“The Economic Cost of Environmental Degradation: A Case Study of Agricultural Land Degradation in Ghana”

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Abstract

Land is a key environment and natural resource assets in Agriculture. It is also the case that the viability of arable land has a direct relationship with productivity. Land degradation caused by soil erosion is a major threat to the sustainability of agriculture. Soil erosion is one of the main forms of land degradation in Ghana, a problem that has been studied and researched by numerous scholars both local and abroad. Since 2006, the agricultural sector's contribution to Gross Domestic Product has declined, possibly because of the negative effects of land degradation i.e. soil erosion challenges among others. The paper assesses the cost of land or soil degradation in the Agricultural Sector and its effect on the economy of Ghana with focus on the on-site effects of soil erosion on agricultural productivity. The study draws on the productivity loss and nutrient replacement cost approaches in estimating the cost of soil degradation in the agricultural sector. The results show the Northern region as the most prone to soil degradation, and that the real cost of agricultural soil degradation as a percentage of real Gross Domestic Product is approximately 2.5% on average, for a 4 year period from 2006 to 2012, which is equivalent to approximately GH¢ 964.92 million in monetary terms. The Sustainable Land Management (SLM) practices would be key in efforts to mitigate land degradation; enhancing agricultural biodiversity, and reducing poverty. SLM should thus be implemented particularly in the northern part of the country.

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List of Abbreviations/Acronyms

₱	Philippine Peso
AEZ	Agro-Ecological Zones
AFAMIN	African Agricultural Market Information Network
AgGDP	Agricultural Gross Domestic Product
AR	Ashanti Region
BAR	Brong Ahafo Region
CEA	Country Environmental Analysis
CLA	Land Area under crops
CMF	Crop/Vegetation Management Factor
CoASD	Cost of Agricultural Soil Degradation
CoED	Cost of Environmental Degradation
CR	Central Region
CSIR	Council for Scientific Industrial Research
DFID	Department for International Development
EEA	European Environmental Agency
EPA	Environmental Protection Agency
EPIC	Erosion Productivity Impact Calculator
ER	Eastern Region
FAO	Food and Agriculture Organization
GAR	Greater Accra Region
GDP	Gross Domestic Product
GLASOD	Global Assessment of Human Induced Soil Degradation
GPRS	Ghana Poverty Reduction Strategy
GSS	Ghana Statistical Service
ha	Hectare
ISSER	Institute of Statistical, Social and Economic Research
Kg	Kilograms
MoFA	Ministry of Food and Agriculture
MUSLE	Modified Universal Soil Loss Equation
NPK	Nitrogen, Phosphorous, Potassium
NR	Northern Region
NRC	Nutrient Replacement Cost

NREG	Natural Resource and Environmental Governance
ODA	Official Development Assistance
PPP	Policies, Plans, and Programmes
PSL	Potential Soil Loss
QYF	Crop Yield Loss
Rp	Indonesian Rupiah
RUSLE	Revised Universal Soil Loss Equation
SEA	Strategic Environmental Assessment
SLM	Sustainable Land Management
SNL	Nutrients Lost in the form of NPK
SoE	State of the Environment
SRID	Statistics Research and Information Directorate
TLA	Total Land Area
TNL	Total Quantity of Nutrients Eroded from Soils
TNRC	Total Nutrient Replacement Cost
TVPL	Total Value of Crop Productivity Loss
UER	Upper East Region
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USLE	Universal Soil Loss Equation
UWR	Upper West Region
VR	Volta Region
WDI	World Development Index
WEPP	Water Erosion Prediction Project
WR	Western Region

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Environmental degradation is one of the major threats facing humanity in recent times. It includes deforestation, desertification, pollution, and climate change, all of which are issues of concern for the international community. Environmental degradation increases the vulnerability of many societies and contributes to the scarcity of resources. Fundamentally, the environment provides the resource base for the economic development of many nations.

The environment refers to the natural and physical surroundings and the relationship of people with it. It includes land, water, air, structures, living organisms, and the social, cultural and economic conditions. The continuity of human life is premised on how sustainably environmental resources are used. For instance land, as an agricultural resource is an important asset upon which the livelihoods of people especially the poor and vulnerable, largely depend. There is thus, the need to protect, conserve, and use environmental resources in a way that ensures sustainable economic growth and development in the long run. Environmental resources are also an essential part of the overall production process i.e. both marketed resources such as metals, minerals, and land, etc. and non-market resources (clean air, favourable weather conditions, biodiversity and ecosystem services, etc.).

Environmental degradation has become a topical issue of intense discussion at diverse levels of decision-making in recent times. It is the deterioration of the natural environment through human activities and natural disasters (United Nations, 1997). UNDESA (2011) notes that environmental degradation and climate change contribute to the increasing occurrence of disasters which are linked to natural hazards". It is also one of the ten threats officially cautioned by the High Level Threat Panel of the United Nations. The United Nations International Strategy for Disaster

Reduction defines environmental degradation as "the reduction of the capacity of the environment to meet social and ecological objectives, and needs". Some forms of environmental degradation may include; deforestation, pollution (air, water, and noise), soil erosion, etc.

There is considerable pressure on the environment in recent times due to rising global population coupled with the attendant problems of urbanization and increased human and industrial activities. These factors have led to the deterioration of the environment through pollution, deforestation, improper disposal and management of household and industrial waste, loss of biodiversity and the alteration of ecosystems.

In Ghana, the environment and natural resources that serves as the base for socio-economic activity, and on which the population's livelihood depend are being depleted at an unsustainable rate. According to the Country Environmental Analysis (CEA) carried out by the World Bank in 2006,[1] more than 50 % of forest areas have been converted to agricultural land by clearance for perennial or annual cropping and slash-and-burn cultivation practices. Crop yields have stagnated, and productivity has declined because of rampant soil erosion. Fish, timber, and non-timber forest product stocks are decreasing rapidly. Coastal towns are facing severe water shortages during the dry season. Wildlife populations and biodiversity are in serious decline. Health-related pollution i.e. indoor and outdoor air pollution, and water and sanitation issues have also emerged as serious health threats for the majority of the population.

[1] The World Bank Country Environmental Analysis (CEA) Report presented an assessment of the country's environmental priorities, the environmental implications of key economic and sector policies, and the country's institutional capacity to address them. It also proposed practical management, institutional, and policy solutions to handle issues of natural resource management, environmental degradation, and sustainability of growth.

1.2 Problem Statement

In 2006, the Country Environmental Analysis (CEA) carried out by the World Bank suggested that the estimated Cost of Environmental Degradation in Ghana (CoED) was 10 % of Gross Domestic Product (GDP) whiles the economy grew at 6 %. The cost of environmental degradation to GDP represented almost one half of Ghana's US$1.5 billion annual Official Development Assistance (ODA). This pointed to the fact that the country was on an unsustainable developmental path and demanded that steps be taken to address these environmental problems. The incidence of environmental degradation particularly land degradation is on the ascendancy. Soil erosion is estimated to cost around 2 % and forest degradation, about 5 % of the national GDP (World Bank, DFID, ISSER, 2005). This is equivalent to about US$ 530 million, or more than one third of Ghana‘s annual ODA.

The effect of this is that prices of commodities and malnutrition may rise as land expansion and technological development fail to compensate for decreasing soil productivity. Soil degradation is thus likely to impact greatly on incomes and output from the agricultural sector as yields decline and input costs rise especially in irrigated, rain-fed, and densely populated poor quality lands. Already, the agricultural sector's contribution to national output has dwindled compared to other sectors of the economy. If essential steps are not taken to mitigate this problem, gains from the sector will be eroded substantially leading to huge unemployment[2]in the country, food shortages, hikes in rural-urban migration, and other attendant problems.

Other studies have also shown that land degradation and its extreme form, desertification is a growing threat. It manifests itself in the form of soil erosion, loss of vegetative cover of land, biodiversity erosion, and breakdown of natural ecosystems, aridity among others. Out of the

[2] It is estimated that more than 50% of the country's population is into agriculture.

country's total land's surface, 23 % is prone to very severe sheet and gully erosion, 46 % to severe erosion and 31 %, moderate to slight erosion. Soil erosion is common and severe in areas of extensive vegetation removal in all the major ecological zones.

Increased cultivation has also contributed to reduced vegetation cover, and the precipitation pattern, with heavy rains on a very dry unprotected soils, thereby increasing the risk of soil erosion. When soil erosion occurs, nutrients and organic matter are removed, which affects soil fertility and agricultural production capacity. With agriculture as a major source of revenue, and employing about 50 % of the population, it can also be concluded that poverty is highly linked to the access and use of land for economic activities.

1.3 Research Questions

The study is driven by a number of plausible questions that border on environmental degradation. It has been argued that, degradation of the environmental resource base will eventually put economic activity itself at risk if measures are not taken to remedy the situation. This study therefore seeks to answer the following questions; what is the cost of agricultural soil degradation in Ghana; how does the loss in productivity affect the prospects of growth in the national output; and how can issues of agricultural soil degradation be sustainably addressed?

1.4 Objectives of the Study

The main objective of the study is to estimate the cost of environmental degradation of agricultural soils and the factors that drive this degradation. The specific objectives of the study however are as follows:

- i) To determine the economic Cost of Agricultural Soil Degradation (CoASD).
- ii) Analyze the trend of agricultural soil degradation from year 2006, 2008, 2010 and 2012, and its effect on the growth in output.

iii) Finally, based on the findings of the study; recommendations and some policy initiatives will be discussed aimed at mitigating agricultural soil/land degradation in Ghana.

1.5 Research Methodology

The process of estimating the cost of environmental degradation involves quantifying or placing a monetary value on its consequences, which often implies estimating the changes in soil productivity. The cost of soil loss is undertaken by estimating the on-site and off-site effects of erosion. The foremost on-site impact is the reduction in soil quality that results from the loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of many eroded soils.

Off-site effects arise when the soil is detached by accelerated water or wind erosion and transported to considerable distances. The main off-site effect of water erosion is the movement of sediment and agricultural pollutants into watercourses. This can lead to the silting-up of dams, disruption of the ecosystems of lakes, and contamination of drinking water. In some cases, increased downstream flooding may also occur due to the reduced capacity of eroded soil to absorb the water. However, due to the unavailability of data on off-site of erosion-induced soil loss, the study will focus primarily on on-site impacts.

There are a number of valuation techniques that can be used in the assessment of soil degradation in agriculture. The study will however adopt the nutrient replacement cost and productivity loss methods in estimating the cost of agricultural soil degradation because of data availabity.

1.5.1 Data requirements and sources

Secondary data sources will mainly be used for the study. Table 1.1 summarizes the data sources and specific data requirements to be used in the estimation.\

Table 1.1: Data sources and requirements

Sources of data/Institutions	**Type of data used for the analysis**
Ministry of Food and Agriculture	Area of land under cultivation in hectares by districts/regions, total crop yield, etc.
Crop Research Institute - Council for Scientific Industrial Research (CSIR)	Potential Soil Loss figures by regions and agro-ecological zones, C-Factor figures, and Nitrogen, Phosphorous and Potassium (NPK) contents of eroded soils from experimental farms from sites in all the agro-ecological zones.
African Agricultural Market Information Network (AFAMIN)	Commercial fertilizer (NPK) prices, market values.
Ghana Statistical Service	Gross Domestic Product (GDP), Contribution of Agriculture to GDP, etc.
Case Studies on soil degradation	Yield loss – Soil loss parameters, expert opinions, e.g. ISSER/DFID/World Bank, 2005, Diao and Sarpong (2007), Quansah (2001), etc.

1.6 Justification and relevance

The contribution of natural resources and the environment to the Gross Domestic Product (GDP) is quite substantial, and in order to safeguard the country's advancement towards an upper middle status, the rate of degradation and depletion of natural capital (natural resources and the environment) must be checked to ensure sustainable socio-economic growth and development. It has been estimated that the loss in annual GDP growth in Ghana due to agricultural soil erosion and poor land management in crop production is 1.1–2.4 % (ISSER/DFID/World Bank, 2005).

Losses resulting from soil degradation pose serious cumulative consequences, generating marginal costs for society, which bears the on-site and off-site economic costs of soil degradation. Marginal costs incurred by farmers are passed on to consumers as price increases for agricultural products.

Social marginal costs are borne by society, together with the adverse effects on their social well-being.

The study would provide information on major arable land use practices, and the current state of the environment especially with regards to agricultural soil/land degradation and its implication for the country. It will also invariably fill the gaps with regards to studies on agricultural soil loss estimations. The findings and results of the study will also inform decision-makers in government i.e. the Ministry of Food and Agriculture, environmental organizations and other interest groups, thereby reshaping policies, plans and programmes (PPP) that border on agriculture and the environment.

1.7 Organization of the Study

The study is presented in five (5) chapters. Chapter one provides a general introduction and background to the study. Chapter two presents an overview of agricultural land degradation. The third chapter presents a review of various literatures on the assessment of Agricultural soil degradation with focus on major environment-poverty dimensions. The methodological frameworks are discussed in chapter four, whiles the results and discussions are presented in chapter five. The final chapter, chapter six presents the conclusion and recommendations for policy design, formulation and implementation.

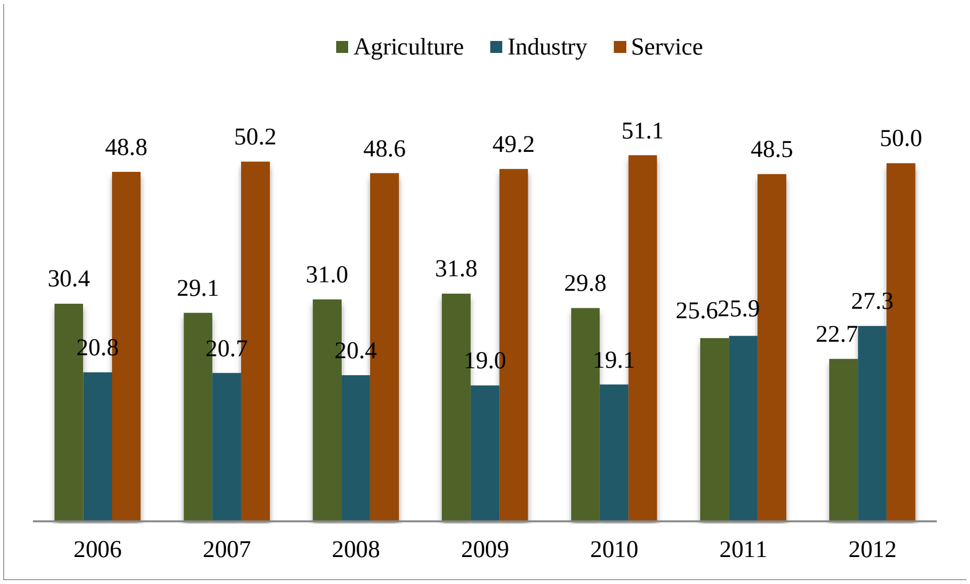
CHAPTER 2

OVERVIEW OF AGRICULTURAL LAND DEGRADATION IN GHANA

2.1 Introduction

The Agricultural sector plays a multi-dimensional role with regards to the environment and the socio-economic development of Ghana. It is predominantly smallholder, traditional and rain-fed (SRID, 2001). The Ministry of Food and Agriculture (MoFA) is the lead ministry responsible for policy formulation and planning for the agriculture sector. It is estimated that about 136, 000 km^2 of land which covers approximately 57 % of the country's total land area is designated as "agricultural land area". A total of 58,000 km^2 i.e. 24.4 % of the total land mass is under cultivation. The sector is also characterized by limited access to irrigation and a high reliance on favourable climatic conditions. Subsistence agricultural practices like slash and burn, shifting cultivation and mechanisation all result in declining soil quality and land degradation which is estimated to affect about 150,000 km^2 of agricultural land.

The economy of Ghana has been predominantly agro-based since the 1980s, with more than 50 % of the population engaged in agriculture i.e. farming, fisheries and animal husbandry, etc. The sector is divided into five (5) main sub-sectors namely; the crops, fisheries, cocoa, livestock/poultry and the forestry sub-sectors. In recent times however, the performance of the agricultural sector with respect to its contribution to national output has changed since 2006. This change has been attributed to the relatively fast growing service sector without giving much thought to the underlying effects of land (soil) degradation in the sector; which is one of the factors that is eroding the gains of the agricultural sector. Figure 2.1 shows the contribution to output of the various sectors from 2006 to 2012.



Source: Ghana Statistical Service (GSS)

Figure 2.1: Sectoral Contribution to National Output (2006-2012*)3

2.2 Land Resources and Use

Land use is mainly classified into agricultural or non-agricultural use. Agricultural land use encompasses the cultivation of annual and tree crops, bush fallow and other uses, and unimproved pasture. Non-agricultural land use includes forest reserves, wildlife reserves, unreserved closed forests, unreserved savannah lands, lands for mining, settlements, and institutional uses which covers about 48 % of the country‘s surface (Quansah, 2001).

There is no doubt that land or soil for that matter is a valuable resource in terms of the creation of wealth in the agricultural sector. Land contributes to the provision, maintenance, and regulation of critical ecosystem functions. Land as a resource may include; forest resources, wildlife, wetlands, and water resources. It also serves as habitats for biodiversity species, supports nutrient cycling, contributes to the provision of food, fresh water and wood, and helps in the regulation of the climate

[3] Percentage of total; 2006 constant prices

and floods. For instance, the forest, savannah, wetland, and coastal ecosystems is reported as habitats for at least 2,975 plant species, 728 birds, 225 mammals, and 221 reptiles. It is also worthy to note that the agriculture sector strives on the productivity of soils. Most rural households (about 63 % of the total population) depend largely on land resources for their livelihoods. The poor are the most dependent on land resources (CEA, 2006).

2.3 Soils and Topography

The major soils are Lixisols, Acrisols, Nitisols, Luvisols, Lithosols, Plinthosols, Gleysols and Cambisols. Alluvial soils (Fluvisols) and eroded shallow soils (Leptosols) are found in all the ecological zones. Most of the soils are developed from thoroughly weathered parent materials, with alluvial soils (Fluvisols) and eroded shallow soils (Leptosols) common to all the ecological zones. Generally, their organic matter content, buffering capacity and cation exchange capacity are low. The soils are consequently of low inherent fertility with nitrogen and phosphorus as the most deficient nutrients. Many of the soils have predominantly light textured surface horizons, heavier textured soils being confined to the valley bottoms and the Accra Plains (MoFA, 2010). The soils in the forest zone are grouped under Forest Oxysols and Forest Acid Gleysols. They are porous, well drained and generally loamy and are distinguished from those of the Savannah zones by the greater accumulation of organic matter in the surface resulting from higher accumulation of biomass. They occur in areas underlain by various igneous, metamorphic and sedimentary rocks, which have influenced the nature and properties of the soil (MoFA, 1998).

Soils of the Savannah zones, especially in the Interior Savannah, are low in organic matter (less than 2% in the topsoil), have high levels of iron concretions and are susceptible to severe erosion. Thus well-drained upland areas tend to be droughty and when exposed to severe incident sun scorch, tend to develop cement-like plinthite. These conditions make it imperative that manure be incorporated regularly into the soils in the Savannah zones (MoFA, 1998). The topography of the country is mainly undulating with most slopes less than 5% and many not exceeding 1%. The topography of the high rainforest is, however, mainly strongly rolling.

2.4 Climate and Agro Ecological Zones

Ghana's climate is characterized by the hot, dry and dusty-laden air mass that move from the north east across the Sahara and by the tropical maritime air mass that moves from the south-west across the southern Atlantic Ocean. The climate ranges from the bimodal rainfall equatorial type in the south to the tropical unimodal monsoon type in the north. The mean monthly temperature over most of the country on the average is above 25ºC, as a result of the low latitude position of Ghana and the absence of high altitude areas. Mean annual temperature averages 27ºC. Absolute maxima approach 40ºC, especially in the north, with absolute minima descending to about 15ºC.

In the coastal areas, where the modifying influence of the sea breeze is felt the annual range of temperature is between 5 and 6ºC. In the interior on the other hand, the range is higher, about 7 to 9°C (Dickson and Benneh, 1988; Benneh et al. 1990). The rainfall generally decreases from the south to the north. The wettest area is the extreme southwest where the rainfall is over 2,000 mm per annum. In the extreme north, the annual rainfall is less than 1,100 mm. The driest area is in the south-eastern coastal tip where the rainfall is about 750 mm. The annual mean relative humidity is about 80% in the south and 44% in the north (Dickson and Benneh, 1988; Benneh et al. 1990).

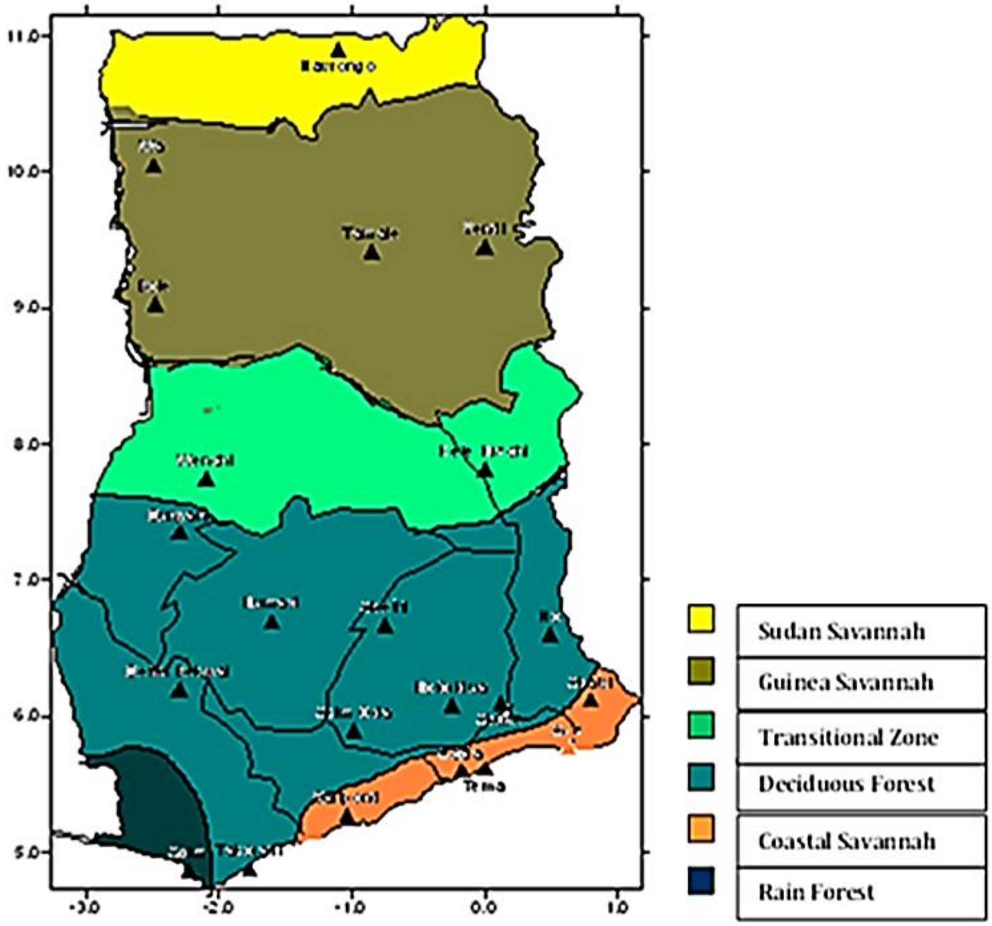
Table 2.1: Rainfall Distribution by Agro-ecological zones

[4]Agro-ecological zone	Mean Annual Rainfall (mm)	Growing Period (Days)	
		Major season	Minor season
Rain forest	2,200	150-160	100
Deciduous Forest	1,500	150-160	90
Transitional	1,300	200-220	60
Coastal	800	100-110	50
Guinea Savannah	1,100	180-200	*
Sudan Savannah	1,000	150-160	*

Source: Meteorological Services Department, MoFA, 2010

Agro-ecological zones are divided into six major zones, namely; Rain Forest, Deciduous Forest, Forest-Savannah Transition, Coastal Savannah and Northern (Interior) Savannah which comprises Guinea and Sudan Savannahs as shown in figure 2.2. The bimodal rainfall pattern in the Forest, Deciduous Forest, Transitional and Coastal Savannah Zones gives rise to major and minor growing seasons. In the Northern Savannah, the unimodal distribution results in a single growing season. The rainfall determines largely the type of agricultural enterprise carried out in each zone. Table 2.1 shows the rainfall distribution by agro-ecological zones in the country.

[4] *Rainfall distribution is bimodal in the Forest, Transitional and Coastal Zones, giving a major and minor growing season; elsewhere (Guinea Savanna and Sudan Savanna), the unimodal distribution gives a single growing season.



Source: Ministry of Food and Agriculture

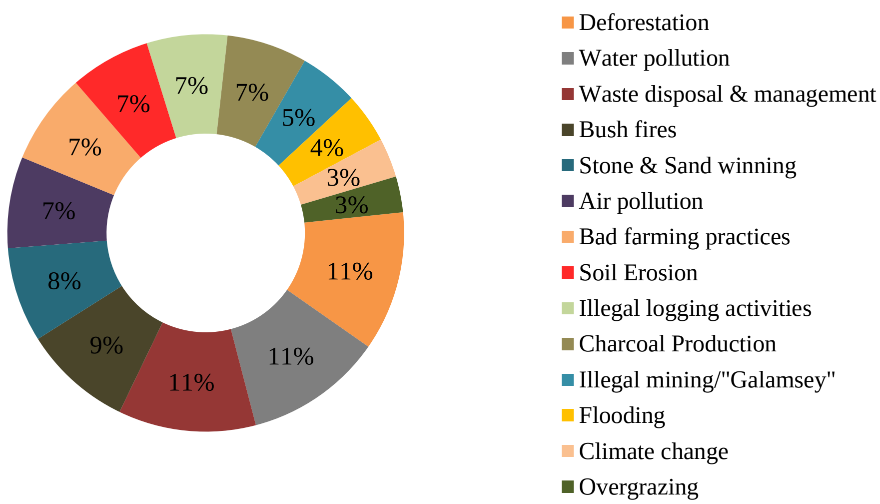
Figure 2.2: Agro-ecological Zones of Ghana

2.5 Land degradation as a major environmental issue

The State of the Environment (SoE) Report, 2004 outlined land degradation, coastal erosion, pollution of water bodies, deforestation, poor waste management, risk from chemical use, indoor and outdoor air pollution and desertification as major [5]environmental problems confronting the nation. An analysis of the Strategic Environmental Assessment Reports of the District Medium-Term

[5] Details of these environmental problems are shown in annex 2 in the appendices.

Development Plans (DMTDP) 2010-2013 shows that some of the most serious environmental threats to the country out of thirty-three (33) threats[6] identified include: deforestation, water pollution, waste disposal & management, bush fires, stone & sand winning, air pollution, bad farming practices, ***soil erosion,*** illegal logging activities, charcoal production, illegal mining/"galamsey", flooding, climate change, and overgrazing. These environmental issues are consistent with those identified in the SoE Report, 2004. These findings seem to suggest that the problem of natural resources and environmental degradation is on the ascendancy and must be effectively addressed. Some of the problems are illustrated in Figure 2.3.



Source: Authors analysis from SEA Reports of District Medium-Term Development Plans (2010-2013)

Figure 2.3: Major Environmental Concerns in Ghana

2.6 Trends and forms of Land Degradation

According to Vitousek et al. 1997, land degradation is a vital societal concern because of its impact on human populations (food security, economics, sustainability, etc.) and environment quality (dust storms, trace gas emissions to the atmosphere, soil erosion, etc.). Ghana has a relatively large amount

[6] See annex 1: Major Environmental Problems in Ghana

of cultivated land per capita; however, most lands are characterized by low fertility and are subject to degradation. To sustain crop production increases and ensure food security, soil, nutrient and water resources need to be properly managed and conserved (Quansah, 1996).

Increasing production through area expansion, unsustainable agricultural practices, rising competing demands for water are factors that have led to the increased degradation of land resources especially in agricultural lands. Illegal logging activities, bushfires and wildfires, encroachment on forest reserves, poaching, and illegal mining i.e. “galamsey” have also contributed largely to the destruction of forests and other natural habitats. Furthermore, the depletion of forest and vegetative covers due to improper land use management have also led to increased siltation, sedimentation, and eutrophication in water bodies (rivers, basins, lakes).

Soil degradation is geographically widespread in all areas of the country. Diverse forms of soil erosion are however present in all agro-ecological zones and regions, although the most degraded areas in the country are the Upper East and Volta Regions (CEA, 2006). Although other regions are also at risk of land degradation, the associated social vulnerability may well be most severe in the north of the country. The Global Assessment of Human Induced Soil Degradation (GLASOD) carried out in 1980s, maps out the severity of soil degradation for most countries. The GLASOD assessment for Ghana identified that soil degradation is very severe in the Upper East Region. Comparatively, the Upper East Region is classified as ‘very severe’, as against the rest of Ghana, which is classified as ranging from light to moderate.

Land degradation can be attributed to physical, chemical and biological processes. The physical processes include soil erosion, compaction, soil crusting, and iron-pan formation. The depletion of soil nutrients, salinity, and acidification mainly result from chemical processes, whiles the loss of organic matter may be as a result of biological processes. The major forms of land degradation include:

2.6.1 Soil Erosion

Soil erosion is the primary form of land degradation in Ghana. Soil erosion is a naturally occurring process on land. The agents of soil erosion are mainly water and wind, with each contributing significantly to soil loss each year. The main forms of soil erosion in Ghana are sheet erosion through surface runoff, rill erosion in permanent and shifting micro channels, and gully erosion in permanent channels. Studies on the extent of erosion reveals land areas susceptible to the various forms of erosion as 70,441 km^2 to slight to moderate sheet erosion, 103,248 km^2 to severe sheet and gully erosion and 54,712 km^2 to very severe sheet and gully erosion (EPA, 2002). Ghana‘s topography does not present steep slopes, and with relatively high rainfalls intensity in all ecological zones, the rains also tend to be highly erosive.

2.6.2 Depletion of Soil Nutrients

The organic matter content in most soils is low i.e. less than 2% (MoFA, 1998) as most of the soils are old and have been percolated over a long period of time. The levels of organic carbon, nitrogen and available phosphorus are also generally low (FAO, 2005). The frequent burning, removal and grazing of crop residues also prevent the build-up of new organic matter in the soil.

2.6.3 Reduction of Vegetation Cover

Forest resources were depleted at a rate of 1.7 % per annum 1990-2000 (WDI 2005), but, according to the National Action Program to combat Drought and Desertification, the rate of depletion was 3 % in most desert-prone areas. The reduction of soil fertility and productivity has forced farmers to expand their cultivated lands and such, cleared forest areas leading to deforestation.

2.7 Agricultural Farming Systems in Ghana

Most agricultural farming systems and practices impact negatively on soil or land resources. Assuming-Brempong, Seini and Botchie (2003) identified some agricultural farming systems in Ghana and their impact on agricultural soils. The effects of these farming practices are summarised in Table 2.2. The main agricultural farming systems are the rotational bush fallow system, permanent tree crop, compound farming, mixed farming, and special horticultural farming systems. The most dominant farming system is the rotational bush fallow system that is characterized by slashing and burning of the surrounding vegetation. The practice makes the soil highly susceptible to erosion leading to soil loss and infertility.

Table 2.2: On-site effects of agricultural practices on agricultural soil in Ghana

Type of farming system	**Farming practice**	**Effects on soil**
Rotational bush fallow System	Slash and burn. Fallow periods. With or without fertilizer	• Destroy vegetative cover. Expose the soil to erosion. • Leaching of soil nutrients
Permanent tree crop system	Slash and burn but provide tree cover	• No serious soil loss consequence identified in this system. • Good forest cover
Compound farming system	Slash and burn with or without fertilizer/manure. Grazing livestock	• Soil loss as a result of erosion • Leaching of soil nutrients, • Compaction from livestock
Mixed farming system	Slash and burn with or without fertilizer/manure	• Soil erosion and nutrient depletion
Special horticultural farming system	Slash and burn with fertilizer/manure and chemical application	• Soil erosion, eutrophication and acidification of the soil as a result of fertilizer and chemical application

Source: Asuming-Brempong, Seini and Botchie (2003)

2.8 Causes of land degradation

Generally, degradation is caused by both natural and human-induced factors. The most common causes of land (soil) degradation among others include poverty, deforestation or indiscriminate felling of trees, overgrazing, unsustainable farming practices, rapid population growth and urbanization, environmentally unfriendly mining activities, and extreme climatic conditions.

2.8.1 Poverty

Poverty is said to be both the cause and effect of soil degradation in Ghana. The link between poverty and environment is an extremely complex phenomenon. Even though poverty is a key contributor to degradation, there is also no doubt that the latter further accentuates poverty especially among the rural population of Ghana. Due to the traditional nature of farming systems coupled with the over-reliance on favourable weather conditions, output of many farmers in the country is low, especially those that are done on subsistence basis. This causes most farmers to supplement their output and incomes by clearing trees and other vegetation for fuelwood, etc. Most farming communities have also abandoned farming and have resorted to illegal mining activities in recent times.

(Diao & Sarpong, 2007)[7] reports that agricultural soil loss reduces the total cumulative agricultural income by approximately five % for the period 2006–2015, which is equivalent to a loss of US$4.2 billion over a 10 year period. Their work further revealed that the effect of soil loss on poverty is significant at the national level, equivalent to five %age points higher poverty rate in the projected year 2015 than would be the case in the absence of soil loss effects.

[7] The paper uses an economy-wide, multimarket model to establish the effects of agricultural soil erosion on crop yields at the subnational regional level for eight main staple crops. It further evaluated the aggregate economic costs of soil erosion, taking into account economy-wide linkages between production and consumption, across sectors and agricultural subsectors.

2.8.2 Deforestation

Deforestation represents probably the most serious form of natural resource degradation in Ghana, and it is one of the main direct causes of soil degradation in the country. Amidst a rapidly growing population, the demand for more land for agriculture, and for fuel wood and other wood products (e.g. firewood, charcoal, etc.), which the majority of rural people rely on for their livelihoods, has increased. The poor enforcement of regulations controlling access to and use of forestry products has in most cases failed to deter and prevent unsustainable logging practices and indiscriminate fuel wood extraction. Lands or soil become extremely prone to soil erosion in the absence of protective vegetative cover.

2.8.3 Overgrazing

Overgrazing caused by the combination of rapid increase in the livestock population, sedentarization of pastoral populations, and the reliance of the livestock sector on extensive grazing on natural pastures and poor development of pasturelands has led to increasing pressures on land resources. Increased livestock population also has a direct link to the physical compaction of most soils. Overgrazing is a major factor in land degradation, causing half of the damage assessed in Africa and one-fourth in other developing regions as revealed by some studies.

2.8.4 Unsustainable farming practices

The traditional farming system (bush-fallow system), which involves slashing and burning of forests and grassland, and the rotation of cultivated fields (rather than crops) over years has proven to be unsustainable given the context of rapidly increasing human and animal population. The absence of sustainable soil and water conservation measures and external nutrient replacement practices has accentuated the degradation of soils in the country. This leads to a progressive reduction of soil nutrients, organic matter, and other chemical processes, and the subsequent decline in productivity and crop yields.

2.8.5 Population growth and Urbanization

Rapid urbanization and increased population have also increased the pressure on land, not only with respect to farming to meet increased food requirements, but also for other competing uses like housing and infrastructure development. Ghana has experienced a rapid population growth in the last decades. Population almost tripled over the last 40 years, from 6.7 million in 1960 to 18.4 million in 2000 (GSS, 2000). In the Upper East, Upper West, and Northern Regions, the regions most prone to land degradation, population density has increased between 1984 and 2000 from 87, 24, and 17 to 104, 31, and 21 persons per km^2, respectively, an increase of 20, 29, and 24 %, respectively (GSS, 2000).

2.8.6 Mining Activities

Mining, particularly illegal mining activities, is one of direct causes of land degradation. These activities are usually accompanied by deforestation and removal of the fertile topsoil of adjacent agricultural lands. Illegal mining activities in recent times, great cause a lot of havoc to many communities, destroying large stretches of arable lands, water bodies, and other sensitive ecosystems.

2.8.7 Climate change

Climate change has also exacerbated the problem of soil degradation. Increased rainfall variability and overall drop in rainfall and rise in temperatures have negative impact on agricultural productivity, increasing the chances of droughts and/or extreme climate events e.g. floods, and desertification particularly in the northern regions.

2.9 Impact of Land Degradation in Ghana

Land degradation is compromising the capacity of ecosystems to provide, maintain, and regulate critical functions and services, including resilience to climate variability and natural hazards e.g. regulating floods and preventing droughts. Upstream land degradation reduces the capacity of ecosystems to retain water and regulate water flows, thus preventing excessive runoff during the rainy season. Downstream sedimentation and siltation reduces the water storage capacity of water bodies, thus reducing their capacity to retain excessive water flows during the rainy season, and their capacity to store water for the dry season.

Rural households, which constitute the most vulnerable part of the population and who directly, depend on land resources for their livelihoods are the most affected by land degradation that results in the reduction of soil productivity and associated increased food insecurity. Some of consequences of land degradation, particularly in the northern regions, include increased migration i.e. from north to south, and from rural areas to urban centres. Land degradation in Northern Ghana has resulted in fragile environmental conditions coupled with harsh climatic conditions of droughts and periodic floods (Destombes**,** 1999). In some other instances persistent drought has manifested in chronic malnutrition and wide spread poverty. The effect of land degradation in Northern Ghana has led to the migration of farmers from degraded regions to the rural areas of the Brong Ahafo Region, which has relatively more fertile agricultural soil.

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

This chapter reviews the different works that have been carried out by other authors and researchers in the areas of assessing the cost of agricultural land (soil) degradation. The review covers discussions under different themes relevant to this study.

Land degradation definitions are very variable and dynamic due to the different spatial, temporal, economic, cultural and environmental complexities (Warren, 2002). Land degradation has been referred to as being a “loss in productivity of the land” (Muchena et al., 2005, p23). This is especially important when one considers the negative effect of land degradation on a community that relies on natural resources for their livelihood. Land degradation is defined as a change in one or more of land’s properties that results in a decline in land/soil quality (Wiebe, 2003). As soil is a fundamental component of land, soil degradation is a fundamental component of land degradation. Lindert (2000) however, defines soil degradation more specifically as any chemical, physical, or biological change in the soil’s condition that lowers its agricultural productivity, which is defined as its contribution to the economic value of yields per unit of land area, holding other agricultural inputs the same.

The key soil characteristics that affect yield are nutrient content, water holding capacity, organic matter content, soil reaction (acidity), topsoil depth, salinity, and soil biomass. Change over time in these characteristics constitutes “degradation” or “improvement.” Degradation processes include erosion, compaction and hard setting, acidification, declining soil organic matter, soil fertility depletion, biological degradation, and soil pollution (Lal and Stewart, 1990). Various types of soil and land degradation have been explained by some authors like (FAO/UNDP/UNEP, 1994) and (Scherr, 1999). As expected, these authors differ in their approach to describing and classifying land (soil) degradation. Douglas (1994) notes that land degradation has five main components namely; soil degradation, vegetation degradation, water degradation, climate deterioration, and losses to urban or industrial development.

3.2 Types of Land (Soil) degradation

Some examples of soil degradation include loss of topsoil through erosion by water or wind, depletion of soil nutrients, loss of soil organic matter, compaction, waterlogging, salinization, and acidification. Soil degradation occurs as a result of both natural and human induced processes, such as agricultural production.

3.2.1 Soil Erosion

Soil erosion, the most visible and most widespread form of soil degradation, could have a serious negative effect on economic development in Ghana as the economy of this country depends heavily on land, forests, and water bodies for its agricultural growth and rural development (Diao & Sarpong, 2007). Generally, soil erosion involves a three-step process that begins with the detachment of soil particles, continues with the transport of these particles, which ends up at a new location. Myers (1993) reports that approximately 75 billion tons of fertile soil are lost from World Agricultural systems each year, with much less erosion taking place in natural systems. In the United States, it is estimated that the amount of soil lost to erosion is about 3 billion tons per annum (Carnell, 2011). The main forms of water-induced erosion include; sheet, gully and rill.

Sheet erosion is the uniform removal of a thin film of soil from the land surface without the development of any recognizable water channels. This type of erosion is barely perceptible, but the loss of a single millimetre of soil depth from an acre of land, which can be easily lost during a single irrigation or rain event, works out to a total loss of up to 6.1 tons of soil (Pimentel, 2000).

Rill erosion unlike the former is easier to recognize. It is the removal of soil through the cutting of multiple small water channels. Rills are small enough to be smoothed by normal tillage operations and will not form again in the same location. Together, sheet and rill erosion account for most soil erosion in agricultural land (Brady and Weil, 1999). Gully erosion occurs in areas where water runoff is concentrated, and as a result cuts deep channels into the land surface.

Gullies are incised channels that are larger than rills. You can remove small, ephemeral gullies by tilling, but they will form again in the same location on the landscape. Gullies actually represent less soil loss than sheet or rill erosion, but they pose added management concerns such as damage to machinery, barriers to livestock and equipment, and increased labour costs to repair eroded areas.

3.2.1.1 Effects of Soil Erosion on Agricultural Soils

The effect of Soil erosion on agriculture is far-reaching, and could be very detrimental if not checked. It basically results in the reduction of soil productivity i.e. a decline in soil fertility leading to low crop yields. According to Troeh et al, 2004, erosion increases water run-off, which decreases water filtration and the water-storage capacity of the soil. Organic matter and other essential plant nutrients like phosphorous, nitrogen, calcium, etc. are also carried away from the soil. Young (1989) estimated that eroded soils contain about three times more nutrients per unit weight than are left in the remaining soil. Nutrient losses are often not directly accounted for and are a hidden cost of soil erosion. Soil erosion is associated with about 85 % of the world's land degradation, and causes a 17 % reduction in crop productivity (Oldeman et al., 1990). Alfsen et al (1997) also indicated that because agriculture in Ghana is characterized by small unit farms, which almost solely rely on land and labour as input factors, it causes nutrients to be mined, and also reduces the productivity of soils.

Soil erosion has adverse effects both on and off production sites as shown in Table 3.1, which have economic consequences that are important to farmers and society (Bennett, 1935; Pimentel et al., 1995; Uri, 1999, 2000, 2001).

Table 3.1: On-site and off-site losses caused by Soil Erosion

On-site	**Off-site**
Soil loss	Sedimentation
Nutrient loss	Flooding
Loss of organic matter	Landslides
Drop in the soil fertility	Eutrophication
Yield drop	Loss of biodiversity
Production loss	Drop in food supply
Shrinkage of the available planting area	Food price increase
	Water treatments
	Destruction of roads, railways, waterways, etc.

Source: Clark (1985), Pimentel et al. (1995), Uri (2001) and Crosson (2007)

Adama (2003) noted that sustainable agricultural production depends on productive soils, but land (soil) resources in Ghana particularly the Upper East Region are being degraded by both natural and anthropogenic factors. Folly (1997) also adds that soil erosion poses a major threat to sustainable agricultural production in the Sudan Savanna regions of the country.

3.2.2 Soil salination

Saline soils are soils that contain sufficient amounts of salts in the root zone that impairs plant growth (Ponnamperuma, 1984). This form of degradation normally occurs in naturally dry areas that undergo irrigation and do not allow for any fallow periods for the land to recover. Irrigation schemes are set up to provide a constant flow of water to drylands so that crops can be grown. Poorly designed irrigation schemes cause the water-table level to rise bringing natural salts to the surface of the soil or land. This restricts the root activity of crops and therefore slows down growth. This problem is further aggravated in areas with high rates of evaporation, as the salts become even more concentrated. The end result is that the soils become too salty for crops to grow in them. Soils affected by salinization are very difficult and expensive to rejuvenate and often remain unused or abandoned.

3.3 Soil degradation and Food Security

The effects of soil degradation on agricultural productivity vary with the type of soil, crop, degradation, and initial soil conditions, and may not be necessarily linear. Lower potential production due to degradation may not show up in intensive, high-input systems until yields are approaching their ceiling. Reduced efficiency of inputs (fertilizer, water, biocides, labor, etc.) could show up in higher production costs rather than lower yields. The loss of agricultural productivity as a result of soil degradation implies the loss of revenue that could be used for the socio-economic development of the nation (Bonsu et al, 1992).

Food security is a multidimensional concept, which encompasses; availability, stability, access and utilization at household, regional, national and global levels. It is also a measure of the percentage of domestic food production over total consumption. Food security is threatened where cropland degradation is allowed to occur because of the significant reduction in crop productivity. Shortages of cropland are already having negative impacts on global food production (Pimentel et al, 2009). According to the Food and Agricultural Organization (FAO), per capita production in terms of grain has been on a decline for more than two (2) decades due to degradation of agricultural soils and lands. This could lead to famine and hunger in some countries. Sub-Saharan African countries like Ghana can be widely affected because agriculture is predominantly subsistent in nature.

Soil degradation has been predicted to impact heavily on agricultural supply, economic growth, rural poverty, and long- term national wealth. Policy, therefore will need to be guided by country assessments, with consideration given to the importance of agriculture in the economy, the vulnerability of agricultural land to degradation (land scarcity, soil vulnerability and resilience, and the anticipated rate of change in crop ping intensity), and the capacity of farmers to respond effectively to the threat of degradation i.e. profitability of farming, availability and cost of soil-conserving technology, and availability of financing for land improvements (Scherr, 1999).

3.4 Link between Population growth and soil degradation

Increasing population size is a major force driving the increase in global food production, and the strain on the environment. Population growth exerts its influence synergistically with other factors. As the global population grows and people over-cultivate scarce land resources, the nutrient values of most soils reduce, which eventually affects productivity. Land degradation leads to population displacement. It is estimated that hundreds of thousands of hectares of land are abandoned annually for being too degraded for either cultivation or grazing. The implication of this is that, people or communities especially the rural poor whose livelihoods depend on these land resources for their subsistence have to move to other areas to settle.

Most parts of the world are currently facing increasingly serious soil erosion of various degrees caused by both natural and human factors. This situation has given rise to widespread concerns in both developed and developing countries (e.g. Boardman, 1998; EEA, 2000; Andrews et al., 2002; Yang, 2004). Processes and impacts of natural resource change in agricultural environments and their relationship with population growth and conservation management are fundamentally influenced by biophysical conditions. Key factors are soil characteristics (affecting crop choice, cropping frequency and input use), rainfall and ground and surface water resources (affecting crop product choice, risks of soil degradation and land use intensity), and topography (affecting the spatial distribution of production systems).

Further landscape differences and resource management challenges arise from variations in settlement history, past history of degradation, crop mix, perennial and livestock components and the mix of commercial and subsistence enterprises (Turner et al., 1993). The modern soil erosion rate is much higher than that in the geological past because of the interaction of socioeconomic and biophysical factors such as increasing population and poorly designed farm policies, or by unfavourable climatic conditions (Roberts, 1994). Population growth is not necessarily harmful to agricultural productivity, nor will relieving demographic pressure necessarily curb land degradation. However, if we can monitor and control demographically-induced changes in the landholding structure, we can diminish their damaging effects on land resources.

3.5 Evidence of the Agricultural Soil Degradation on the Ghanaian Economy

Alfsen et al. (1997, 2007), identified soil degradation, deforestation and pollution from mining industries as the most serious environmental problems in Ghana. With regards to soil degradation, they addressed two main issues; how the loss of land productivity affects the prospects for economic growth in Ghana, and how the productivity loss can be combated in an economically efficient way.

World Bank et al., 2005 also estimated annual cost of land degradation mainly through erosion, ranges from 1.1 to 2.4% of the GDP corresponding to 2.9 and 6.3% of Agricultural Gross Domestic Product (AgGDP). This is consistent with the estimate of 5% of AGDP for cost of annual production loss through erosion and nutrient depletion (Convery and Tutu, 1990). Using the Replacement Cost Approach, Quansah et al. (2000) estimated the seasonal cost of Nitrogen, Phosphorous, Potassium (NPK) lost through erosion per hectare under a maize monocrop grown under excessively tilled land as ¢ 15,528.00, equivalent to $7. Akyea (2009) reported the total cost in Ghana Cedis terms of replacing lost nutrients by straight fertilizers under various tillage treatments for cassava cultivation as 1,304.90, 831.70, 875.90, 210.15 for bare plot, planting on the flat, zero tilled plot and ridging across slope respectively.

3.6 On-Site Costs of Soil Erosion on Java, Indonesia

Magrath and Arens (1989) conducted an analysis of the on-site costs of soil erosion for mainly upland rainfed cropping systems in Java, Indonesia[8] using the ***change in agricultural productivity*** approach. The study assumed that yields and farm revenues would decline as erosion persist, and that costs that tend to fall along with output account for a small share of production costs in Javanese agricultural systems. The study accounted for possible adjustments in cropping systems by constructing farm budgets for a variety of representative dryland cropping systems across Java, which were then used to estimate the effects of yield losses from erosion on net farm incomes. This was done for a single year i.e. 1985. Based on the assumption that the one-year loss in net income recurs over each successive year, the study capitalized the one-year cost of erosion to obtain a total present value of current and future losses. On-Site cost of soil erosion in Java was thus, equivalent to the total present value of future losses.

The method and results are illustrated in Table 3.2. The one-percent decline in productivity and the predicted average yield declines from soil erosion for dryland farming systems in each province of Java are applied to the total area of these cropping systems. This yields the single-year cost of soil erosion for 1985. This one-year loss is then capitalized to obtain the present value of losses in farm income in current and future years. For Java as a whole, this on-site cost of soil erosion in 1985 was estimated to be approximately Rp 539.6 million (US$ 327 million), which amounted to around 4% of the total value of dryland crops in Java.

[8] Given data limitations, Magrath and Arens (1989) were able to provide an estimation of on-site erosion costs for 1985 only. However, the results for 1985 were extrapolated for other years over the 1971-85 period by indexing physical erosion rates to the dryland cropping area in each year and indexing the costs of erosion to dryland crop prices in each year.

Table 3.2: On-Site Costs of Soil Erosion in Java, 1985
Indonesian Rupiah (Rp) 1,650 = US$ 1

	Dryland Area ('000 ha)	Estimated Current Net Farm Income (Rp/ha)	Weighted Production Loss (%)	Annual Cost of a 1 % Productivity Decline (Rp/ha)	Single Year Cost (Rp mil.)	Capitalized Cost (Rp mil.)	On-Site Cost as a % of Total Dryland Crop Value
West Java	1,440	95,039	4.4	3,718	23,508	235,080	10%
Central Java	1,366	8,196	4.1	859	4,810	48,100	1%
Jogyakarta	196	9,531	4.7	1,026	948	9,480	1%
East Java	1,744	14,499	4.1	3,453	24,690	246,900	4%
ALL JAVA	4,747	83,649	4.3	2,686	53,956	539,560	4%

Source: Magrath and Arens (1989)

3.7 On-Site Costs of Soil Erosion, Magat Watershed, the Philippines

Cruz, Francisco and Conway (1988) estimated the on-site costs of soil erosion in the Magat watershed of the Philippines using the ***nutrient replacement cost*** method. The average annual sheet erosion rate for grasslands was estimated to be around 88 tons per hectare compared to 28 tons for all other land uses. The nutrient losses associated with this erosion on representative land unit areas for grasslands were translated into equivalent quantities of inorganic fertilizers; nitrogen (N), phosphorous (P) and potassium (K) lost per ton of soil erosion. The cost of replacing these equivalent fertilizer losses was then valued in terms of both nominal and shadow fertilizer prices. The resulting estimate was considered to be the on-site cost of soil erosion from land conversion in the Magat watershed as shown in Table 3.3. On-Site cost of soil erosion was estimated to be ₱1,068 per ha (US$ 50.1/ha) in nominal prices and ₱2,716 per ha (US$ 127.5/ha) in shadow prices.

Table 3.3: On-Site Costs of Soil Erosion, Magat Watershed, the Philippines

Philippine Peso (₱) 21.3 = US$ 1

	Quantity (kg)	Valuation in terms of	
		Nominal Price (₱)	Shadow Price (₱)
Urea			
Price		3.60/kg	9.86/kg
Amount lost/ton of soil eroded	3.08	11.09	30.37
Amount lost/ha of affected land	118.13	677.23	1,854.96
Solophos (P_2O_5)			
Price		2.50/kg	6.20/kg
Amount lost/ton of soil eroded	0.79	1.98	4.90
Amount lost/ha of affected land	70.65	176.63	438.03
Muriate of Potash (K_2O)			
Price		4.20/kg	8.28/kg
Amount lost/ton of soil eroded	0.57	2.39	4.72
Amount lost/ha of affected land	51.07	214.49	422.86
All Fertilizers			
Cost/ton of soil eroded		**15.46**	**39.99**
Cost/ha of affected land		**1,068.35**	**2,715.85**

Source: Cruz, Francisco and Conway (1988).

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

This chapter discusses the available methodology that has been used by different scholars in assessing the cost of agricultural soil degradation in different countries. The chapter examines the relative strengths and weaknesses of these methods and discusses into detail the approach adopted by the study i.e. the productivity loss and nutrient replacement cost approaches.

Land and other environmental resources supply goods and a flow of direct and indirect services to society. Socio-economic activity in this regard usually leads to changes in the flow of these services and the quality of these goods. Unfortunately, changes in the flow processes are not incorporated in the value of environmental goods and ecosystem services and for that do not reflect in terms of market prices. This is due to the fact that natural resources and environmental goods typically are public goods. This lack of market prices is often interpreted as if the environmental resource has no value, a problem that leads to overuse of the natural resources and environmental degradation.

Different methods for defining the value of environmental resources and the cost associated with their overuse or degradation have been developed in recent times by numerous experts. The principal motivation for environmental valuation is to make it possible to include environmental impacts in cost-benefit analysis. Valuation methods are usually divided into two different approaches: [9]stated preferences and [10]revealed preferences methods.

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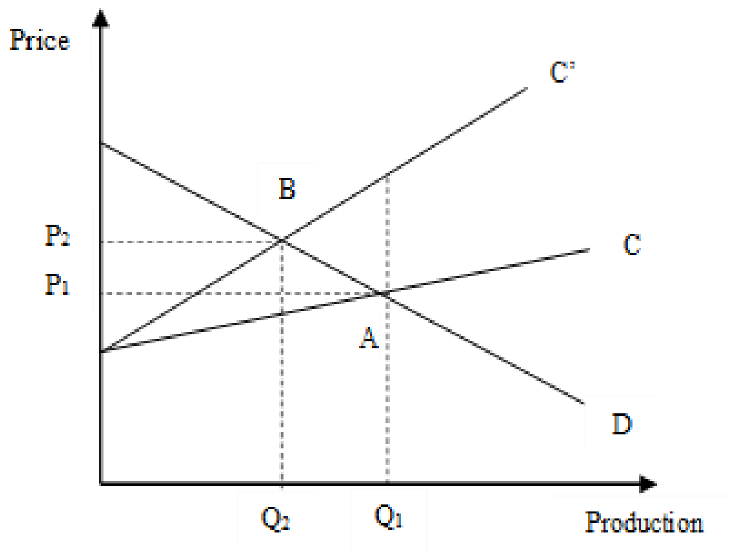
[9] A set of pricing methods where people are asked how much they would agree to pay for avoiding a degradation of the environment or, alternatively, how much they would ask as a compensation for the degradation.

[10] Revealed preference techniques associate a non-market good or service with the actual markets for a complementary (i.e. proxy) good or service.

4.2 Measuring the Cost of Soil Erosion: Methodologies and Models

Soil is one of the most important natural resource assets for humans. It is a limited, strategic resource of huge social, economic and environmental significance. However, the use of inappropriate farming methods can lead to erosion and limit the productive capacity of the soil (Lal, 2006; Sparovek and De Maria, 2003). Most human activities have a negative impact on the environment. In order to estimate the costs associated with these impacts, economic concepts have been used to develop models that estimate the costs of these forms of environmental degradation as well as the benefit of safeguarding these natural resources. For instance, when soil degradation (erosion) occurs, it causes changes in prices and production (i.e. both demand and supply side). This illustrated in Figure 4.1.



Source: Telles et al. 2013

Figure 4.1: Changes in prices and production as a result of soil degradation

C represents the costs of agricultural production, expressed in terms of the amount of work and inputs required for cropping; D represents the demand for agricultural products and is equivalent to the marginal social benefits; C' represents the costs of soil degradation, i.e. the sum of on-site and off-site costs; P represents the price and Q the production of agricultural commodities. For the farmer, the losses incurred by soil erosion can be computed as a marginal social cost that is higher than his marginal production cost. Initially, the farmer maximizes his profits on curve C, producing quantity Q_1 at price P_1 at point A, equal to the marginal cost. However, as the degradation i.e. erosion process continues overtime, there is a drop in soil fertility and productive capacity, forcing the farmer’s cost curve to move towards C'. This shift creates a new intersection at point B, where the quantity produced drops to Q_2 and the price rises to P_2.

The total cost of soil degradation/erosion is the summation of both on-site and off-site erosion, expressed as:

$$C' = C_{on-site} + C_{off-site}$$

where C' = total costs of agricultural soil erosion; $C_{on\text{-}site}$ = costs resulting from losses occurring on agricultural property; and $C_{off\text{-}site}$ = costs resulting from losses occurring away from agricultural property and affecting society as a whole. A modified version of the total costs of agricultural soil erosion (C') focusing on only on-site costs is given by:

$$C' = C_{on-site} \qquad (3.1)$$

$$C_{on-site} = \sum_{i=1}^{m} (C_i Q_i) \qquad (3.2)$$

where C_i = prices of different types of nutrients (per unit); Q_i =quantities of nutrients carried off by soil estimated by USLE; and i = nutrient.

4.2.1 Valuation of On-Site Effects

There are two main methods used in the valuation of on-site effects of erosion: the impact on the properties of the soil and the impact on agricultural production. The effects of erosion on soil properties can be examined from the perspective of soil as a resource, or in terms of certain soil characteristics as indicators of soil productivity e.g. soil nutrient content, soil moisture capacity. The effects of erosion on agricultural production can be valued in terms of reductions in crop yields. This may be the reduction in market value of crop production or, where the farming system involves the production of fodder crops, erosion can be valued in terms of the decrease in livestock production. Crop yields are not dependent on soil productivity alone; yields are determined by the interaction of a number of factors such as fertiliser application rates, climate, pests, and the use of irrigation systems. The impact of erosion on soil properties can however cause declining crop yields, especially in the absence of increased inputs.

4.3 Empirical and Theoretical Models

The models that are used in the estimation of soil degradation (erosion) in the literature include; the Universal Soil Loss Equation (USLE), the Revised Universal Soil Loss Equation (RUSLE), Modified Universal Soil Loss Equation (MUSLE) and the Water Erosion Prediction Project (WEPP).

4.3.1 Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) predicts the long-term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. It only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non-agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning.

The model uses five (5) major factors to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages. It is expressed as:

$$\mathrm{A} = \mathrm{R} \times \mathrm{K} \times \mathrm{LS} \times \mathrm{C} \times \mathrm{P}$$

where:

A = potential long-term average annual soil loss in tons per hectare per annum

R = rainfall and runoff factor by geographic location

K = soil erosivity index

LS = slope length-gradient factor

C = crop/vegetation and management factor

P = support practice factor

The USLE examines only sheet and rill erosion and excludes gully erosion. It also calculates soil movement, not soil loss, as it does not account for the deposition of sediment. In summary, the USLE is not suitable for studies in areas for which appropriate factor values are not available.

Day et al (1992) calculated the effects of soil conservation on erosion rates in Mali, using different combinations of soil conservation technologies and crop management strategies. Erosion rates are calculated for the different combi-nations by multiplying the maximum potential erosion rate by factors for soil physical structure and crop cover adjusted for West African conditions. The erosion rates are entered into a soil-water balance/crop yield response model to calculate the impact on crop yields. The yield data are entered into a linear programming model of a typical farming system, which maximises net cash income subject to resource constraints, and the fulfilment of household requirements for grain consumption.

4.3.2 Erosion-Productivity Impact Calculator (EPIC)

There are a number of empirical models used to estimate the effects of erosion on crop yields. The models range from relatively simple relationships derived from regression analysis to highly complex computer simulations of crop growth, such as the Erosion-Productivity Impact Calculator (EPIC). They are based on specific assumptions and are generally representative only of the geographical area in which they are developed. Some of the models require small quantities of data that are relatively easy to obtain whiles others require large data sets that are rarely available in developing countries. Benson et al (1989) to study the effects of erosion on soil productivity over a 100-year period and to examine its effect on yields over the soil's productive life.

4.3.3 Contingent Valuation and Hedonic Pricing

Contingent valuation and hedonic pricing are alternative methods for valuing the on-site effects of soil erosion. Contingent valuation involves questioning individuals such as farmers about their willingness to accept compensation for the effects of erosion or their willingness to pay for the benefits of reduced erosion e.g. as a result of soil conservation. Purvis et al (1989) used this approach in the valuation of the on-site effects of filter strips under a conservation programme in Michigan, US. Farmers were questioned about their willingness to accept compensation in return for the establishment of filter strips on their land. The aim of the filter strips was to reduce the sediment washed off the land and into streams. Filter strips have few benefits to the farmer (access, amenity, recreation); the farmer bears the cost of a reduction in crop area and, under the given programme, 50% of the costs of establishment. The data for the analysis were collected using postal questionnaires.

The sample of farmers was divided into twelve groups, each of which was offered a different annual compensatory payment in return for the establishment of filter strips. Data were collected on the willingness of farmers to accept the payment offered and, at the given level of payment, the area of land they would be willing to place under the programme. [11]Tobit analysis was carried out on the data and the resultant equation was used to estimate the area of land that filter strips could be established on for different levels of compensatory payment.

Hedonic pricing uses land prices to estimate the economic value of soil erosion. Sale prices or rental charges for plots of land that experience different rates of soil erosion are assessed using regression analysis. The results quantify the relationship between land prices and soil loss and so can be used to infer the cost of erosion. Several such studies have been carried out in the US. For example,

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[11] The Tobit model is a statistical model proposed by James Tobin (1958) to describe the relationship between a non-negative dependent variable Y_{i} and an independent variable X_i.

Miranowski and Hammes (1984) examine the effects of both depth of topsoil and potential soil erodibility on land prices in Iowa and were able to estimate costs of each of these factors. There are however, a number of problems that arise in the valuation of soil erosion with hedonic pricing. The use of land prices to estimate the cost of erosion requires data on land prices and a well-developed market for agricultural land.

Neither of these conditions are met in most developing countries. Hedonic pricing assumes that individuals take into account erosion-induced degradation in making decisions whether to purchase or rent a piece of land. In many cases individuals are unaware of the extent of degradation due to insufficient information or the masking effects of technology. Individuals may not even be concerned with the quality of the land, especially when making purchases on the basis of investment speculation or for reasons of personal security or status.

4.4 Productivity Loss Method

Soil degradation affects agricultural productivity directly. The productivity loss approach is one of the methods used in valuing on-site costs by estimating the opportunity cost i.e. farm revenues foregone due to soil loss or a reduction in the top soil depth. It relies on the impact of degradation on crop yields. However, due to the unavailability of data, off-site costs are not captured.

Under this approach, the potential soil losses with respect to the type of soils in each region are converted to actual soil losses by multiplying by the crop/vegetation management factor (C-Factor). The [12]potential soil losses are estimated based the Universal Soil Loss Equation (USLE) on bare uncultivated soils. Table 4.1 below shows the potential soil losses on the types of soil in each respective region of the country.

[12] The potential soil losses are derived from Geographical Information Systems (GIS) imagery with additional observations from the field. These estimates are based on 2005 estimates.

Table 4.1: Potential Soil Loss estimates on regional basis

Region	Total land Area (ha)	Potential soil loss (ton/ha)	Average
Ashanti	2,439,000	480-870	675
Brong Ahafo	3,956,000	260-530	395
Central	983,000	240-420	330
Eastern	1,932,000	380-620	500
Greater Accra	324,000	110-220	165
Northern	7,038,000	490-770	630
Upper East	884,000	140-240	190
Upper West	1,848,000	110-220	165
Volta	2,057,000	360-590	475
Western	2,392,000	540-770	655

Source: MoFA, 2010 & ISSER/DFID/World Bank (2005)

The following assumptions are made in order to estimate the cost of soil degradation using the productivity loss approach:

(i) On-site cost of erosion damage is equivalent to the value of lost crop production valued at market prices.

(ii) In the absence of total land use by groupings in the regions, emphasis is placed on land use as a result of cropping activities i.e. soil erosion and crop production. The computation is assumed for one cropping year.

(iii) Sub-divided land use under cropping into [13]Cassava-Maize mix and leguminous crops parametres.

[13] Cassava-Maize mix includes areas under Cocoa less than 4 years.

The Actual soil loss (ASL) is estimated for each region using the expression;

$$ASL_r = \frac{CLA_{ir}}{TLA_r} \times PSL_r \times CMF_i \qquad (1.0)$$

where TLA_r is the total land area of each region, PSL_r is the potential soil loss in each region, CLA_{ir} is the land area under crops in each region, CMF_i represents the crop management factor for each crop category, and r is the region.

Crop Yield Loss (QYL) per region, which is the shortfall in crop yield, is also estimated based on the equation:

$$QYL_r = MYL \times ASL_r \qquad (2.0)$$

where $MYL = \text{Marginal crop yield loss}$. The value of crop productivity lost ($VCPL_r$) is then obtained as a product of the total quantity of crop output lost due to soil loss and the market price of each crop, which is the average wholesale price (WSP). This is also expressed as:

$$VCPL_r = {}^{14}TQYL_r \times WSP \qquad (3.0)$$

Finally, the total value of crop productivity loss is computed by summing up all the crop productivity loss per region. Thus,

$$\text{Total Value of Crop Productivity lost (TVPL)} = \sum_{r=1}^{10} VCPL_r \qquad (4.0)$$

[14] The total quantity of crop yield lost ($TQYL_r$) is equal to the Crop Productivity Loss (QYL) aggregated over the total area under crop categories for each region i.e. $TQYL_r = QYL_r \times CLA_r$

4.5 Nutrient Replacement Cost Method

The replacement cost approach estimates the cost of additional inputs required to compensate for the reduction in soil fertility as a result of soil degradation (erosion). These include labour inputs, the increased application of fertilizers, among others. Thao, 2001 reported that loss of crop output could serve as a proxy to the loss income to the farmer from soil erosion. Quansah (2001) identified the two most common deficient nutrients as nitrogen and phosphorous particularly in the savannah soils where the organic matter is very low.

Some of the variables and parametres used in the productivity approach are also used in the nutrient replacement cost approach. Nevertheless, one key parametre used in this method is *an estimate of crop nutrient content in eroded soils,* which is specific to each agro-ecological zone. Table 4.3 presents agro-ecological zone specific data used in this approach. The C-Factor is also used in the computation of the actual soil loss specific to an agro-ecological zone. Thus,

$$\mathrm{ASL_z} = \frac{\mathrm{CLA_z}}{\mathrm{TLA_z}} \times \mathrm{PSL_z} \times \mathrm{CMF_z} \qquad (1.0)$$

where z = specific agro-ecological zones.

Table 4.2: Agro-ecological zone specific data

[15]Agro-ecology	Total land area (ha)	Total land area under food crops excluding rice and legumes (ha)	Quantity of nutrients eroded			Potential soil loss (ton/ha)
			N	P	K	
Forests	9,803,000	1,676,190	0.0560	0.0274	0.0100	2,635
Transition	3,956,000	669,370	0.0360	0.0191	0.0085	395
Interior Savannah	9,770,000	1,425,540	0.0084	0.0165	0.0072	985
Coastal Savannah	324,000	10,060	0.0270	0.0180	0.0059	165

Source: MoFA, 2011

Nutrients lost from eroded soils are converted to the form in which it is available in commercial fertilizer i.e. NPK fertilizer. The NPK compound fertilizer and the nutrients are in the form N, P_2O_5, and KO_2. The conversion from the form lost in eroded soils to the form in the commercial fertilizer is accomplished by multiplying the content in the eroded soils by the given constants (i.e. 1.00, 2.29 and 1.20 for N, P and K, respectively) as;

$$\text{Nutrient in fertilizer} = \text{Nutrient eroded from soil} \times \text{constant}$$

The three estimates are summed up to arrive at nutrients lost in the form of NPK, which is denoted by (SNL_z). The total quantity of NPK eroded from soils as contained in commercial fertilizer (TNL_z) is then computed based on the assumption that NPK is a 15-15-15 compound fertilizer and that

[15] The Forest AEZ includes the WR, ER, AR, CR and VR, Transitional AEZ is BAR, Interior Savannah are NR, UER, UWR, and Coastal Savannah is GAR.

1 ton of 15-15-15 fertilizer contains 0.45[16] tons of NPK by composition. Thus, total quantity of NPK eroded from soils as contained in commercial fertilizer (TNLz) can be expressed as:

$$\mathrm{TNLz} = \frac{(SNL_z \times 1)}{0.45} \qquad (2.0)$$

The quantity of fertilizer required to replace an NPK 15-15-15 equivalent lost from eroded soils (NRQ_Z) for each agro-ecological zone is then estimated as:

$$\mathrm{NRQ_z} = \mathrm{CLA_z} \times \mathrm{ASL_z} \times \mathrm{TNL_z} \qquad (3.0)$$

Nutrient replacement cost (NRC) is estimated given the market price of a 15-15-15 NPK fertilizer as the product of NRQ_z and the price per ton (P) of a 15-15-15 NPK fertilizer. Finally, this is estimated for each zone and then aggregated across zones based on the expression:

$$\mathrm{NRC_z} = \mathrm{NRQ_z} \times \mathrm{P} \qquad (4.0)$$

$$\mathrm{TNRC} = \sum_{\mathrm{z}=1}^{4} \mathrm{NRC_z} \qquad (5.0)$$

Bennett (1955), Pimentel et al. (1995) and Uri (2001) are among the leading authorities on the estimation of both on-site (nutrient losses and drops in yield) and off-site soil erosion. Adhikari et al., 2011; and Bertol et al., 2005 report that on-site costs can be calculated using the cost of nutrient replacement, associating the physical quantity of erosion with nutrient losses (calcium, phosphorus, magnesium, nitrogen and potassium, etc.) and calculating on the basis of the market prices for

[16] Assumption here is that if 0.45 tons of NPK is contained in a ton of NPK 15-15-15, then how many tons would be contained in SNLz tons/ha.

commercial fertilizers and the quantity necessary to replace these lost nutrients, in addition to the application cost.

Hertzler et al. (1985) conducted a study on the cost of soil use, based on a generalized Leontief function, split into two parts namely; nutrient losses and soil physical degradation. Estimates were made using information on annual crop yield, initial soil depth, nutrient stocks, erosion rate, and annual remaining nutrient stocks in the topsoil layer subject to erosion, and fertilizer prices. Pimentel et al. (1995) and Uri (2001) also estimated the costs of erosion taking account of variables over and above nutrient losses, such as the type of management and loss of yield and quality, as well as the off-site costs, extrapolating their estimates to the entire US territory. These studies however vary at different levels: local, district, regional or national.

4.6 Methodology: Strengths and Weaknesses

The main reason for using the productivity loss and nutrient replacement cost approaches is the availability of data and other relevant information. These methods are able to produce general and average estimates that can be used in macro-level economic analysis. The theoretical base is relatively simple and user-friendly, and can be used by researchers and other middle-level managers of public institutions.

The limitation of these methods however is that, estimations are primarily based on on-site effects i.e. soil and productivity losses. van Baren and Oldeman (1998) note that there is no consensus among researchers with regard to the effect of soil erosion on agricultural production and soil productivity although most researchers agree that soil erosion is a serious problem. The challenge of estimating the effect of the loss of a unit of soil on the yield of a crop arises from the fact that there is no direct link between erosion and productivity (Perrens et al, 1984; Erenstein, 1999).

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter presents the results and discussions on the estimation of agricultural soil degradation on aggregate level for the years 2006, 2008, 2010 and 2012. The aggregated agricultural soil degradation is sub-divided into two; the productivity losses and nutrient replacement cost as indicated in the previous chapter.

The methods are fundamentally based on the effects of erosion-induced soil loss on crop output or yield. In other words, what it costs in monetary value terms to replace nutrients lost as a result of soil loss. The rationale behind the productivity loss method is that on-site soil loss resulting from soil erosion can result to declining crop yields. The quantity of yield loss attributable to erosion damage is then valued at market prices (i.e. the value of crop output lost due to the soil loss). In the case of the nutrient replacement approach, the objective was to estimate how much it costs to replace the nutrients lost from soil as a result of soil degradation or erosion. That is, estimating the value of the quantity of fertilizer (NPK) required to replace the soil nutrients eroded to some extent. Crosson (1997) however notes that impacts on the soil biota, which causes great harm to crop production, cannot be offset by the usage of more inputs i.e. fertilizers.

5.2 Presentation of Results

The results are presented in tables for each year, which consists of both the estimated productivity losses and nutrient replacement cost approaches.

5.2.1 Estimation of Agricultural Soil Degradation for the year, 2006[17]

Table 5.1: Agriculture Productivity Loss (Estimates using Maize-Cassava mix and Legume Parameters) 2006

Region (s)	Total Land Area (ha)	Cropped Area (ha)	Avg. Potential Soil Loss (ton/ha)	C-Factor	Actual Soil Loss (ton/ha)	Marginal Crop Yield Loss (ton/ha)	Crop Productivity Loss (ton/ha)	Total Crop Productivity Loss (ton)	Avg. Whole sale price of crops (GH¢/ton)	Total Value of Crop Productivity Loss (mil GH¢)
Ashanti	2,439,000	505,922	675	0.0730	10.2211	0.0270	0.2755	139,360.83	194.50	27.11
Western	2,392,000	225,704	655	0.0730	4.5117	0.0270	0.1216	27,443.55	194.50	5.34
Central	983,000	244,595	330	0.0730	5.9942	0.0270	0.1615	39,512.74	194.50	7.69
Volta	2,057,000	154,460	475	0.0730	2.6037	0.0270	0.0702	10,838.60	194.50	2.11
Northern	7,038,000	589,113	630	0.2200	11.6015	0.0193	0.2239	131,907.20	590.60	77.90
Eastern	1,932,000	486,218	500	0.0730	9.1858	0.0270	0.2480	120,590.08	194.50	23.45
Greater Accra	324,000	9,879	165	0.0730	0.3673	0.0270	0.0099	97.96	194.50	0.02
Brong Ahafo	3,956,000	588,952	395	0.0730	4.2928	0.0270	0.1159	68,263.29	194.50	13.28
Upper West	1,848,000	401,749	165	0.3100	11.1198	0.0039	0.0430	17,257.50	768.20	13.26
Upper East	884,000	447,397	190	0.3100	29.8096	0.0039	0.1152	51,519.76	768.20	39.58
Total (current prices)										**209.73**

Source: Author's calculation

[17] Estimations are made with year 2006 as the base year. GDP Deflators; 2006 = 100, 2008 = 139.80, 2010 = 189.80, 2012 = 242.90. Upper east and west is leguminous based so an average C-factor for legumes is used. Northern region is a maize-cassava-legume farming system (assume C-factor is 0.22). All other regions are maize cassava farming system. Total cropped area includes 6% rice area on the assumption that 6% rice is rain fed and subject to soil erosion.

Table 5.2: Agriculture Nutrient Replacement Cost, 2006

Agro-Ecological Zones (AEZ)[18]	Avg. Potential Soil Loss (ton/ha)	Total Land Area (ha)	Cropped Area (ha)	C-Factor	Actual Soil Loss (ton/ha)	Nutrients eroded from a ton of soil/ha			Nutrients lost in the form of NPK(ton/ha)				Total NPK lost from eroded soils in the form of NPK 15-15-15	Fertilizer needed for replacement (ton)	Price of fertilizer (GH¢/ton)[19]	Replacement Cost (mil GH¢)
						N	P	K	N	P	K	Total				
Constants						**1.000**	**2.290**	**1.200**				**45.0%**				
Forest	2,635	9,803,000	1,616,899	0.0002	0.0914	0.056	0.027	0.010	0.0560	0.0627	0.0115	0.1302	0.2893	42,762.85	404.80	17.31
Transitional	395	3,956,000	588,952	0.0350	2.4362	0.036	0.019	0.009	0.0360	0.0438	0.0102	0.0900	0.2001	287,091.26	404.80	116.21
Interior Savanna	985	9,770,000	1,438,259	0.0100	1.4247	0.008	0.017	0.007	0.0084	0.0378	0.0086	0.0548	0.1218	249,647.38	404.80	101.06
Coastal Savanna	165	324,000	9,879	0.0100	0.0540	0.027	0.018	0.006	0.0270	0.0413	0.0070	0.0753	0.1674	89.37	404.80	0.04
Total (current prices)																**234.62**

Source: Author's calculation

[18] The Forest AEZ includes the WR, ER, AR, CR and VR, Transitional AEZ is BAR, Interior Savannah are NR, UER, UWR, and Coastal Savannah is GAR. Upper east and west is leguminous based so an average C-factor for legumes is used. Northern region is a maize-cassava-legume farming system (assume C-factor is 0.22). All other regions are maize cassava farming system. Total cropped area includes 6% rice area on the assumption that 6% rice is rain fed and subject to soil erosion.

[19] All fertilizer prices used are without government subsidy.

5.2.2 Estimation of Agricultural Soil Degradation for the year, 2008

Table 5.3: Agriculture Productivity Loss (Estimates using Maize-Cassava mix and Legume Parameters) 2008

Region (s)	Total Land Area (ha)	Cropped Area (ha)	Avg. Potential Soil Loss (ton/ha)	C-Factor	Actual Soil Loss (ton/ha)	Marginal Crop Yield Loss (ton/ha)	Crop Productivity Loss (ton/ha)	Total Crop Productivity Loss (ton)	Avg. Whole sale price of crops (GH¢/ton)	Total Value of Crop Productivity Loss (mil GH¢)
Ashanti	2,439,000	509,331	675	0.0730	10.2900	0.0270	0.2773	141,245.24	385.50	54.45
Western	2,392,000	237,827	655	0.0730	4.7541	0.0270	0.1281	30,470.81	385.50	11.75
Central	983,000	274,936	330	0.0730	6.7377	0.0270	0.1816	49,923.53	385.50	19.25
Volta	2,057,000	190,880	475	0.0730	3.2177	0.0270	0.0867	16,552.43	385.50	6.38
Northern	7,038,000	562,447	630	0.2200	11.0763	0.0193	0.2138	120,235.99	883.80	106.26
Eastern	1,932,000	492,766	500	0.0730	9.3095	0.0270	0.2514	123,859.97	385.50	47.75
Greater Accra	324,000	9,745	165	0.0730	0.3623	0.0270	0.0098	95.32	385.50	0.04
Brong Ahafo	3,956,000	617,387	395	0.0730	4.5001	0.0270	0.1215	75,014.01	385.50	28.92
Upper West	1,848,000	421,093	165	0.3100	11.6553	0.0039	0.0450	18,959.39	1,149.60	21.80
Upper East	884,000	320,807	190	0.3100	21.3750	0.0039	0.0826	26,489.60	1,569.10	41.56
Total (Current prices)										**338.15**
Total (Constant 2006 prices)										**241.88**

Source: Author's calculation

Table 5.4: Agriculture Nutrient Replacement Cost, 2008

[20]Agro-Ecological Zones (AEZ)	Avg. Potential Soil Loss (ton/ha)	Total Land Area (ha)	Cropped Area (ha)	C-Factor	Actual Soil Loss (ton/ha)	Nutrients eroded from a ton of soil/ha			Nutrients lost in the form of NPK (ton/ha)				Total NPK lost from eroded soils in the form of NPK 15-15-15	Fertilizer needed for replacement (ton)	Price of fertilizer (GH¢/ton)	Replacement Cost (mil GH¢)
						N	**P**	**K**	**N**	**P**	**K**	**Total**				
Constants						**1.000**	**2.290**	**1.200**				**45.0%**				
Forest	2,635	9,803,000	1,705,740	0.0002	0.0917	0.056	0.027	0.010	0.0560	0.0627	0.0115	0.1302	0.2893	45,246.29	874.00	39.55
Transitional	395	3,956,000	617,387	0.0350	2.1576	0.036	0.019	0.009	0.0360	0.0438	0.0102	0.0900	0.2001	266,538.12	874.00	232.95
Interior Savanna	985	9,770,000	1,304,347	0.0100	1.3150	0.008	0.017	0.007	0.0084	0.0378	0.0086	0.0548	0.1218	208,974.88	874.00	182.64
Coastal Savanna	165	324,000	10,181	0.0100	0.0518	0.027	0.018	0.006	0.0270	0.0413	0.0070	0.0753	0.1674	88.37	874.00	0.08
Total (current prices)																**455.22**
Total (constant 2006 prices)																**325.62**

Source: Author's calculation

[20] The Forest AEZ includes the WR, ER, AR, CR and VR, Transitional AEZ is BAR, Interior Savannah are NR, UER, UWR, and Coastal Savannah is GAR. Upper east and west is leguminous based so an average C-factor for legumes is used. Northern region is a maize-cassava-legume farming system (assume C-factor is 0.22). All other regions are maize cassava farming system. Total cropped area includes 6% rice area on the assumption that 6% rice is rain fed and subject to soil erosion.

5.2.3 Estimation of Agricultural Soil Degradation for the year 2010

Table 5.5: Agriculture Productivity Loss (Estimates using Maize-Cassava mix and Legume Parameters) 2010

Region (s)	Total Land Area (ha)	Cropped Area (ha)	Avg. Potential Soil Loss (ton/ha)	C-Factor	Actual Soil Loss (ton/ha)	Marginal Crop Yield Loss (ton/ha)	Crop Productivity Loss (ton/ha)	Total Crop Productivity Loss (ton)	Avg. Whole sale price of crops (GH¢/ton)	Total Value of Crop Productivity Loss (mil GH¢)
Ashanti	2,439,000	476,005	675	0.0730	3.4878	0.0270	0.2592	123,366.33	413.70	51.04
Western	2,392,000	234,313	655	0.0730	12.8065	0.0270	0.1262	29,577.03	413.70	12.24
Central	983,000	259,841	330	0.0730	9.8927	0.0270	0.1716	44,592.05	413.70	18.45
Volta	2,057,000	206,902	475	0.0730	0.3945	0.0270	0.0940	19,447.79	413.70	8.05
Northern	7,038,000	650,306	630	0.2200	5.0811	0.0193	0.2472	160,733.65	1,195.80	192.21
Eastern	1,932,000	523,634	500	0.0730	13.0749	0.0270	0.2671	139,863.75	413.70	57.86
Greater Accra	324,000	10,611	165	0.0730	19.3517	0.0270	0.0107	113.02	413.70	0.05
Brong Ahafo	3,956,000	697,101	395	0.0730	3.4878	0.0270	0.1372	95,635.44	413.70	39.56
Upper West	1,848,000	472,384	165	0.3100	12.8065	0.0039	0.0505	23,859.36	1,569.10	37.44
Upper East	884,000	290,440	190	0.3100	9.8927	0.0039	0.0748	21,712.04	1,569.10	34.07
Total (Current prices)										**450.95**
Total (Constant 2006 prices)										**237.59**

Source: Author’s calculation

Table 5.6: Agriculture Nutrient Replacement Cost 2010

Agro-Ecological Zones (AEZ)[21]	Avg. Potential Soil Loss (ton/ha)	Total Land Area (ha)	Cropped Area (ha)	C-Factor	Actual Soil Loss (ton/ha)	Nutrients eroded from a ton of soil/ha			Nutrients lost in the form of NPK(ton/ha)				Total NPK lost from eroded soils in the form of NPK 15-15-15	Fertilizer needed for replacement (ton)	Price of fertilizer (GH¢/ton)	Replacement Cost (mil GH¢)
						N	P	K	N	P	K	Total				
Constants						**1.000**	**2.290**	**1.200**				**45.0%**				
Forest	2,635	9,803,000	1,700,695	0.0002	0.0914	0.056	0.027	0.010	0.0560	0.0627	0.0115	0.1302	0.2893	44,979.04	964.40	43.38
Transitional	395	3,956,000	697,101	0.0350	2.4362	0.036	0.019	0.009	0.0360	0.0438	0.0102	0.0900	0.2001	339,809.71	964.40	327.71
Interior Savanna	985	9,770,000	1,413,130	0.0100	1.4247	0.008	0.017	0.007	0.0084	0.0378	0.0086	0.0548	0.1218	245,285.58	964.40	236.55
Coastal Savanna	165	324,000	10,611	0.0100	0.0540	0.027	0.018	0.006	0.0270	0.0413	0.0070	0.0753	0.1674	95.99	964.40	0.09
Total (current prices)																**607.74**
Total (constant 2006 prices)																**320.20**

Source: Author's calculation

[21] The Forest AEZ includes the WR, ER, AR, CR and VR, Transitional AEZ is BAR, Interior Savannah are NR, UER, UWR, and Coastal Savannah is GAR. Upper east and west is leguminous based so an average C-factor for legumes is used. Northern region is a maize-cassava-legume farming system (assume C-factor is 0.22). All other regions are maize cassava farming system. Total cropped area includes 6% rice area on the assumption that 6% rice is rain fed and subject to soil erosion.

5.2.4 Estimation of Agricultural Soil Degradation for the year 2012

Table 5.7: Agriculture Productivity Loss (Estimates using Maize-Cassava mix and Legume Parameters) 2012

Region (s)	Total Land Area (ha)	Cropped Area (ha)	Avg. Potential Soil Loss (ton/ha)	C-Factor	Actual Soil Loss (ton/ha)	Marginal Crop Yield Loss (ton/ha)	Crop Productivity Loss (ton/ha)	Total Crop Productivity Loss (ton)	Avg. Whole sale price of crops (GH¢/ton)	Total Value of Crop Productivity Loss (mil GH¢)
Ashanti	2,439,000	486,286	675	0.0730	9.8244	0.0270	0.2648	128,752.93	740.53	95.35
Western	2,392,000	196,048	655	0.0730	3.9189	0.0270	0.1056	20,705.54	740.53	15.33
Central	983,000	250,431	330	0.0730	6.1372	0.0270	0.1654	41,420.78	740.53	30.67
Volta	2,057,000	191,777	475	0.0730	3.2328	0.0270	0.0871	16,708.37	740.53	12.37
Northern	7,038,000	754,989	630	0.2200	14.8681	0.0193	0.2870	216,646.92	2,503.60	542.40
Eastern	1,932,000	529,807	500	0.0730	10.0093	0.0270	0.2703	143,180.83	740.53	106.03
Greater Accra	324,000	10,300	165	0.0730	0.3829	0.0270	0.0103	106.49	740.53	0.08
Brong Ahafo	3,956,000	701,320	395	0.0730	5.1119	0.0270	0.1380	96,796.55	740.53	71.68
Upper West	1,848,000	459,453	165	0.3100	12.7170	0.0039	0.0491	22,570.99	3,186.30	71.92
Upper East	884,000	255,956	190	0.3100	17.0541	0.0039	0.0659	16,862.36	3,186.30	53.73
Total (Current prices)										**999.56**
Total (Constant 2006 prices)										**411.51**

Source: Author's calculation

Table 5.8: Agriculture Nutrient Replacement Cost 2012

[22]Agro-Ecological Zones (AEZ)	Avg. Potential Soil Loss (ton/ha)	Total Land Area (ha)	Cropped Area (ha)	C-Factor	Actual Soil Loss (ton/ha)	Nutrients eroded from a ton of soil/ha			Nutrients lost in the form of NPK(ton/ha)				Total NPK lost from eroded soils in the form of NPK 15-15-15	Fertilizer needed for replacement (ton)	Price of fertilizer (GH¢/ton)	Replacement Cost (mil GH¢)
						N	**P**	**K**	**N**	**P**	**K**	**Total**				
Constants						**1.000**	**2.290**	**1.200**				**45.0%**				
Forest	2,635	9,803,000	1,654,349	0.0002	0.0889	0.056	0.027	0.010	0.0560	0.0627	0.0115	0.1302	0.2893	42,560.98	864.40	36.79
Transitional	395	3,956,000	701,320	0.0350	2.4509	0.036	0.019	0.009	0.0360	0.0438	0.0102	0.0900	0.2001	343,935.35	864.40	297.30
Interior Savanna	985	9,770,000	1,470,398	0.0100	1.4824	0.008	0.017	0.007	0.0084	0.0378	0.0086	0.0548	0.1218	265,569.14	864.40	229.56
Coastal Savanna	165	324,000	10,300	0.0100	0.0525	0.027	0.018	0.006	0.0270	0.0413	0.0070	0.0753	0.1674	90.44	864.40	0.08
Total (current prices)																**563.72**
Total (constant 2006 prices)																**232.08**

Source: Author's calculation

[22] The Forest AEZ includes the WR, ER, AR, CR and VR, Transitional AEZ is BAR, Interior Savannah are NR, UER, UWR, and Coastal Savannah is GAR. Upper east and west is leguminous based so an average C-factor for legumes is used. Northern region is a maize-cassava-legume farming system (assume C-factor is 0.22). All other regions are maize cassava farming system. Total cropped area includes 6% rice area on the assumption that 6% rice is rain fed and subject to soil erosion.

5.3Summary and discussion of results

Table 5.9: Annual Estimates of the Cost of Productivity Loss and Nutrient Replacement

Year (s)	Productivity loss		Nutrients replacement	
	Current prices (mil GH¢)	Constant 2006 prices (mil GH¢)	Current prices (mil GH¢)	Constant 2006 prices (mil GH¢)
2006	209.73	209.73	234.62	234.62
2008	338.15	241.88	455.22	325.62
2010	450.95	237.59	607.74	320.20
2012	999.56	411.51	563.72	232.08

Table 5.10: Annual Cost of Agricultural Soil Degradation

Year (s)	Current prices (mil GH¢)	Constant 2006 prices (mil GH¢)	Real AgGDP (mil GH¢)	Real cost as a % of AgGDP	Real GDP (mil GH¢)	Real Cost as a % of Real GDP
2006	444.35	444.35	5,415.00	8.21	17,809.70	**2.49**
2008	793.37	567.50	5,716.00	9.93	20,343.90	**2.79**
2010	1,058.69	557.79	6,453.00	8.64	23,220.00	**2.40**
2012	1,563.28	643.59	6,657.00	9.67	28,825.00	**2.23**

The results in Table 5.10 show that between the year 2006 and 2008, the cost of agricultural soil degradation increased from 444.35 to 567.50 million Ghana Cedis. This represents a 27.71% increase. The cost estimate for 2012 (GH¢ 643.59 million) was the largest even though the year recorded the lowest as a percentage of real GDP i.e. 2.3%. This can probably be explained by the huge average growth (i.e. about 11.5%) in Gross Domestic Product over the period. The results also showed that agricultural soil degradation is pronounced in the Northern region with respect to productivity losses for all the periods i.e. 2006, 2008, 2010 and 2012.

These figures represent very huge losses to the economy, especially the agricultural sector. The real cost of soil degradation over the periods considered represent close to 10% of the total contribution of the sector to national output. Perhaps, soil degradation is one of the factors that have eroded the gains of the sector in terms of its contribution to GDP since the year 2006. In all, the estimates of this prove to be consistent with the results of ISSER/DFID/World Bank, 2005 that estimated that the loss in annual GDP growth in Ghana due to agricultural soil erosion and poor land management in crop production is 1.1–2.4 %.

5.4Economic consequences of agricultural soil degradation

The loss in agricultural productivity has several indirect effects on the rest of the economy. The agricultural sector's demand for intermediates except fertilizers and pesticides decreases in relative significance, holding back production in sectors producing intermediates as well. These reductions generate a decrease in income that partially reduces private consumption and investments. Reduced supply of agricultural commodities due to loss of productivity also increases the prices of these commodities.

Real GDP growth rate for 2008, 2010 and 2012 were 14.23%, 14.14% and 24.14% respectively. This puts the average real GDP growth rate at approximately 17.5%, and the average Cost of Agricultural Soil Degradation in constant 2006 prices at approximately 13.8% over the period. This presupposes that the rate of growth in GDP would be higher on average in a low degradation scenario than it is for these periods.

5.5Key policy interventions and recommendations

Sustainable Land Management (SLM) practices have broadly been used on a global scale to address and mitigate the impacts of soil erosion. Sustainable Land Management is the adoption of land use systems that, through appropriate management practices, enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources (FAO, 2009).

In the area of agriculture, SLM includes the maintenance over time of soil productivity. This requires the combination of soil fertility treatment including the application of mineral and organic fertilizers with soil and water conservation measures (implementation of agronomic, soil management and physical measures, such as contour ridging, terracing, tied ridges or providing ground cover through mulching, use of plants and leaving crop residues).

SLM prioritizes different elements of this combination depending on the terrain, ecosystem, climate and land use that determine the potential forms of degradation. It will always encompass all elements of farming; small and large livestock, commercial and subsistence crops and agroforestry that impact on the ecosystem. Ghana is currently implementing the Sustainable Land Management Programme for mitigating land degradation, enhancing agricultural biodiversity and reducing poverty. It is thus essential that the programme is implemented in a way that will cause the nation, particularly areas (the northern part of the country) that are prone to degradation to reap the optimum benefits of the programme.

Some specific policy interventions and strategies that can address the issue of agricultural land degradation in the country among others include:

i) Development of a long-term land conservation plan. These long-term plans need to be fashioned to suit the exact needs and requirements of each region, and should be guided by three key principles; improving land use, obtaining the participation of the land users and developing the necessary institutional capacities and support.
ii) Review of policies that affect the economics of land use, and where necessary fine-tuning of these policies to encourage productive and sustainable land use rather than destructive and unsustainable agricultural practices.
iii) Creation of fiscal savings that provide opportunities to compensate farmers, who are often extremely poor by relaxing subsidies on agricultural inputs and materials.

iv) Establishment of effective monitoring and evaluating systems that assesses and enforces regulations on activities that result in negative environmental externalities at the expense of the welfare of society.

v) Increase investment and research in the development of technologies for sustainable agriculture. Soil as a resource is semi non-renewable and it is thus essential to pursue strategies that ensure sustainability.

CHAPTER 6

CONCLUSION AND WAY FORWARD

6.1 Conclusion

The magnitude and extent of agricultural soil degradation in Ghana is increasing on the average with reference to the results and findings presented in the previous chapter. The agricultural sector plays a very crucial role in Ghana's economy, contributing substantially to output i.e. GDP, employment and poverty reduction particularly among the rural population of the country. It is therefore imperative that policies and strategies driving the sector address these problems to ensure that gains made by the sector are not undermined by these negative environmental impacts.

This study has presented an estimated economic cost of agricultural soil degradation from 2006, 2008, 2010 and 2012. The study adopted the agricultural productivity loss and nutrient replacement cost approaches in the estimation. Regional data i.e. total cropped area, total land area, potential soil loss of agro-ecological zones, among others were used to estimate the cost of soil degradation. The results indicate the steady in soil degradation in the agricultural sector over the periods considered in the study. The cost of soil degradation is estimated at an average rate of 2.5% of real GDP, which is consistent with the findings of similar studies. The estimation focused primarily on the on-site effects of land degradation i.e. soil erosion, analysing the trade-offs between the costs and gains forgone i.e. the opportunity cost.

6.2 Way forward

The cost of soil degradation also has implications for net farmer-income levels and the impact it could have on the economy in terms of poverty reduction especially among the rural poor and the northern part of the country where agricultural soil degradation is most severe. The inability of the methodology used in the study to incorporate other off-site effects of soil erosion or degradation might presuppose that the results are underestimated, and as such may not reflect the actual situation on the ground in most of the regions. Notwithstanding this limitation, the findings of the study have serious implications for agriculture in Ghana and make a compelling case for decision-makers and other relevant stakeholders to adopt proactive measures to address the issue of soil degradation in the agricultural sector.

It is hoped that the findings of the study will among others; raise awareness and inform decision-makers and other stakeholders of the need to formulate policies and strategies that will promote sustainable agriculture in Ghana for the well-being of the society and the environment.

ANNEXES

Annex 1: Major Environmental Problems in Ghana

Regions/ Key Environmental Issues	Waste disposal & management	Water pollution	Soil Erosion	Bush fires	Air Pollution	Deforestation	Sand & Stone Winning	Bad farming facilities	Illegal logging activities	Inadequate Sanitary facilities	Illegal Mining	Land degradation	Charcoal Production	Climate Change	Flooding	Inadequate Water Supply	Poor drainage systems	Noise Pollution/Nuisance	Biodiversity loss	Destruction of Wildlife	Overgrazing	Invasive Aquatic weeds	Destruction of Ecosystems	Landslides	Quarrying (Vibrations)	Sea Erosion	Settlement Erosion	Desertification	Poor Sanitation	Poor toilet facilities	Loss of Soil fertility	Encroachment on Eco-tourism sites	Siltation
Ashanti	17	21	12	13	12	20	12	15	11	3	12	12	9	5	5	8	8	3	2	0	1	0	0	0	0	0	0	0	7	7	0	0	0
Eastern	12	13	8	9	9	14	6	7	9	1	7	8	5	3	8	2	4	5	3	0	4	1	0	1	0	0	0	0	2	2	1	0	1
Volta	11	10	5	9	6	8	8	6	4	5	3	4	4	4	4	0	0	3	2	2	3	1	0	0	0	1	0	0	0	1	1	0	1
Greater Accra	2	3	1	0	1	1	2	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Western	7	6	3	1	5	4	2	0	3	1	4	4	1	1	1	0	0	0	0	1	0	1	1	0	0	0	1	0	2	1	0	1	0
Northern	12	8	3	9	4	11	8	8	2	5	1	5	9	2	1	0	0	1	0	1	9	0	0	0	0	0	0	0	0	0	0	0	1
Upper East	2	2	3	4	0	4	3	2	1	0	2	3	2	0	2	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1
Upper West	0	0	2	4	2	3	3	1	2	0	0	3	5	2	1	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Brong Ahafo	9	6	3	10	6	5	3	7	9	0	2	6	6	2	1	0	0	2	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0
Central	5	8	5	2	6	8	6	5	6	1	2	5	4	3	3	0	1	1	2	0	0	0	1	0	1	0	0	0	0	0	0	0	1
	77	**77**	**45**	**61**	**51**	**78**	**53**	**51**	**47**	**16**	**33**	**51**	**45**	**22**	**28**	**10**	**13**	**16**	**10**	**8**	**20**	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**13**	**11**	**2**	**1**	**6**

Source: Author's analysis from SEA Reports of District Medium-Term Development Plans 2010-2013

Annex 2: Environmental Problems in Ghana

No.	Nature of concern	Causes	Effects	Indicators
1	Land degradation	• Traditional farming methods • Bush fires • Clearing of watersheds • Sand and stone winning • Harvesting of firewood	• Loss of top soil • Loss of biodiversity • Loss of medical plants • Siltation of rivers • Salination of soil	• Area affected by erosion • Area affected by salinization • Area of land contamination • Area of water logging
2	Coastal erosion	• Rising sea level • Sand wining on beaches • Harbor construction	• Erosion of coast • Loss of spawning	• % land loss to erosion • No of sand sites on beach
3	Pollution of water bodies	• Mining activities • Indiscriminate waste disposal • Farming along river banks • Indiscriminate defecation	• Damage to aquatic life • Poor water quality • Toxic water sources	• Increase BOD in rivers • % loss in aquatic life • % faecal coliform in rivers • Use of agricultural pesticide
4	Deforestation	• Timber exploitation • Fuel wood extraction • Shifting cultivation • Bushfires	• Loss of biodiversity • Drying of streams • Soil erosion	• % loss of fauna, flora • % loss of forest land/year • Number of bushfire/year • Annual allowance Cut
5	Poor waste management	• Human activities • Mining activities • Industrial activities • Agricultural activities	• Increased soil toxicity • Poor water quality • Visual intrusion • Increase in diseases • Emerging diseases	• Volume of types of waste • No of waste treatment plants

No.	Nature of concern	Causes	Effects	Indicators
6	Risk from chemical use	• Use of chemicals in fishing • Use of chemicals in hunting • Agrochemical/pesticides use • Industrial use of chemicals • Spillage from mining activities	• Polluted water bodies • Polluted air • Increase crop toxicity • Death related to pesticides	• Increase pesticides use • Level of pesticide in crops • Increase in pesticide related disease • Chemical poisoning
7	Indoor air pollution	• Use of charcoal and fuel wood • Use of insecticides • Use of mosquito coils • Smoking cigarettes	• Poor air quality • Increase chest problems • Increase in coughs	• Emission of CO_2 • Respiratory infections • Expenditure on air pollution
8	Outdoor air pollution	• Vehicular pollution • Industrial pollution • Dust from road construction • Release of methane • Stench from waste	• Health problems increase • Poor air quality • Loss of flora and fauna	• Emission of Nitrogen oxide • Emission of CO2 • Emission of Sulphur oxide • Air quality • Emission of GHG
9	Desertification	• Climate change • Deforestation • Poor farming practices • Drying of local streams	• Loss of livelihood • Erosion • Loss of vegetation cover	• Increase in vegetation loss • Decrease in food production • Loss of soil moisture • % loss of surface water
10	Large scale development	• Mining activities • Factories near rivers • Building on waterways	• Loss of arable land • Waste generation • Flooding in cities	• Pollution levels of air, water • Loss of aquatic life • Houses flooded annually

Source: Adapted from the SEA of GPRS, 2003 and Sustainable Development Indicators for Ghana

REFERENCES

Adama, A.I. (2003). The Effect of Different Tillage Practices on Soil Erosion, Water Conservation and Yield of Maize in the Semi-Deciduous Forest Zone of Ghana. Unpublished M.Sc. Thesis. Department of Crop and Soil Sciences, KNUST, Kumasi, Ghana

Adhikari, B.; Nadella, K. 2011. Ecological economics of soil erosion: a review of the current state of knowledge. Annals of the New York Academy of Sciences 1219: 134-152.

Akyea, A.O. (2009). Effect of Different Land Preparation Methods on Erosion, Growth and Yield of Cassava. Unpublished M.Sc. Thesis. Department of Crop and Soil Sciences, KNUST, Kumasi, Ghana.

Alfsen K.M., T. Bye, S. Glomsrod, and H. Wiig. 1997. Soil Degradation and Economic Development in Ghana. Environment and Development Economics 2: 119-143.

Andrews, S.S., Karlen, D.L., Mitchell, J.P., 2002. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystems & Environment 90, 25– 45.

Asuming-Brempong, S., Botchie, G., Seini W. (2003). Socio Economic Analysis and the Roles of Agriculture in Developing Countries. Country Case Study Ghana. FAO roles of Agriculture Project, ISSER, University of Ghana, Legon.

Benneh, G., Agyepong, G.T. and Allotey, J.A. 1990. Land degradation in Ghana. Food Production and Rural Development Division. Commonwealth Secretariat, Marlborough House. Pall Mall. London.

Bennett, H.H. 1955. Elements of soil conservation. 2nd Ed. McGraw-Hill, New York, NY, USA.

Benson, V.W., Rice, O.W., Dyke, P.T., Williams, J.R. & Jones, C.A. (1989) Conservation impacts on crop productivity for the life of the soil. Journal of Soil & Water Conservation (Nov-Dec) 601-604.

Bertol, I.; Cogo, N.P.; Schick, J.; Gudagnin, J.C.; Amaral, A.J. 2007. Financial aspects of nutrient losses by water erosion in different soil management systems. Revista Brasileira de Ciência do Solo 31: 133-142

Boardman, J., 1998. An average soil erosion rate for Europe: myth or reality? Journal of Soil and Water Conservation 53, 46– 50.

Bonsu, M. and Quansah, C. (1992). The Importance of Soil Conservation for Agricultural and Economic Development of Ghana. In Proceedings of the 12th and 13th Annual General Meetings of the Soil Science Society of Ghana, Accra, Ghana. pp. 77-80.

Brady, N. C., and R. R. Weil. 1999. Soil erosion and its control. In the nature and properties of soils. 12th Edition, pp. 680. Upper Saddle River, NJ: Prentice Hall Inc.

Clark, E.H. II 1985. The off-site costs of soil erosion. Journal of Soil and Water Conservation 40: 19-22.

Convery, F., and K. Tutu. 1990. Evaluating the Costs of Environmental Degradation: Ghana – Applications of economics in the environmental action planning process in Africa. Dublin, Ireland: University College of Dublin, Environmental Institute.

Crosson, P. 2007. Soil quality and agricultural development. p. 2911-2932. In: Evenson, R.; Pingali, P., eds. Handbook of agricultural economics, v.3. Agricultural development: farmers, farm production and farm markets. North-Holland, Amsterdam, Netherlands.

Cruz, W., Francisco, H.A. and Conway, Z.T. 1988. "The On-Site and Downstream Costs of Soil Erosion in the Magat and Pantabangan Watersheds." Journal of Philippine Development 15(26, 1): 85-111.

Day, J.C., Hughes, D.W. & Butcher, W.R. (1992) Soil, water and crop management alternatives in rainfed agriculture in the Sahel: an economic analysis. Agricultural Economics 7 262-287.

den Biggelaar, C., Lal, R., Wiebe, K. & Breneman, V. (2004a). The global impact of soil erosion on productivity: I: Absolute and relative erosion-induced yield losses. In: Sparks, D. L. (Ed.) Advances in Agronomy, pp. 1-48. Academic Press.

den Biggelaar, C., Lal, R., Wiebe, K., Eswaran, H., Breneman, V. & Reich, P. (2004b). The global impact of soil erosion on productivity: II: Effects on crop yields and production over time. In: Sparks, D. L. (Ed.) Advances in Agronomy, pp. 49-95. Academic Press.

Destombes, J., (1999). Nutrition and Economic Destitution in Northern Ghana, 1930 – 1959. A Historical Perspective on Nutritional Economics.

Diao, X., & Sarpong, D. (2007). Cost implications of agricultural land degradation in Ghana: an economy wide, multimarket model assessment. Retrieved from http://pdf.usaid.gov/pdf_docs/pnads122.pdf

Dickson, K.B. and Benneh, G. 1988. A new geography of Ghana. Longman Group UK Limited. Longman House, Burnt Mill, Harlow, Essex, England.

Douglas, M.G. 1994. Sustainable Use of Agricultural Soils. A Review of the Prerequisites for Success or Failure. Development and Environment Reports No. 11, Group for Development and Environment, Institute for Geography, University of Berne, Switzerland.

EEA, 2000. Down to earth: soil degradation and sustainable development in Europe. Environmental Issues Series, vol. 16. European Environment Agency, Copenhagen, p. 32.

EPA (2002). National Programme to Combat Drought and Desertification. Accra.

FAO/UNDP/UNEP. 1994. Land Degradation in South Asia: Its Severity, Causes and Effects upon the People. (World Soil Resources Report #78.) FAO, Rome.

Folly, A. (1997). Land Use Planning to Minimize Soil Erosion – A Case Study from the Upper East Region in Ghana. Ph.D. thesis, Institute of Geography, University of Copenhagen.

http://www.omafra.gov.on.ca/english/engineer/facts/12-051.htm (Assessed on: 14th July, 2014)

ISSER/DFID/WB (2005). Economic Assessment of the Sustainability of Growth Dependent upon Renewable Natural Resources, Ghana.

Lal, R. 2006. Managing soils for feeding a global population of 10 billion. Journal of the Science of Food and Agriculture 86: 2273-2284.

Magrath, W. and Arens, P. 1989. The Costs of Soil Erosion on Java: A Natural Resource Accounting Approach. Environment Department Working Paper No. 18. The World Bank, Washington DC.

Mikesell F. R. 1992. Economic Development and the Environment: A comparison of Sustainable Development with Conventional Development Economics. London: Mansell Publishing.

Miranowski, J.A. & Hammes, B.D. (1984). Implicit prices of soil characteristics for farm land in Iowa. American Journal of Agricultural Economics (Dec) 745-749.

Muchena FN; Onduru DD; Gachini, G. N., and Jager, A. (2005). Turning the tides of soil degradation in Africa: capturing the reality and exploring opportunities. Land Use Policy. 22: 23 – 31

Oldeman, L., R. Hakkeling, and W. Sombroek. 1990. “World map of the status of soil degradation, an explanatory note.” International Soil Reference and Information Center, Wageningen. The Netherlands and the United Nations Environmental Programme, Nairobi, Kenya.

Pimentel, D. 2000. Soil erosion and the threat to food security and the environment. Ecosystem Health 6:221–226.

Pimentel, D.; Marklein, A.; Toth, M.A.; Karpoff, M.; Paul, G.S.; McCormack, R.; Kyriazis, J.; Krueger, T. Food versus biofuels: Environmental and economic costs. Hum. Ecol. 2009, 37, 1–12.

Purvis, A., Hoehn, J.P., Sorenson, V.L. & Pierce, F.J. (1989) Farmers' response to a filter strip program: results from a contingent valuation survey. Journal of Soil & Water Conservation (Sept-Oct) 501-504.

Quansah, C. (1996) Soil, water and nutrient management needs for sustainable crop production. Proceedings of DSE International Seminar on Tools for Analysis and Evaluation for sustainable Land use in Rural Development. pp 38-46 DSE, Zscortan, Germany.

Quansah, C. (2000). Country Case Studies: Ghana. In: FAO (ed.), Integrated Soil Management for Sustainable Agriculture and Food Security- Case Studies from 4 Countries in West Africa (Burkina Faso, Ghana, Nigeria, and Senegal). FAO Regional Office for Africa, Accra, Ghana.

Quansah, C. (2001). Integrated Soil Management for Sustainable Agriculture and Food Security. Country case study: Ghana. FAO Regional Office for Africa.

Quansah, C., Safo, E. Y., Ampontuah, E. O. and Amankwaah, A. S. (2000). Soil Fertility Erosion and the Associated Cost of NPK Removal under Different Soil and Residue Management in Ghana. Ghana Journal of Agriculture Science, 33(1): 33-42.

Richards, P. D., Myers, R. J., Swinton, S. M., & Walker, R. T. (2012). Exchange rates, soybean supply response, and deforestation in South America. Global Environmental Change, 22(2), 454-462.

Roberts N (1994).The global environmental future. In: Roberts N (Ed) The changing global environment. Blackwell, Oxford, pp 3–21.

Scherr, S.J. 1999. Soil Degradation: A Threat to Developing-Country Food Security by 2020? International Food Policy Research Institute, Washington, DC.

Sparovek, G.; De Maria, I.C. 2003. Multiperspective analysis of erosion tolerance. Scientia Agricola 60: 409-416.

Telles, T. S., Carmela, S., Dechen, F., Gustavo, L., Souza, A. De, & Guimarães, M. D. F. (2013). Point of view, (June), 209–216.

Turner II, B.L., Hyden, G., Kates, R. (Eds.), 1993. Population Growth and Agricultural Change in Africa. University Press of Florida, Gainesville.

UN (1997). Environmental degradation, glossary of environmental statistics, Studies in methods, Series F, Number, 67.

Uri, N.D. 2001. The environmental implications of soil erosion in the United States. Environmental Monitoring and Assessment 66: 293-312.

Wiebe, K. (2003.). Linking Land Quality, Agricultural Productivity, and Food Security, (823).

World Bank, ISSER, DFID. (2005). Natural Resource Management and Growth Sustainability. Africa Region. Washington D.C: World Bank.