23.81	0.12	0.905	NS
	30-60	6.72±2.88	3.14	12.26	9.13±8.29	2.33	33.64	1.06	0.302	NS
Na	0-30	0.66±0.12	0.49	0.91	0.78±0.16	0.47	1.1	2.32	0.028	*
	30-60	0.54±0.10	0.39	0.71	0.76±0.13	0.57	0.94	5.01	0.001	**
Mg	0-30	1.78±0.36	1.37	2.70	3.28±1.96	1.49	7.94	2.92	0.011	*
	30-60	1.71±0.66	1.01	3.86	5.26±7.14	1.39	27.55	1.92	0.076	NS
C	0-30	0.8±0.3	0.3	1.4	1.5±0.8	0.4	3.4	2.93	0.007	**
	30-60	0.4±0.2	0.01	0.74	0.9±0.7	0.2	2.7	2.93	0.007	**
OM	0-30	1.4±0.6	0.6	2.5	2.5±1.5	0.03	5.9	2.48	0.021	*
	30-60	0.6±0.4	0.01	1.28	1.6±1.2	0.3	4.7	3	0.006	**
TN	0-30	0.1±0.1	0.01	0.26	0.5±0.1	0.3	0.8	10.21	0.001	**
	30-60	0.08±0.03	0.04	0.15	0.5±0.1	0.4	0.6	16.2	0.001	**

S.D = Standard deviation, SD = Significantly Different, NS = Not significant

Soil properties such as magnesium, sodium, calcium and potassium measured in (Cmol (+) kg^{-1}), carbon, total nitrogen and organic carbon measured in (%)

4.3.5 Calcium

The variation of calcium (0-30 cm) in burnt and unburnt sites are, burnt site vary from 4.13 to 13.10 (Mean 8.57 Cmol (+) $kg^{-1}$and Standard deviation 2.85) and unburnt site from 1.59 to 23.81 (mean 8.78 Cmol (+) kg^{-1} and standard deviation 6.22) as shown in Table 6. The t-test showed there is no difference in calcium between burnt and unburnt sites (t = 0.12, df = 28, $P < 0.905$). The content of calcium (30-60 cm) at burnt site vary from 3.14 to 12.26 (mean 6.72 Cmol (+) kg^{-1} and standard deviation 2.88), and at the unburnt site 2.33 to 33.64 (mean 9.13 Cmol (+) kg^{-1} and standard deviation 8.29). The t-test showed that there is no significant difference in calcium content between unburnt and and unburnt sites (t = 0.12, df = 28, $P < 0.302$).

4.3.6 Organic carbon

The percentage of carbon (0-30 cm) at the burnt site range from 0.34 to 1.44 (mean 0.82% and standard deviation 0.33), and at the unburnt site from 0.35 to 3.44% (Mean 1.50% and Standard deviation 0.83), see Table 6. The t-test showed that there is no significant difference in carbon content between unburnt site and burnt site (t = 2.93, df = 28, P < 0.007). Within the 30-60 cm depth of soil, the percentage of carbon at the burnt site had 0.01 to 0.74 (mean 0.38% and standard deviation 0.21) and at the unburnt site had 0.18 to 2.72 (mean 0.93% and standard deviation 0.70). The t-test showed that there is no significant difference in carbon content between the unburnt and burnt sites (t = 2.93, df = 28, P < 0.007).

4.3.7 Total nitrogen

Again in Table 6, the percentage of total nitrogen within (0-30 cm) at the burnt site range from 0.01 to 0.26 (mean 0.09% and standard deviation 0.06), and at the unburnt site 0.30 to 0.75(Mean 0.45% and Standard deviation 0.13). The t-test showed that the total nitrogen in unburnt site is significantly greater at the burnt site (t = 10.21, df = 28, P < 0.001). And also within the 30-60 cm depth of soil in the burnt site had 0.04 to 0.15 (mean 0.08% and standard deviation 0.03), and at the unburnt site had 0.36 to 0.62 (mean 0.49% and standard deviation 0.11). The t-test showed that total nitrogen within the 30-60 cm depth of soil in unburnt site is significantly greater than at the burnt site (t = 16.20, df = 28, P < 0.001).

4.4 Correlation coefficients between analysed soil parameters

4.4.1 Sites of charcoal production

Table 7: Values of Pearson correlation between top soil parameters at burnt site; K = potassium, C= carbon, Na = sodium, Ca = calcium, OM = Organic matter, Mg = magnesium, EC = Electrical conductivity, TN = Total nitrogen and HC = Hydraulic conductivity

Variables	SAND	CLAY	SILT	K	Na	Ca	Mg	C	OM	pH	EC	TN	HC
SAND	1												
CLAY	-0.806**	1											
SILT	-0.759**	0.236	1										
K	0.481*	-0.501**	-0.243	1									
Na	0.245	-0.263	-0.133	0.692**	1								
Ca	0.266	-0.007	-0.432*	-0.014	0.111	1							
Mg	0.143	-0.066	-0.293	0.313	0.206	-0.262	1						
C	0.328	-0.431*	-0.097	0.702**	0.641**	-0.055	0.276	1					
OM	0.301	-0.411*	-0.076	0.700**	0.660**	-0.077	0.293	0.994**	1				
pH	0.028	-0.067	-0.006	0.191	0.133	0.212	0.108	0.206	0.167	1			
EC	0.411*	-0.448*	-0.222	0.571**	0.725**	-0.372*	0.235	0.645**	0.648**	0.193	1		
TN	0.095	-0.125	-0.022	0.454**	0.305	-0.045	0.018	0.338	0.335	0.078	0.244	1	
HC	0.750**	-0.888**	-0.256	0.384*	0.140	0.086	0.054	0.414*	0.394*	-0.029	0.355	0.083	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).
Soil properties such as magnesium, sodium, calcium and potassium measured in (Cmol (+) kg^{-1}), sand, clay, silt, total nitrogen and organic carbon measured in (%), electrical conductivity (µS/cm3) and hydraulic conductivity (cm h^{-1}).

Table 7 gives correlations between analysed parameters in soil samples taken from sites of charcoal production. Relationships between soil parameters within burnt sites were analysed using Pearson's correlation coefficients. Positive significant correlation were observed between K and Sand (r = 0.48), Na and K (r = 0 .69), C and K (r = 0.70), C and Na (r = 0.64), OM and K (r = 0.70), OM and Na (r = 0.66), OM and C (r = 0.99), EC and Sand (r = 0.41), EC and K (r = 0.57), EC and Na (r = 0.73), EC and C (r = 0.65), EC and OM (r = 0.65), TN and K (r = 0.45), HC and Sand (r = 0.75), HC and K (r = 0.38), HC and C (r = 0.41), HC and OM (r = 0.39). Figure 6 (a) and (b) shows positive significant correlations between C and K as well as EC and Na at burnt and unburnt sites.

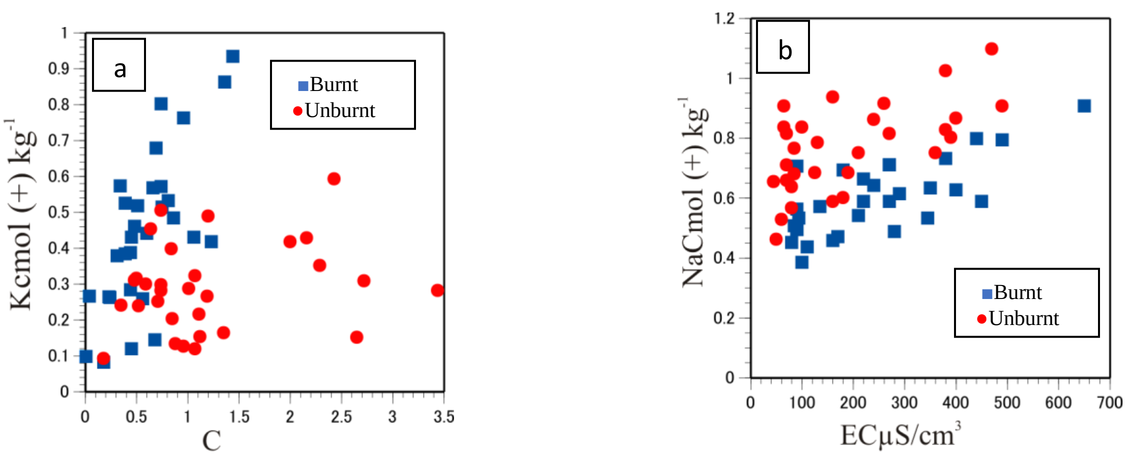


Figure 6: *(a) and (b): Correlations of soil parameters at Burnt and Unburnt sites*

On the other hand, negative significant correlation is found between Clay and Sand (r = -0.81), Silt and Sand (r = -0.76), K and Clay (r = -0.50), Ca and Silt (r = -0.43), C and Clay (r = -0.43), OM and Clay (r = -0.41), EC and Clay (r = -0.45), EC and Ca (r = -0.37), HC and Clay (r = -0.89).

However, there were no significant correlations observed between Silt and Clay (r = 0.24), K and Silt (r = -0.24), Na and Sand (r = 0.25), Na and Clay (r = -0.26), Na and Silt (r = -0.13), Ca and

Sand (r = 0.27), Ca and Clay (r = -0.01), Ca and K (r = -0.01), Ca and Na (r = -0.11), Mg and Sand (r = 0.14), Mg and Clay (r = -0.07), Mg and Silt (r = -0.29), Mg and K (r = 0.31), Mg and Na (r = 0.21), Mg and Ca (r = -0.26), C and Sand (r = 0.33), C and Silt (r = -0.10), C and Ca (r = -0.14), C and Mg (r = 0.28), OM and Sand (r = 0.30), OM and Silt (r = -0.08), OM and Ca (r = -0.08), and the rest.

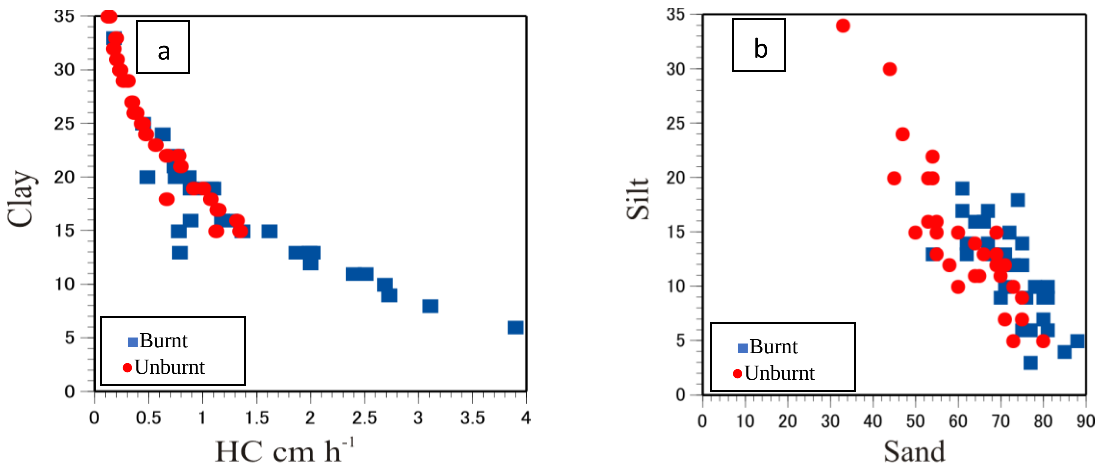


Figure 7: (a) and (b): Correlations of soil parameters at Burnt and Unburnt *sites*

4.5 Sites without charcoal production (unburnt sites)

4.5.1 Correlation coefficients between analysed soil parameters

Table 8: Values of Pearson correlation between top soil parameters at unburnt site; K = potassium, C= carbon, Na = sodium, Ca = calcium, OM = Organic matter, Mg = magnesium, EC = Electrical conductivity, TN = Total nitrogen and HC = Hydraulic conductivity.

Variables	SAND	CLAY	SILT	K	Na	Ca	Mg	C	OM	pH	EC	TN	HC
SAND	1												
CLAY	-0.850**	1											
SILT	-0.875**	0.494**	1										
K	-0.075	0.024	0.111	1									
Na	-0.388*	0.334	0.351	0.559**	1								
Ca	-0.381*	0.435*	0.256	0.253	0.406*	1							
Mg	-0.246	0.138	0.269	-0.006	0.177	0.001	1						
C	0.147	-0.194	-0.068	0.221	0.043	-0.183	0.184	1					
OM	0.178	-0.240	-0.076	0.225	0.010	-0.208	0.178	0.995**	1				
pH	-0.488**	0.353	0.491**	0.432*	0.511**	0.410*	0.128	0.082	0.059	1			
EC	-0.600**	0.575**	0.485**	0.287	0.613**	0.634**	0.140	-0.120	-0.164	0.516**	1		
TN	-0.219	0.214	0.140	-0.144	0.021	0.201	-0.051	-0.369*	-0.378*	0.048	0.347	1	
HC	0.825**	-0.951**	-0.491**	-0.113	-0.287	-0.359	-0.105	0.112	0.143	-0.319	-0.493**	-.164	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).
Soil properties such as magnesium, sodium, calcium and potassium measured in (Cmol (+) kg^{-1}), sand, clay, silt, total nitrogen and organic carbon measured in (%), electrical conductivity (µS/cm3) and hydraulic conductivity (cm h^{-1}).

Table 8, gives correlations between analysed parameters in soil samples taken from control (unburnt) sites. Some observations made in terms of positive relationship between soil parameters in unburnt soil samples using correlation of Pearson (Table 8). The results showed positive significant correlations between Silt and Clay (r = 0.49), Na and K (r = 0.56), Ca and Clay (r = 0.44), Ca and Na (r = 0.41), OM and C (r = 0.99), pH and Silt (r = 0.49), pH and K (r = 0.43), pH and Na (r = 0.51), pH and Ca (r = 0.41), EC and Clay (r = 0.58), EC and silt (r = 0.49), EC and Na (r = 0.61), EC and Ca (r = 0.63), EC and pH (r = 0.52) and then HC and Sand (r = 0.83). Figure 8(a) and (b) shows significant correlations between HC and Sand as well as EC and Ca at burnt and unburnt sites.

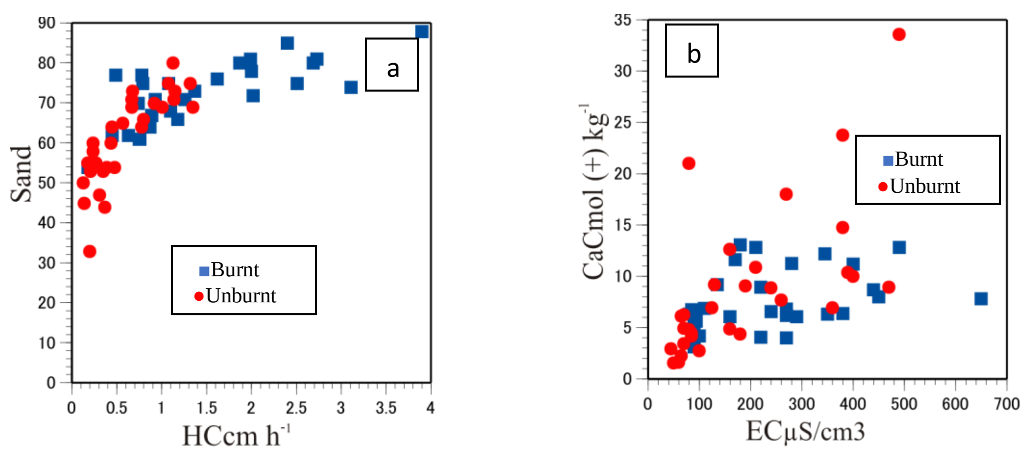


Figure 8 *(a) and (b): Correlations of soil parameters at Burnt and Unburnt sites*

However, negative significant correlation was observed between Clay and Sand (r = -0.85), Silt and Sand (r = -0.88), Na and Sand (r = -0.39), Ca and Sand (r = 0.38), PH and Sand (r = -0.49), EC and Sand (r = -0.60), TN and C (r = -0.37), TN and OM (r = -0.38), HC and Clay (r = -0.95), HC and Silt (r = -0.49), and then HC and EC (r = -0.49). Negative significant correlations as in the case of Clay and Sand as well as Sand and Silt shown in figure 9(a) and (b)

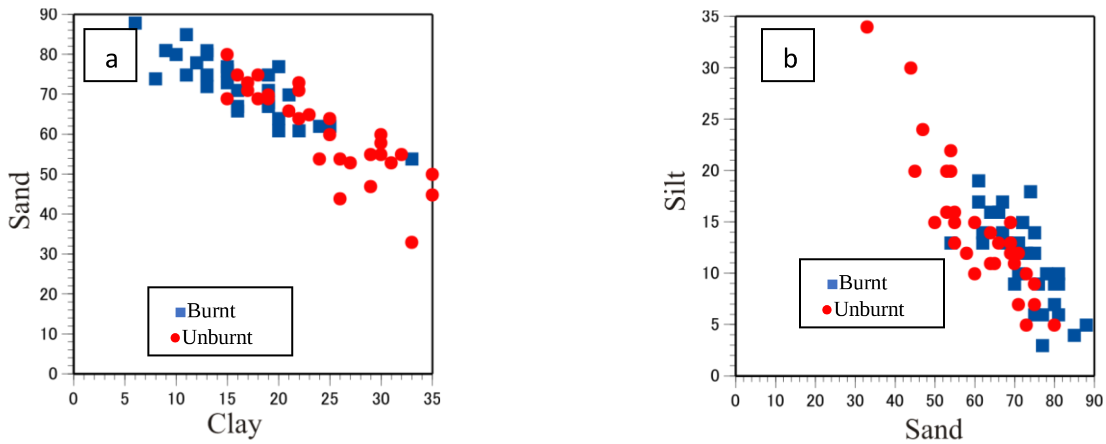


Figure 9 *(a) and (b): Correlations of soil parameters at Burnt and Unburnt sites*

There was however no significant correlation observed in K and Sand (r = -0.08), K and Clay (r = 0.02), K and Silt (r = 0.11), Na and Clay (r = 0.33), Na and Silt (r = 0.35), Ca and silt (r = 0.26), Ca and K (r = 0.25), Mg and Sand (r = -0.25), Mg and Clay (r = 0.14), Mg and Silt (r = 0.27), Mg and K (r = -0.01), Mg and Na (r = 0.18), Mg and Ca (r = 0.01), C and Sand (r = 0.15), C and Clay (r = -0.19), C and Silt (r = -0.07), C and K (r = 0.22), C and Na (r = 0.04), C and Ca (r = -0.18), C and Mg (r = 0.18), OM and Sand (r = 0.18), OM and Clay (r = -0.24), and the rest.

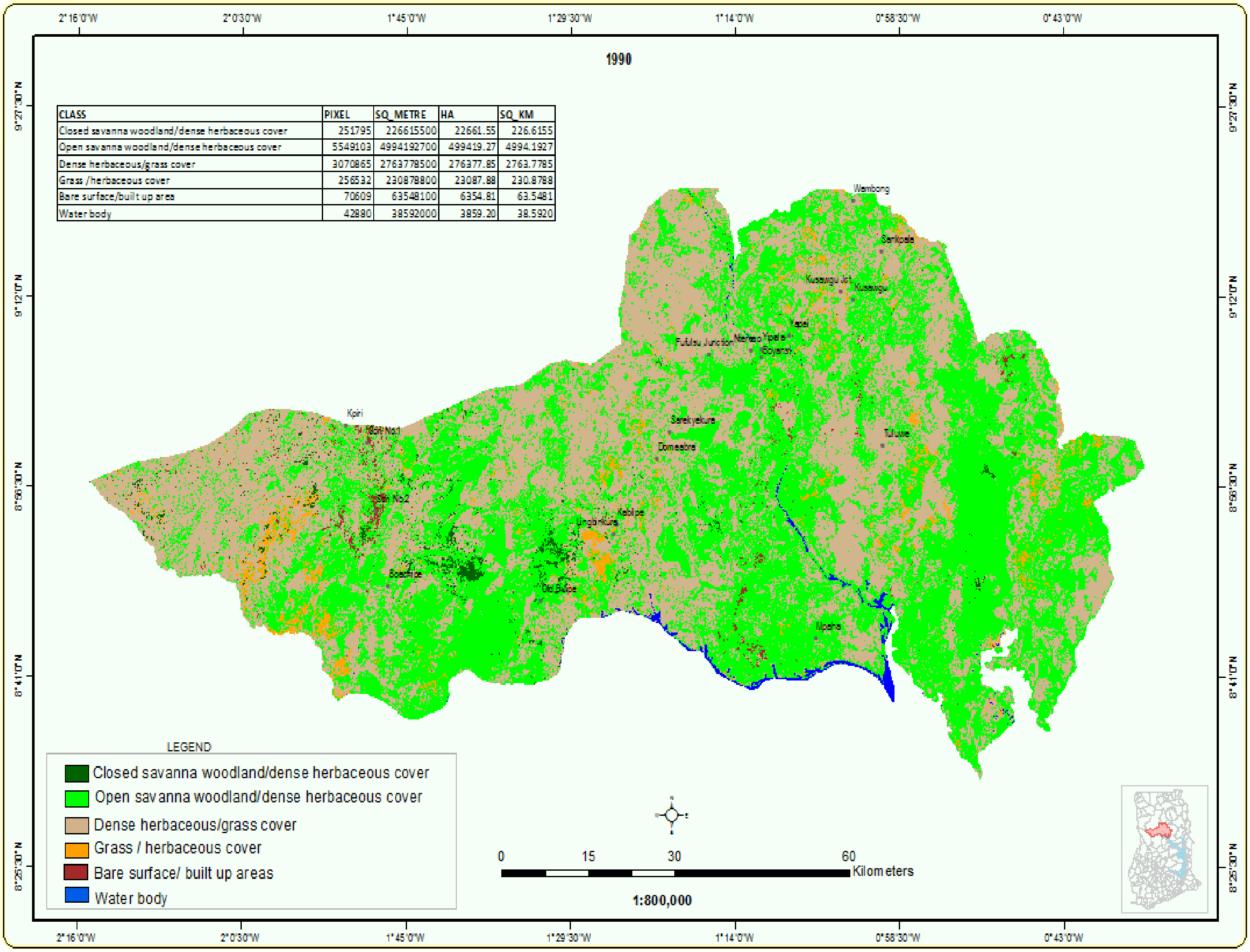
4.6 Land use and land cover change in the Central Gonja District

Figure 10, shows land use and land cover change in the Central Gonja District from 1990 to 2010. From the figure, it is indicated that the land cover of the area has experienced changes in the composition and distribution of woody, herbaceous, built up areas over the 20 year period under study.

4.6.1. Types of land use and land cover

The classification of the satellite images of 1990, 2000 and 2010 based on the land use and the land cover of the Central Gonja District revealed six units of classes. The six units include; a) Closed savannah woodland/dense herbaceous cover (CSW), referred to as a savannah woodland with tree stands of more than 150 per hactare (Agyapong et al., 1999 as cited in Duadze, 2004), b) Open savanna woodland/dense herbaceous cover (OSW), as the cover of trees between 75-150 per hactare, c) Dense herbaceous/grass cover (DHG) considered as savannah vegetation with trees density population between 10-75 per hactare, d) Grass/herbaceous cover (GHC) this class is described as a mixture of grassland (short grasses) and sparse herbaceous cover, movement within this type of vegetation is said to be easy, and e) Bare surface/built up areas (BSU), this is made up of mixture of settlements and exposed surfaces due to intensive farming, sand winning , stone querying and construction activities, and f) Water body (WBO), referred to as land surface area covered by streams, ponds, rivers, dams and others. (See Figure 10)

CLASSIFIED SATELLITE IMAGE OF CENTRAL GONJA DISTRICT - BUIPE (CHARCOAL PRODUCTION SITES)



CLASS	PIXEL	SQ_METRE	HA	SQ_KM
Closed savanna woodland/dense herbaceous cover	251795	226615500	22661.55	226.6155
Open savanna woodland/dense herbaceous cover	5549103	4994192700	499419.27	4994.1927
Dense herbaceous/grass cover	3070865	2763778500	276377.85	2763.7785
Grass /herbaceous cover	256532	230878800	23087.88	230.8788
Bare surface/built up area	70609	63548100	6354.81	63.5481
Water body	42880	38592000	3859.20	38.5920

Figure 10: *Satellite images of vegetation dynamics of the study area in 1990. (Source: produced by Tetteh, Dept of Geography, UG, 2013)*

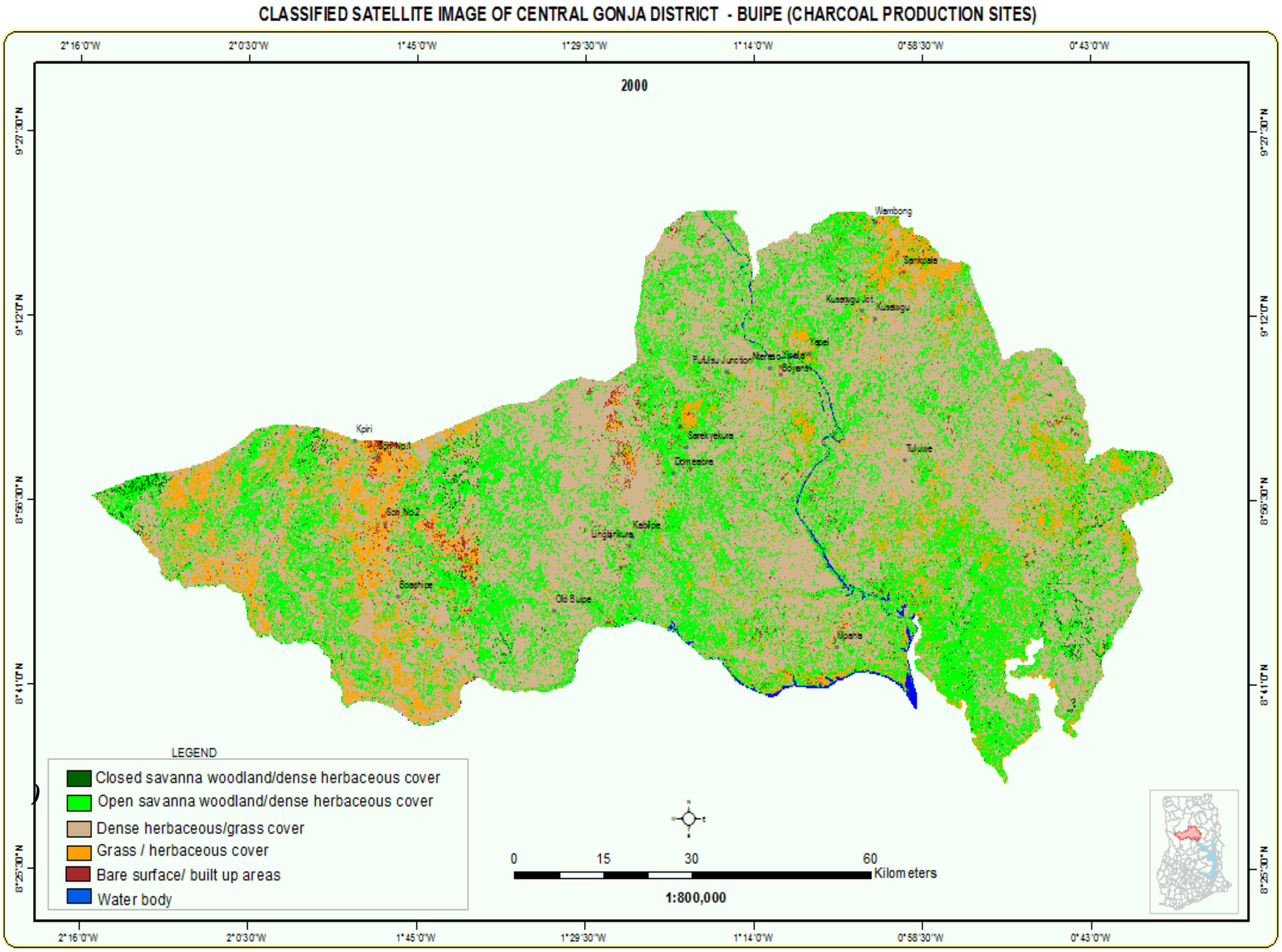


Figure 11: *Satellite images of vegetation dynamics of the study area in 2000. (Source: produced by Tetteh, Dept of Geography, UG, 2013*

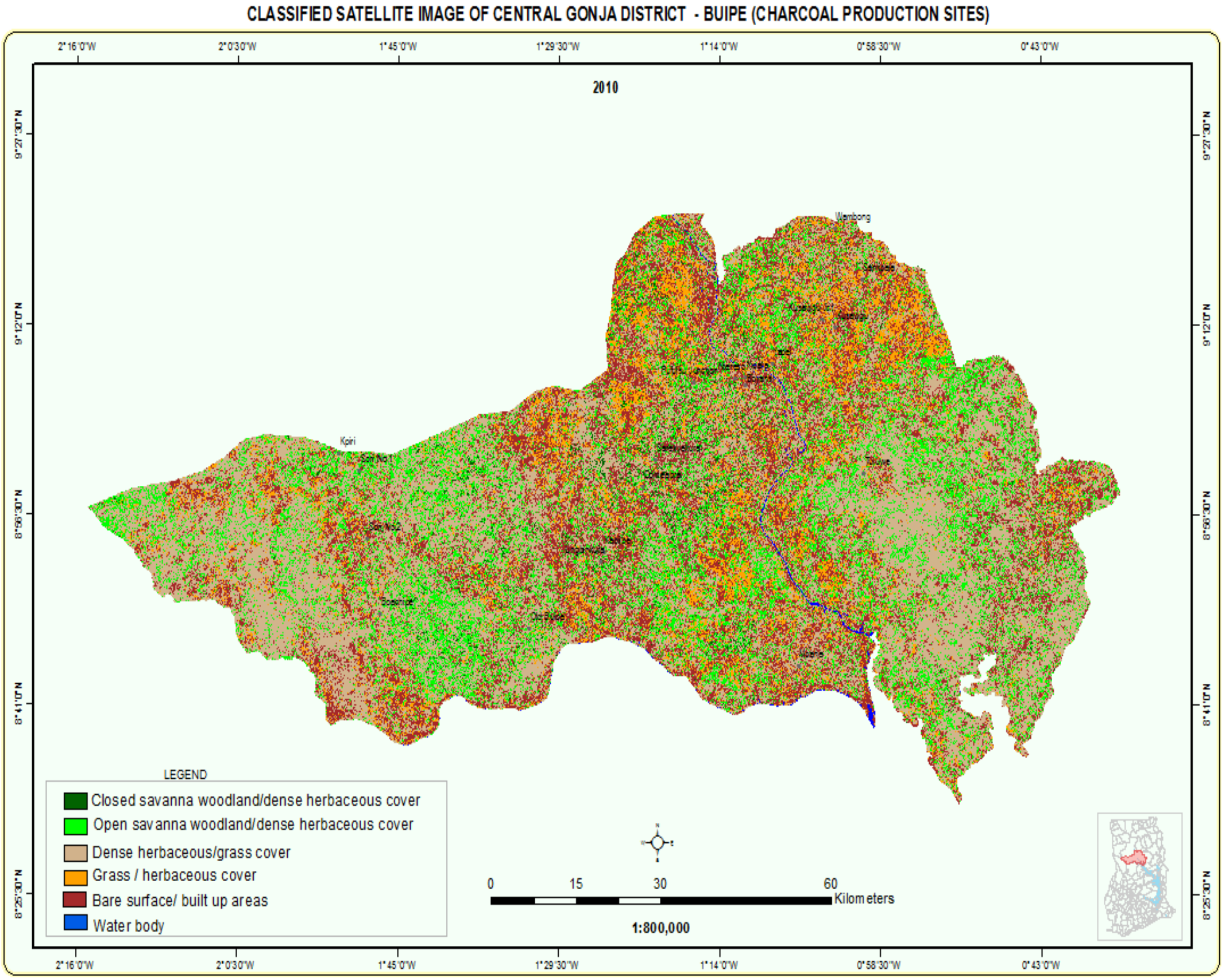


Figure 12: *Satellite images of vegetation dynamics of the study area in 2010. (Source: produced by Tetteh, Dept of Geography, UG, 2013)*

In 1990, 63% of the area was covered by woody vegetation which included; closed savannah woodland/dense herbaceous cover (made up of 2% of the surface area) and Open savannah woodland/dense herbaceous cover (61%) (see Table 9). While the remaining area was covered by dense herbaceous/grass cover, grass/herbaceous cover, bare surface/built up areas and water body. In 2010, there was a reduction of the woody vegetation from 22662 to 11739 ha, and for closed savannah woodland/dense herbaceous cover and from 499419 to 256809 ha. The woody vegetation was replaced by dense herbaceous/grass cover, grass/herbaceous cover, bare surface/built up area.

Table 9: Land use and land cover of Central Gonja District

Land cover type	1990	%	2000	%	2010	%	2010-1990	%
CSW	22662	3	21494	3	11739	1	-10922	-1
OSW	499419	60	352247	42	256809	31	-242610	-29
DHE	276378	33	371261	45	384425	46	108047	13
GHC	23088	3	76086	9	95148	11	72060	9
BSU	6355	1	8069	1	81702	10	75348	9
WBO	3859	0.	2603	0.	1938	0.	-1922	0.

Closed savannah woodland/dense herbaceous cover (CSW), Open savannah woodland/dense herbaceous cover (OSW), Dense herbaceous/grass cover (DHE), Grass/herbaceous cover (GHC), Bare surface/built up areas (BSU) and Water body (WBO).

4.7 Charcoal producers' perception of the environmental impacts of charcoal burning

4.7.1 Socio-demographic characteristics of charcoal producers

The socio-demographic characteristics of the 250 charcoal producers interviewed are presented in Table 10. Majority (80%) of the charcoal producers were women. Charcoal producers ages ranged from less than 20 to over 60 years, however, the majority (49.6%) were those between 20-39 years old. About 18.4% were those less than 20 years old, 16.4% were between 40-59 years old and 15.6% of the respondents were 60 and above years old. 52.4% of the charcoal producers were Gonjas, 42.8% were Mole-Dagomba stock and 4.8% were other ethnic groups. About 47.8% of the charcoal producers were married, 46.5% were single, the rest of the 5.7% were either widowed/widower. Most (40.8%) of the charcoal producers had no formal education, 27.2% had primary education, 19.4% and 12.6% had Junior High and Senior High education respectively. About 32.0% of the charcoal producers were born in Tamale, 20.4% were born in

Buipe, 3.6% were born in Kumasi while 44% of the respondents said they were born in places other than Tamale, Buipe and Kumasi.

Majority (54.8%) of the charcoal producers had household size of less than 5 persons, 26.0% had 5-7 household size, 11.6% had 8-11 household size and 7.6% had 12 and more household size. A large number (52.8% of respondents) had less than three dependents, 39.2% had 3-5 dependents and 8.0% had 5^+ dependents. Income from charcoal trade are spent on food (43.6% respondents), 30.0% spent on cloths, 18.8% spent on school fees and 7.6% on health care. Figure 11 shows the home towns of charcoal producers. Most (55.8% respondents) came from the district, the rest came from 15.2% from Tamale, Damongo, 11.9% 8.5% and Bole, 3.9%.

Table 10: Socio-demographic characteristics of respondents

Characteristic of respondents		Response (%)
Sex	Male	20.0
	Female	80.0
Age	□20	18.4
	20-39	49.6
	40-59	16.4
	60^{+}	15.6
Ethnic background	Gonja	52.4
	Mole-Dagomba	42.8
	Others	4.8
Marital status	Single	46.5
	Married	47.8
	Widow/widower	5.7
Education level	No formal education	40.8
	Primary	27.2
	Junior High School	19.6
	Senior High School	12.4
Place of birth	Kumasi	3.6
	Buipe	20.4
	Tamale	32.0
	Others	44.0
Household size	□5	54.8
	5-7	26.0
	8-11	11.6
	12^{+}	7.6
Number of dependents	□3	52.8
	3-5	39.2
	5^{+}	8.0
Expenditure pattern	Food	43.6
	Clothes	30.0
	School fees	18.8
	Health	7.6

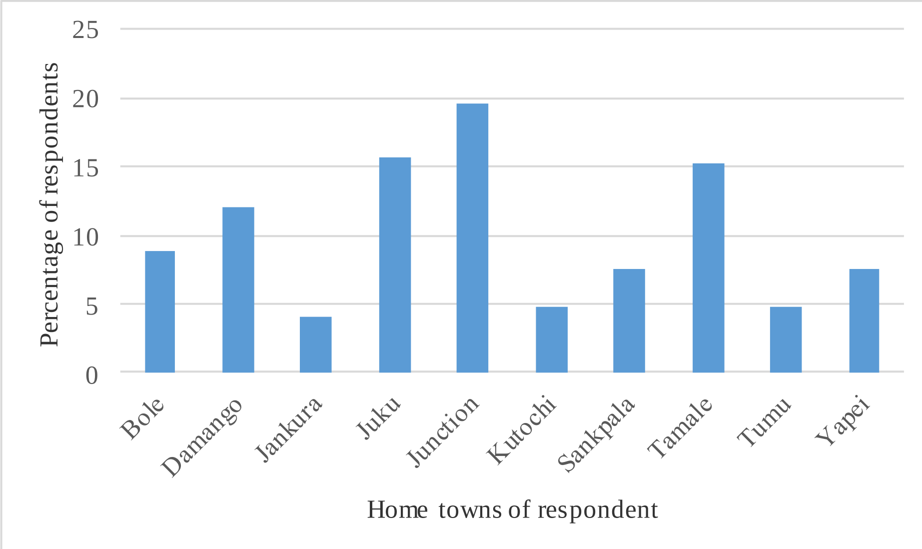


Figure 13*: Home towns of charcoal producers in Gonja Central District*

4.7.2 Impacts of charcoal production on the environment

Table 8 shows the perception of the charcoal producers regarding the impact of charcoal production on the enivronment. According to 60.6% of the respondents, charcoal production have had some negative effects on the enivironment, leading to deforestation (55.4% respondents), bush fire (30.6% respondents) and soil erosion that may link to loss of biodiversity, desertification and climate change.

Table 11: Effects of charcoal production on the environment

Variable/question	Response (%)
Does charcoal production impact on the local environment?	
Yes	60.6
No	39.4
Extent of impact of charcoal production on environment	
High	39.2
Moderate	50.0
Undecided	10.8
Environmental problems associated with charcoal production	
Deforestation	55.4
Bush fires	30.6
Soil erosion	14.0
What goes into choice of spot/location for charcoal burning?	
Open area	96.0
Clustered trees	4.0

4.7.3 Nature of charcoal production and source of raw materials in the district

Perceptions relating to the issue of source of raw materials for charcoal production are presented in Table 12. Majority (92%) of the charcoal producers used live trees, 8% used dry wood/trees for charcoal production. About (83.2%) said it was not easy to get wood/raw materials for charcoal production, while 16.8% said they did not know. Majority (92.4%) said charcoal producers do not replace/plant trees cut for burning charcoal, 7.6% said they do.

Table 12: Nature of raw materials

Variable/question	Response (%)
Constituents of raw materials for charcoal production	
Trees	92.0
Drywood	8.0
Access to raw materials	
Not easy	83.2
Don‘t know	16.8
Source of raw materials	
Reserved land	7.6
Family land	23.6
Communal land	68.8
Do charcoal producers replant/replace the trees they cut?	
Yes	7.6
No	92.4

4.7.4 Reasons for charcoal production in communities

Reasons for charcoal production in the communities are presented in Table 13. The charcoal business seems to be a matter of succession in the area, as 63.2% of the respondents indicated they learnt the trade from their parents or closed relatives. Charcoal is generally produced from April to June (80.8% of respondents) which coincide with the rainy season, the right time to produce charcoal according to the producers. Most (96%) of the charcoal producers used traditional/earth mound method to burn charcoal in the district. Most (52% of respondents) cited ready market, 43.2% said the need for cash income and 4.8% said lack of skills were reasons given by charcoal producers for going into the trade. Trees exempted from charcoal burning according to (54.8% respondents) were based on economic reasons, while 45.2% said it was based on tradition. Majority (85.2%) of the charcoal producers' burn charcoal all year round, 14.8% said they burn charcoal seasonally. About 60% of the charcoal producers said they use 3-4 weeks to produce a cycle of charcoal for sale, 12.4% use 1-2 weeks and 25.6% use 5 and more weeks. Majority (96%) of the charcoal producers have used traditional/earth mound method to burn charcoal, only 4% used other methods.

Table 13: Reasons for charcoal production

Variable/question	Response (%)
Period of year when charcoal production is deemed most suitable	
January-March	19.2
April-June	80.8
Time (years) spent in the charcoal trade by respondents	
□1	4.8
1-3	19.2
4-6	18.8
7-9	14.8
10+	42.4
Reasons for going into charcoal trade	
Need for cash income	43.2
Availability of market	52.0
Lack of skills	4.8
Mode of getting into the charcoal production trade	
Apprenticeship	63.2
By myself	36.8
Are some trees exempted from charcoal production?	
Yes	100.0
No	0.0
Reasons why certain trees are exempted from charcoal production	
Tradition	45.2
Economic	54.8
Frequency (how often) of charcoal production by respondents	
Seasonally	14.8
All year round	85.2
Average time (in weeks) spent on producing one cycle of charcoal	
1-2 weeks	12.4
3-4 weeks	62.0
5+ weeks	25.6
Commonly used method of charcoal production in the community	
Traditional/earth mound	96.0
Other	4.0

CHAPTER FIVE

DISCUSSION

5.1 Impact of charcoal production on soil

The analysis of soil particle size shows a significant difference between burnt and unburnt in the top 0-30 cm in clay and sand but showed no similar difference in the 30-60 cm. This however, was different in the case of silt which showed no significant difference in both burnt and unburnt or at the two different levels of soil samples. This determination runs contrary to the findings of (Ogundele et al., 2011), who did their work on the impacts of charcoal production on soil properties in the derived savannah, Oyo State in Nigeria, and concluded there were no significant difference in soil particle size composition between charcoal burning site and the control site.

It however, confirmed Oguntunde et al. (2008) work on the impacts of charcoal production on soil properties in Ghana. And as in the case of Oguntunde el al. (2008) the significant increase in soil physical properties such as sand and clay content in charcoal burning sites compared to control sites could come about due to the exposure of the soil to high temperatures resulting in the fusion of clay and silt particles into sand-sized.

The results also showed significant difference in the mean values of soil properties like total nitrogen, hydraulic conductivity, potassium and sodium of both between the burnt and unburnt sites at the top 0-30 cm under consideration at 5% confidence level. Except in the case of total nitrogen which has shown significant difference at both two sample levels, the significant difference seems to be limited to the top soils in all the other cases. Oguntunde et al., 2008, also discovered a significant differences in burnt and unburnt sites in terms of hydraulic conductivity of (P < 01). But this was not the case with regards to results of potassium, sodium and total nitrogen. They noted that due to the fusion because of high temperatures the coarsening of severely heated surface soils may eventually lead to a poor water-holding capacity impacting on hydraulic conductivity of soil at the burning site.

According to Ogundule et al., (2011), sodium has the tendency of doubling its content under burnt site. Some of the reasons associated with these differences in results in different countries or even within countries in the literature, are mostly attributed to different parent materials of soils, existing soil nutrients as well as sampling periods. The results showed mean organic matter and carbon increased slightly at all the levels in the burnt over the unburnt sites, similar to (Ogundule et al., 2011). The mean values of pH and electrical conductivity appeared to have no difference at all, in both burnt and unburnt as well as the two different levels. This was however contrary to the findings of (Ogundule et al., 2011).

5.2 Relationship between soil parameters

There were both positive and negative correlations found between soil parameters in both burnt and unburnt samples.

The analysis of soil parameters shows positive significant correlation were found between K (Sand, Na, Mg, C, EC and OM), Na (Mg, C and OM) and OM (HC, EC and Mg) as shown in figure 14(a) and (b) below. According to Dennis et al. (2013) the effect of burning on these soil element is significant especially when soils are collected immediately after burning without been allowed sometime to mineralised. It is also, in line with Hubbert et al. (2006) analysis of burning on soil properties.

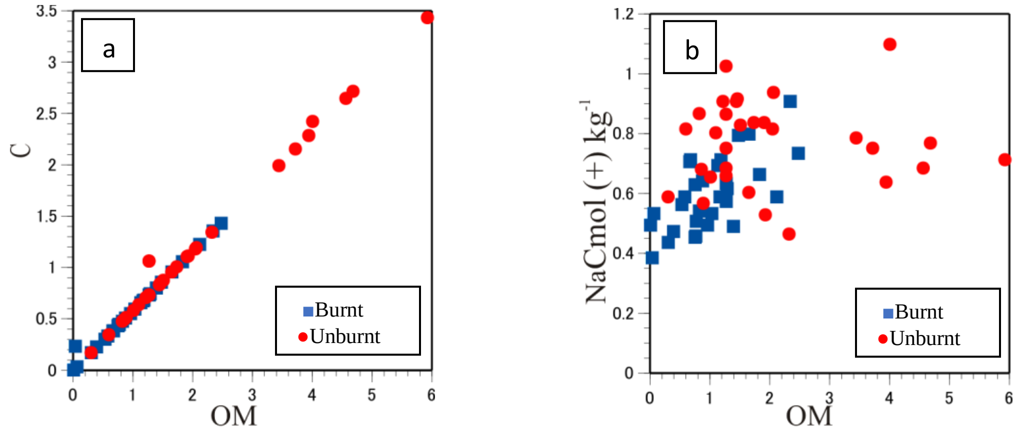


Figure 14 *(a) and (b): Correlations of soil parameters at Burnt and Unburnt sites*

While negative significant correlation appeared between Clay (Sand, K, OM, HC and C), also between Silt and Sand, a few of which are illustrates in figure 15(a) and (b) below. In explaining heating effect on soil texture, Chadle et al. (1983) assessed that excessive heat (>400^{o}C) as pertain in charcoal production can alter clay texture by aggregating clay particles into stable sand-side particles making the soil texture coarse and easily erodible.

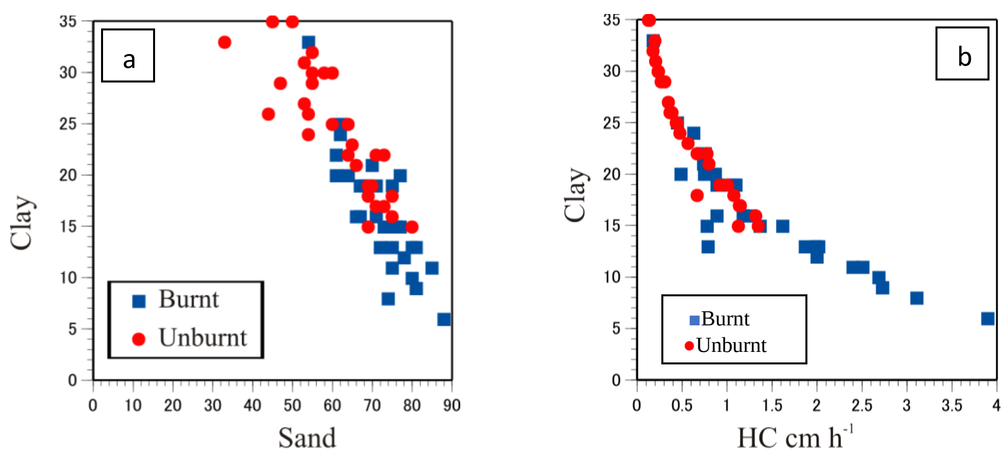


Figure 15 *(a) and (b): Correlations of soil parameters at Burnt and Unburnt sites*

And a few others which did not show either positive or negative correlation at all. The unburnt sites also showed positive significant correlation between Silt (Clay, EC and pH), Na (pH, K and EC), EC and pH, HC and Sand. And negative significant correlation between Sand (Clay, Silt, Na, EC and pH), Silt and HC, HC and EC, then HC and Clay. And few others been neither positive nor negative significant correlation. There was no similar correlation determination in the available literature to compare, but similar works on the correlation between physico-chemical properties and available nutrients in sandy loam soils by Chaudhari et al., (2012), shows similar correlations between soil parameters, which they attributed to burning effects on soil physic-chemical elements.

5.3 Dynamics of land use and land cover

The loss of closed savannah woodland and the corresponding increase in grass/herbaceous as well as bare land are the observable facts from the Landsat TM images of 1990, 2000 and 2010 about the study area. These phenomena are manifestations of the drivers of land use change in a broader scale. However, the uniqueness of certain activities like charcoal production in the area and its contribution to deforestation as it has been overly emphasised in the (FGD) cannot be underestimated. Agyemah et al., 2012, explained how charcoal production contributes to land degradation when they worked the among of wood required to produce a maxi bag of charcoal and the total number of charcoal bags produced in the Upper West region, and concluded that the culture of indiscriminate felling of trees without accompanying planting could be responsible for that.

Results of this study showed that in 1990, 63% of the area was covered by woody vegetation which included; closed savannah woodland/dense herbaceous cover (made up of 2% of the surface area), Open savannah woodland/dense herbaceous cover (61%). While the remaining area was covered by dense herbaceous/grass cover, grass/herbaceous cover, bare surface/built up areas and water body. In 2010, there was a reduction of the woody vegetation, from 22662 to 11739 ha for closed savannah woodland/dense herbaceous cover and from 499419 to 256809 ha.

The loss of woody vegetation was replaced by dense herbaceous/grass cover, grass/herbaceous cover, bare surface/built up area. Modeling results based on charcoal consumption data in Tanzania by Tazanzia Msuya et al., (2011) showed a serious relationship between charcoal production/consumption and deforestation.

With charcoal production being visible all across the district, it would not be out of place to attribute the fast rate of the land use change to this activity like many other ones in the district. More so, looking at the fact that charcoal production is based on exploitation of the natural forest as source of raw. This was confirmed during the focus group discussions and the response of the individual charcoal producers.

5.4 Consequences of charcoal production on the environment

Majority (55.4% respondents) of the charcoal producers identified deforestation as the environmental consequence of charcoal production in the area. Due to the indiscriminate felling of trees for charcoal production in the area, charcoal producers during (FGD) indicated they now travel long distances to access wood for their activities. 83.2% of them said it was difficult to access wood/raw materials for charcoal production. Also, Anang et al. (2011); Agyemah et al. (2012) maintained that charcoal producers acknowledged the impact of their activities on the vegetation in their respective study areas in Ghana. The long term effects of this deforestation could be perminent desertification, siltation of water bodies as well as loss of soil fertility. These and many other environmental impacts of charcoal production have been identified by Msuya et al. (2011), and Oguntunde et al. (2008).

The study identified that persons of different age and sex groups were engaged in charcoal production in the area. However, the most dominant age groups were the 20-39 years (49.6%

respondents) and 40-59 years. Previous works on the environmental impacts of charcoal production Msuya et al. (2011), Mason, (2009) and Agyemah et al. (2012) indicated that the taditinal/mound method of charcoal production is not only ineffective (as conversion rate is very poor) but it also has serious consequences on the land and the air quality. Incidentally, the majority (96%) of the charcoal producers said they use the traditional/mound method of charcoal production. On the background of the people into the charcoal trade, the study established that though most of the people were native Gonjas, some other tribes who were found in the area also endulge in charcoal production.

Charcoal production in the district was identified to be a major source of household income. And those engaged in the trade indicated they spend their income on three principal items (food, cloths, school fees). Both Anang et al. (2011) and Agyemah et al. (2012) independently argued that cash income was a big motivating factor for the charcoal producer, especially the female. The individual interviews as well as (FGD) in the communities also confirmed this previous findings. While the majority of the people said that certain period of the year was more ideal for charcoal production, most (83.2% respondents) maintained that they produce charcaol all year round because of the constant demand of the product by people outside the community. This situation, could prove detrimental to the environment since presure would also be on the resources. The daily demand of charcoal by outsiders is major factor why the trade continue to increase despite the common knowledge of the environmental challenges associated with the trade.

Figure 16: *Charcoal bags ready for sale at Juku*

Charcoal users are said to come from major towns including Tamale, Kumasi, Accra and buyer charcoal ranging from one maxi to truck loads. According to the information gathered during the focus group discussions (FGD), these people mostly pay in cash and that helps them to earn cash income associated with the charcoal business. A trip along the major roads in the area reveals the extent of charcoal burning in the area. Similarly, Chidumayo and Gumbo (2013) and Msuya et al. (2011) revealed that urban dwellers in Tanzania like those in Dar re Salam bought and used most of the charcoal produced in the rural Tanzania.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In this study, key findings have been made regarding the impact of charcoal production on the environment. Evidence from the study showed that charcoal production has significant impact on physical and chemical soil properties.

The analysis of soil particle size shows a significant difference between burnt and unburnt in the top 0-30 cm in clay and sand but showed no similar difference in the 30-60 cm. This however, was different in the case of silt which showed no significant difference in both burnt and unburnt or at the two different levels of soil samples. The results also showed significant difference in the mean values of soil properties like total nitrogen, hydraulic conductivity, potassium and sodium of both between the burnt and unburnt sites at the top 0-30 cm under consideration at 5% confidence level. Except in the case of total nitrogen which has shown significant difference at both two sample levels, the significant difference seems to be limited to the top soils in all the other cases. There were both positive and negative correlations found between soil parameters in both burnt and unburnt samples. The analyses of soil parameters shows positive significant correlation were found between K (Sand, Na, Mg, C, EC and OM), Na (Mg, C and OM) and OM (HC, EC and Mg).

At the same time, it was discovered from the Landsat TM images of the 1990, 2000 and 2010 that the regular harvesting of trees for the production of charcoal in the area alongside other land use practices had led to change in the vegetation of the district. Part of this concluding chapter has therefore been dedicated to some recommendations based on these findings.

Remote sensing data and GIS classification of Landsat TM images of the area strongly suggest that land use and land cover have changed over the study period, from 1990 to 2010. There appears to be a reduction of the pristine guinea savannah vegetation of the area (closed woody savannah vegetation) from 22,662 to 11,739 ha, from 1990 to 2010. However, the grass/herbaceous and the built up areas increased from 23,088 to 95,148 and 6,355 to 81,702, respectively, within the same period.

The reduction in closed savannah woodland vegetation, and the expansion of grass/herbaceous and bare/built up areas can be attributed to the indiscriminate tree felling for charcoal burning and other land use types in the area. The observation is made based on the information gathered from the focus group discussions and also the findings from the interview guide in which charcoal producers said charcoal burning causes deforestation, bushfires and soil erosion. This may have direct or indirect impact on climate change.

Discussions with focus groups indicates that raw materials (basically trees) for charcoal production are now scarce and difficult to come by compared to five years ago due to charcoal production. The impact of this is the gradual expansion of dryland conditions in most parts of the areas.

Another troubling finding in this study is related to charcoal production taking place within the natural reserve, the Yakombo forest, Bouchipe in Buipe. The Bouchipe community is within the Yakombo forest reserve, but the burning of charcoal which residents of the community say is practically illegal in the reserve area is a threat to the forest reserve. This is more so, because charcoal production in the District is based on indiscriminate felling of trees and charcoal producers use the traditional/earth mound method of charcoal burning considered to have low charcoal convertion ratio compared to modern methods. At the same time, the Forestry Commission appears helpless to stop charcoal activities in the reserve due to inadequate staffing and logistical constraints.

6.2 Recommendations

Based on the findings, the following recommendations are made for consideration in terms of combating the environmental challenges associated with the charcoal trade in the research area.

In the first place, there is the need for intensive environmental education in the area, importantly among charcoal producers. This also future prominently from the focus group discussions held in the communities. Discussants, were of the opinion that a better understanding of sustainable charcoal production through education could serve both their interest as well as the environment.

Secondly, the Central Gonja District Assembly should as a matter of urgency, initiate or forge a workable collaboration with the charcoal producers. This, the assembly could do by taking the lead and developing community based project proposals on woodlots for funding from the Ghana Environmental Management Project (GEMP) which is current being implemented in the three northern regions considered to be the most desert prone areas in the country. This if well done would provide good source of raw materials for the charcoal producers and also in the long run help grow the habit of tree planting among charcoal producers which is currently lacked by the people. This could be done in collaboration with Forest Commission, Traditional Authorities, Ministry of Food and Agriculture as well as Environmental Protection Agency.

Thirdly, the assembly should collaborate with the traditional rulers of the area to develop workable bye-laws that would have regulate the charcoal trade. This is highly possible since the traditional authorities in the past have shown interest in the direction when they imposed ban on commercial charcoal production but failed to sustained the ban probable due to lack of mechanism of achieving the ban. The district, on the other hand, has the resources to develop feasible mechanisms to bring about sustainability if not outright ban in the sector.

Fourthly, as a long term measure, efforts should be made to build on the existing traditional conservation elements among the people. It was observed that charcoal producers exempted trees like *Butyrospermum parkii* (shea), and *Parkia clappertonniana*, (dawadawa) from charcoal production either due to tradition or economic benefit they drive from those trees. This also has another side, it makes sense to think that if economic trees like mango and cashew plantation is promoted, these charcoal producers who are concerned about getting cash income as indicated in their interview respondents could easily be turned into plantation farmers.

Finally, the district assembly being the central point of initiating development should identify organisations like (New Energy) to help develop efficient tools for charcoal burning in a way to moderning the method of production in order to help improve on the efficiency. This is necessary if alternative livelihood systems are not going to take place anytime soon.

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APPENDICES

Appendix 1: Research interview guide

University of Ghana

Faculty of Science

Environmental Science Programme

Impact of Charcoal Production on Soil properties and Vegetation in the Central Gonja District.

Interview Guide

This interview guide is being administered to residents of some selected charcoal producing communities in the Central Gonja District to assess people's perceptions on the environmental impact of charcoal production.

This interview guide is a partial requirement for the award of Master of Philosophy Degree in Environmental Science. All information is therefore for academic purpose and will be treated very confidentially. Your genuine response is required. Please indicate your answers by ticking and specify by writing where necessary.

Interview Date………………………….. Questionnaire No. ……………………………..

Interviewer ……………………………. Locality ………………………………………..

Section A: Demographic information of respondent

1. Gender of respondent. A) Male ( ) B) Female ( )
2. Age category of respondent. A) < 20 ( ) B) 20-39 ( ) C) 40-59 ( ) D) 60+ ( )
3. Home Town & Region of respondent.

   ………………………………………………………………………………….

4. Place of birth of respondent. A) Buipe ( ) B) Tamale ( ) D) Kumasi ( ) C) Accra ( ) E) others, specify …………………………………………………….

5. Ethnic group of the respondent. A) Gonja ( ) B) Mole-Dagomba ( ) C) Akan ( ) D) Ga-Adangbe ( ) E) Ewe ( ) F) Others, specify……………………………………………………………………

6. Marital status of respondent A) Married ( ) B) Single ( ) C) Widow ( ) D) Divorce ( )

7. Level of education attained by respondent. A) None ( ) B) Primary ( ) C) Junior High ( ) D) Senior High ( ) E) Others, specify……………………………………………………………..

8. Household size of respondent A) <5 ( ) B) 5-7 ( ) C) 8-11 ( ) D) 12+ ( )

9. Number of dependents of respondent A) <3 ( ) B) 3-5 ( ) C) 5+ ( )

10. Which of the following do you spend most of your income on? A) Food ( ) B) Clothes ( ) C) School fees ( ) D) Health ( ) Funerals ( ) E) Others, specify ………………………………………………………………………………..

Section B: Nature of charcoal production and source of raw materials in the district.

11. Which of the following constitutes raw material for charcoal production in the area? A) Trees ( ) B) shrubs ( ) C) Dry wood ( ) D) Wet/live wood ( ) E) Others, specify ……………………………………………………………………………………….

12. How easy is getting raw materials for charcoal production compared to five years back? A) Very easy ( ) B) Easy ( ) C) Not easy ( ) D) Don't know ( )

13. Which of the following sources do charcoal producers get their raw materials? A) Family land ( ) B) Community land ( ) C) Reserved land ( ) D) Private/personal land ( ) E) Others, specify ……………

14. How regular is charcoal produced in this community? A) Daily ( ) B) Weekly ( ) C) Monthly ( ) D) Seasonally ( )
15. On the average, how long would a charcoal producer take to produce one cycle of charcoal? A) 1-2 weeks ( ) B) 3-4 weeks ( ) C) 5+ weeks ( )
16. Do people outside this village use charcoal produced from this village? A) Yes ( ) B) No ( )
17. If yes, how do they pay for the charcoal? A) Through gifts ( ) B) Through loans ( ) C) Through cash ( ) D) Others, specify …………………………………………………………………
18. What method of charcoal production is/are commonly used in the community for charcoal production? A) Traditional Earth Kiln ( ) B) Mobile metal kiln ( ) C) Others, specify……………
19. What period of the year is charcoal production deemed most suitable? A) Jan.-March ( ) B) April-June ( ) C) July-Sept. ( ) D) Oct.-Dec. ( )
20. Apart from tree trunks used, have you used any of the following for charcoal production? A) Water ( ) B) Fire ( ) C) Soil ( ) D) Tree leaves ( ) E) None ( )
21. Has your activities ever led to outbreak of bushfire? A) Yes ( ) B) No ( )
22. Do you also use water for charcoal production? A) Yes ( ) B) No ( )
23. If yes, what is the source of your water? A) Community dam ( ) B) Dug well ( ) C) Nearby stream ( ) D) Others, specify………………………………………………..

Section C: People's perceptions about the environmental impact of charcoal production.

24. What do you say about the state of your local environment? A) Very good ( ) B) Good ( ) C) Poor ( ) D) Very poor ( ) E) Undecided ( )

25. Do you think charcoal production in your area has any impact on the local environment? A) Yes ( ) B) No ( )

26. If yes, to what extent do you think charcoal production has affected the environment of your area? A) Highly ( ) B) Moderately ( ) C) Slightly ( ) E) Undecided ( )

27. Are trees cut for charcoal burning replaced through tree planting by charcoal producers? A) Yes ( ) B) No ( )

28. Type of trees commonly used for charcoal production.

    …………………………………………………………………….

29. What goes into choice of spot/location for charcoal burning? A) Open area ( ) B) Clustered trees ( ) C) Close to stream or river ( ) D) Close to anthill ( ) E) Others, specify……………………………………………………………………………………….

30. In cutting trees for charcoal production, are some trees exempted? A) Yes ( ) B) No ( )

31. If yes, what are some of the reasons for this exemption? A) Tradition ( ) B) Religion ( ) C) Economic ( ) D) Others, specify ………………………………………………………..

32. What are the environmental problems associated with charcoal production? A) Deforestation ( ) B) Bush fires ( ) C) Soil erosion ( ) D) Others, specify

    …………………………………………..

33. What can be done to ensure that charcoal burning activities do not lead to the above environmental problems? A) Environmental education ( ) B) Bye-laws ( ) C) Community woodlots ( ) D) Others, specify ………………………………………………………..

Section D: When, Why and how community members go into charcoal production in the district.

34. What is/are the reasons that motivated you to go into charcoal production? A) Low soil fertility ( ) B) Need for cash income ( ) C) Availability of market ( ) D) Lack of other skills ( ) E) Others, specify………………………………………………………………………

35. How did you get into charcoal production? A) Through apprenticeship ( ) B) By myself ( ) C) By contract ( ) D) Others, specify…………………………………………………………..

Section E: Nature of Charcoal demand in the District

36. Where do you usually sell the charcoal produced? A) In the village ( ) B) District capital ( ) C) Outside the district D) Others, specify……………………………………………..

37. Do consumers prefer charcoal from specific trees to others? A) Yes ( ) B) No ( )

38. How often do the people outside the community comes to buy charcoal here? A) Daily ( ) B) Weekly ( ) C) Monthly ( ) D) Quarterly ( )

39. How is charcoal produced in the area carried away? A) By Head load ( ) B) By Trucks ( ) C) By donkey carts ( ) D) Others, specify………………………….

40. How do middle men/women outside the community pay for the charcoal produced? A) Cash ( ) B) Loans ( ) C) Exchange for other goods ( ) D) Others, specify………………………………………………………..

Appendix 2: Results of analysis of soil properties

Table 3: Analysis of properties of soil within the depths of 0-30 and 30-60cm at both burnt and unburnt sites

		Burnt site (CPS)			Control site (CS)					
Property	**Depth (cm)**	**Mean ± S.D**	**Minimum**	**Maximum**	**Mean ± S.D**	**Minimum**	**Maximum**	***t*-value**	***P-value***	***F - probability***
Clay (%)	0-30	13.7±4.8	6.0	22	24.9±6.1	15	35	5.56	0.001	**
	30-60	17.6±6.0	7.0	32	23.5±6.4	15	33	2.63	0.014	*
Sand (%)	0-30	75.2±8.1	62	88	60.7±11.8	44	80	3.92	0.001	**
	30-60	69.7±7.8	54	80	61.0±10.7	33	75	2.54	0.055	NS
Silt (%)	0-30	9.7±4.7	2.0	16	13.8±7.3	3.0	30	1.84	0.761	NS
	30-60	11.6±5.0	3.0	19	14.6±6.2	9.0	34	1.47	0.154	NS
Potassium Cmol (+) kg^{-1}	0-30	0.52±0.21	0.15	0.94	0.29±0.14	0.12	0.59	3.35	0.002	**
	30-60	0.36±0.21	0.08	0.80	0.29±0.11	0.10	049	1.12	0.274	NS
Calcium Cmol (+) kg^{-1}	0-30	8.57±2.85	4.13	13.10	8.78±6.22	1.59	23.81	0.12	0.905	NS
	30-60	6.72±2.88	3.14	12.26	9.13±8.29	2.33	33.64	1.06	0.302	NS
Sodium Cmol (+) kg^{-1}	0-30	0.66±0.12	0.49	0.91	0.78±0.16	0.47	1.1	2.32	0.028	*
	30-60	0.54±0.10	0.39	0.71	0.76±0.13	0.57	0.94	5.01	0.001	**
Magnesium Cmol (+) kg^{-1}	0-30	1.78±0.36	1.37	2.70	3.28±1.96	1.49	7.94	2.92	0.011	*
	30-60	1.71±0.66	1.01	3.86	5.26±7.14	1.39	27.55	1.92	0.076	NS
Carbon (%)	0-30	0.8±0.3	0.3	1.4	1.5±0.8	0.4	3.4	2.93	0.007	**
	30-60	0.4±0.2	0.01	0.74	0.9±0.7	0.2	2.7	2.93	0.007	**
Organic matter (%)	0-30	1.4±0.6	0.6	2.5	2.5±1.5	0.03	5.9	2.48	0.021	*
	30-60	0.6±0.4	0.01	1.28	1.6±1.2	0.3	4.7	3	0.006	**
pH	0-30	6.4±0.3	6.1	7.0	6.3±0.8	4.8	7.5	0.46	0.659	NS
	30-60	6.4±0.2	6.1	6.7	6.3±0.8	4.5	7.2	0.1	0.923	NS
Electrical conductivity (µS/cm3)	0-30	305.3±149.8	94	650	172.0±121.7	50	380	2.67	0.012	*
	30-60	178.0±113.2	80	400	209.3±157.2	45	490	0.63	0.536	NS
Total Nitrogen (%)	0-30	0.1±0.1	0.01	0.26	0.5±0.1	0.3	0.8	10.21	0.001	**
	30-60	0.08±0.03	0.04	0.15	0.5±0.1	0.4	0.6	16.2	0.001	**
Hydraulic conductivity ($cm\ h^{-1}$)	0-30	1.8±1.0	0.6	3.9	0.5±0.3	0.1	1.1	4.67	0.001	**
	30-60	1.2±0.8	0.2	3.1	0.7±0.4	0.2	1.4	2.29	0.029	*

S.D = Standard deviation, SD = Significantly Different, NS = Not significant

Appendix 3:l Relationship between soil parameters in burnt sites

Values of Pearson correlation between top soil parameters at burnt site; K = potassium, C= carbon, Na = sodium, Ca = calcium, OM = Organic matter, Mg = magnesium, EC = Electrical conductivity, TN = Total nitrogen and HC = Hydraulic conductivity.

Variables	%SAND	%CLAY	%SILT	K_ Cmol (+) kg^{-1}	Na Cmol (+) kg^{-1}	Ca Cmol (+) kg^{-1}	Mg Cmol (+) kg^{-1}	%C	%OM	pH1:1	EC (µS/cm3)	%TN	HC cm h^{-1}
%SAND	1												
%CLAY	-0.806**	1											
%SILT	-0.759**	0.236	1										
K Cmol (+) kg^{-1}	0.481*	-0.501**	-0.243	1									
Na Cmol (+) kg^{-1}	0.245	-0.263	-0.133	0.692**	1								
Ca_Cmol (+) kg^{-1}	0.266	-0.007	-0.432*	-0.014	0.111	1							
Mg Cmol (+) kg^{-1}	0.143	-0.066	-0.293	0.313	0.206	-0.262	1						
%C	0.328	-0.431*	-0.097	0.702**	0.641**	-0.055	0.276	1					
%OM	0.301	-0.411*	-0.076	0.700**	0.660**	-0.077	0.293	0.994**	1				
pH1:1	0.028	-0.067	-0.006	0.191	0.133	0.212	0.108	0.206	0.167	1			
EC (µS/cm3)	0.411*	-0.448*	-0.222	0.571**	0.725**	-0.372*	0.235	0.645**	0.648**	0.193	1		
%TN	0.095	-0.125	-0.022	0.454**	0.305	-0.045	0.018	0.338	0.335	0.078	0.244	1	
HC (cm h^{-1})	0.750**	-0.888**	-0.256	0.384*	0.140	0.086	0.054	0.414*	0.394*	-0.029	0.355	0.083	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Appendix 4: Relationship between soil parameters in unburnt sites

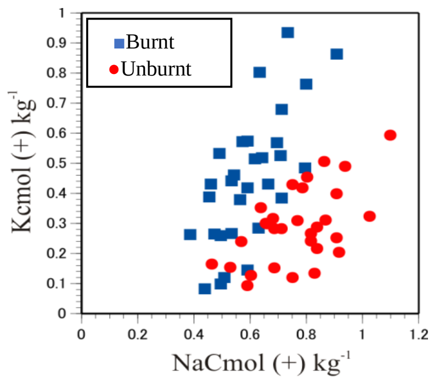
Table 5: Values of Pearson correlation between top soil parameters at unburnt site; K = potassium, C = carbon, Na = sodium, Ca = calcium, OM = Organic matter, Mg = magnesium, EC = Electrical conductivity TN = Total nitrogen and HC = Hydraulic conductivity.

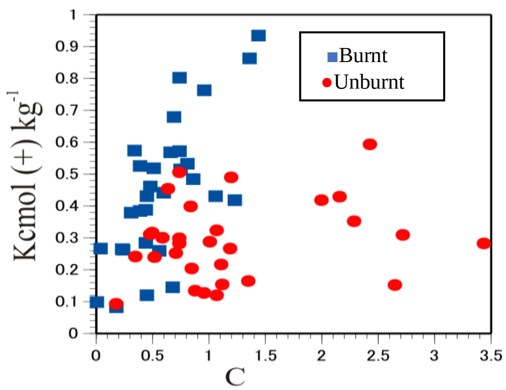
Variables	%SAND	%CLAY	%SILT	K Cmol (+) kg^{-1}	Na Cmol (+) kg^{-1}	Ca Cmol (+) kg^{-1}	Mg Cmol (+) kg^{-1}	%C	%OM	pH1:1	EC (µS/cm3)	%TN	HC (cm h^{-1})
%SAND	1												
%CLAY	-0.850**	1											
%SILT	-0.875**	0.494**	1										
K Cmol (+) kg^{-1}	-0.075	0.024	0.111	1									
Na Cmol(+)kg^{-1}	-0.388*	0.334	0.351	0.559**	1								
Ca Cmol (+) kg^{-1}	-0.381*	0.435*	0.256	0.253	0.406*	1							
Mg Cmol (+) kg^{-1}	-0.246	0.138	0.269	-0.006	0.177	0.001	1						
%C	0.147	-0.194	-0.068	0.221	0.043	-0.183	0.184	1					
%OM	0.178	-0.240	-0.076	0.225	0.010	-0.208	0.178	0.995**	1				
pH 1:1	-0.488**	0.353	0.491**	0.432*	0.511**	0.410*	0.128	0.082	0.059	1			
EC (µS/cm3)	-0.600**	0.575**	0.485**	0.287	0.613**	0.634**	0.140	-0.120	-0.164	0.516**	1		
%TN	-0.219	0.214	0.140	-0.144	0.021	0.201	-0.051	-0.369*	-0.378*	0.048	0.347	1	
HC (cm h^{-1})	0.825**	-0.951**	-0.491**	-0.113	-0.287	-0.359	-0.105	0.112	0.143	-0.319	-0.493**	-.164	1

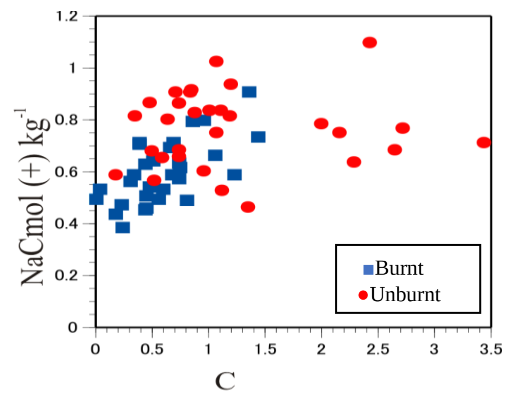
** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

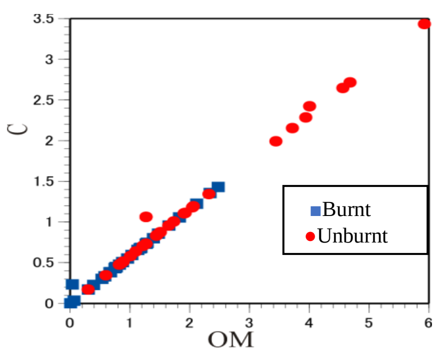
Appendix 5: Graphical relationship between soil parameters in burnt and unburnt sites

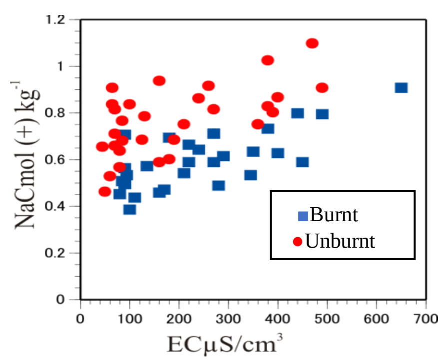
The figures below illustrates significant positive correlation as in the case of Na and K, C and K, C and Na, OM and C, EC and Na, OM and K. Also, significantly negatively correlated such as HC and Clay, Sand and Clay as well as Sand and Silt.

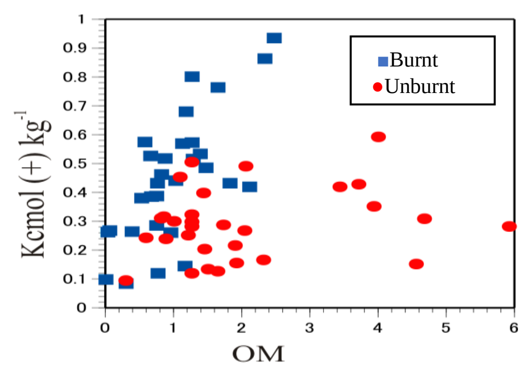


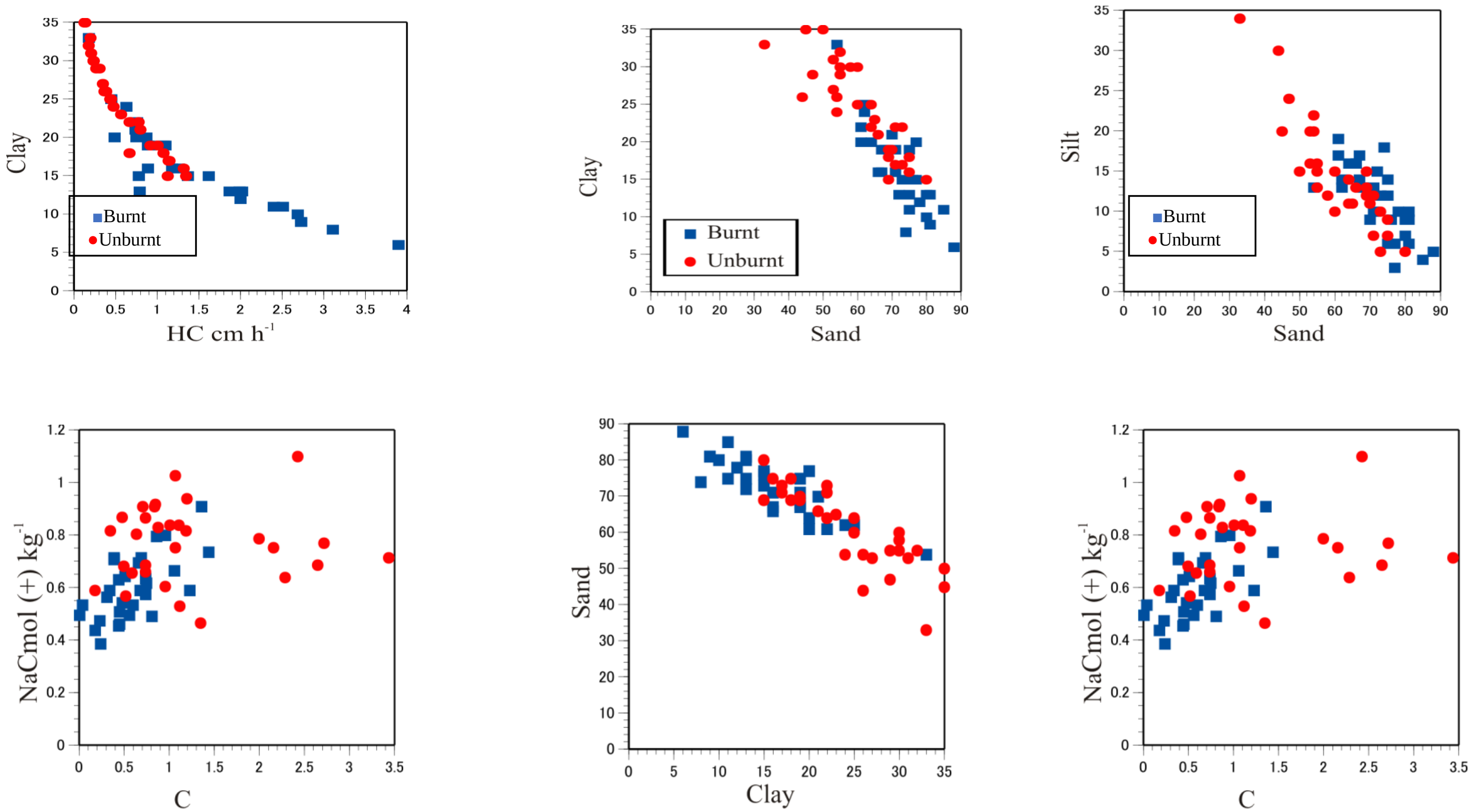


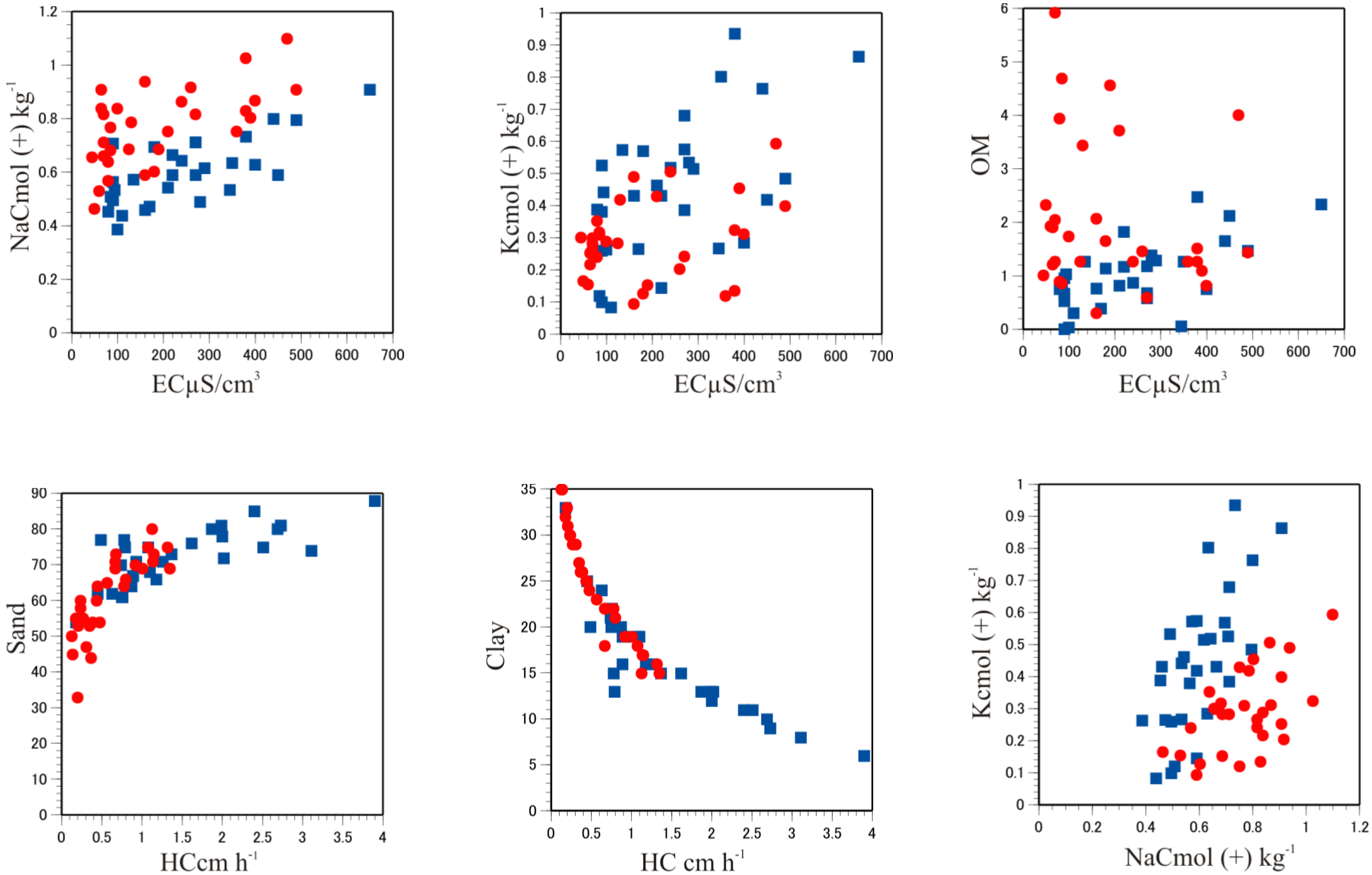









Clay
HC cm h-1
Burnt
Unburnt
Clay
Sand
Burnt
Unburnt
Silt
Sand
Burnt
Unburnt
NaCmol (+) kg-1
C
Sand
Clay
NaCmol (+) kg-1
C


NaCmol (+) kg-1
ECμS/cm3
Kcmol (+) kg-1
ECμS/cm3
OM
ECμS/cm3
Sand
HCcm h-1
Clay
HC cm h-1
Kcmol (+) kg-1
NaCmol (+) kg-1

Appendix-5 Pictures from field visits.

Charcoal bags ready for sale at Juku

Site being mapped for sampling

Soil sample taken for laboratory analysis