

ANALYSIS OF CROP FARMERS' VULNERABILITY TO SOIL
DEGRADATION AND ADAPTATION STRATEGIES IN THE NIGER-
DELTA STATES OF NIGERIA.

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CERTIFICATION

This is to certify that this research on Analysis of Crop Farmers' Vulnerability to Soil Degradation and Adaptation Strategies in the Niger-Delta States of Nigeria, was carried out by Offor, Ijeoma R. with Reg. No. 20114770978 in partial fulfillment for the award of Doctor of Philosophy (Ph.D) Degree in Agricultural Economics of Federal University of Technology Owerri.

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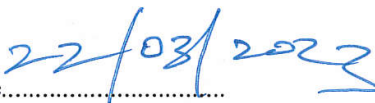
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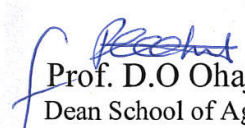
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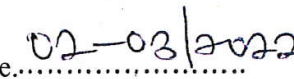

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DEDICATION

To my husband Arc. Onyeka Simplicious Ezebuike and my children
Chisaramokwu and Cindy.

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ABSTRACT

This study analyzed crop farmers vulnerability to soil degradation and adaptation strategies in the Niger Delta States of Nigeria. The objectives of the study were to examine the socio-economic characteristics of the crop farmers, identify the forms and perceived levels of soil degradation, determine the effect of soil degradation indicators and production factors on the output of dominant staple crops in the study area, ascertain the level of vulnerability of the crop farmers to soil degradation, determine the factors influencing the levels of vulnerability of the crop farmers to shock due to soil degradation in the study area, determine the types and perceived level of adaptation strategies to soil degradation and influencing factors and ascertain the trend in output of major staple crops namely cassava and maize in the study area. Data were collected with a well structured questionnaire from 152 randomly selected farmers. Data were analyzed using descriptive statistics, vulnerability index, multiple regression analysis using ols, ordered probit model, soil degradation index and time trend analysis. Results showed that the mean age of the farmers is 51 years. Results showed that the overall perceived level of soil degradation in the study area is high with a mean of 2.1. The regression result of the effects of soil degradation and production factors on cassava output showed that loss of vegetative cover, decreased soil and water absorption, sub-surface compaction and decline in soil organic matter, labour; planting material, fertilizer and farm size were statistically significant at 1%, while leaching of soil nutrients was significant at 5% level. The regression result of the effects of soil degradation and production factors on maize output showed that loss of vegetative cover, leaching of soil nutrients, sub – surface compaction, decline in soil organic matter, planting material and farm size were statistically significant at 1% level, while the coefficients of labour and fertilizer were significant at 5% level. Result of the vulnerability level of the farmers showed that farmers in the study area are vulnerable to soil degradation with a mean value of 2.09. Results of the ordered probit model show that gender (x_1), level of education (x_2), age (x_3) etc were statistically significant at 1% level, while extension contact (x_8) and farming experience (x_{10}) were statistically significant at 5% level, implying that these are the factors influencing the levels of farmers' vulnerability to soil degradation in the study area. Results also showed that perceived level of adaptation is moderate in the study area with a mean of 2.24. Results of the ordered probit model show that level of education (x_2), age (x_3), farm income (x_5), off – farm income (x_6), farm size (x_7), farming experience (x_{10}) and nature of soil degradation (x_{11}) were statistically significant at 1% level, implying that these are the socioeconomic factors influencing the levels of farmers adaptation strategies to soil degradation in the study area. The result of the trend of output of cassava and maize in the study area from 1995-2016 revealed that there is fluctuation in both cassava and maize output which can be attributed to the effect of soil degradation. It was recommended that farmers should be motivated to invest their labour and limited financial resources in the use of adaptation strategies such as soil and water conservation technologies.

Keywords: Crop, Farmers, Vulnerability, Ordered Probit, Soil, Degradation

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Soil degradation is one of the major environmental problems confronting the world today. It occurs when there is a decline in the productive or functional capacity of the soil. According to Nwaiwu (2017), 72% of Nigerian arable land has already been degraded. This has led to a decline in crop productivity (Gomiero, 2016). According to Inoni *et al* (2006) crop failures have become a recurring decimal among farming communities especially in Niger Delta region of Nigeria due to soil degradation. This has put the livelihood of farmers in the area at risk (Gomiero, 2016), thus making them vulnerable.

Although soil degradation can occur naturally, it has been exacerbated by a wide range of human activities (Feddema, 1998). A range of natural and human induced factors that cause soil degradation were identified in Oguoma (2004) and Xinshen *et al.*, (2007) as both natural and human (anthropogenic) factors. The natural factors include the physical faults that may enhance erodibility, reduction in water retentive capacity and poorly drained ability. These physical faults may lead to the soils inability to either hold soil nutrient or make them available when needed. The human factors include: unsustainable farming practices, removal of vegetation cover (including deforestation, bush burning and overgrazing), mining activities (including sand mining for building), and urbanization and industrialization. The factors are population induced as increased human activities due to population explosion has put significant pressure on the natural resource base available for human sustenance. Farming practices such as bush fallow and shifting cultivation is giving rise to continuous cropping, land use intensification practices that is rapidly degrading the soil, reducing land productivity and disrupted water movement in the

soil (Oladeji, 2007). Declining output per capita, according to Shiferaw and Holden (2001), has forced rural people to either expand farming into marginal erodible slopes or encroach on the remaining forests, thereby expanding the total area dedicated to agriculture even as productivity declines.

Agricultural policies in Nigeria have focused on strengthening agricultural production, growth and development. The favourable policies have engendered good performances in economic growth through the sector. The rural population has 70% of its inhabitation as farmers who produced over 90% of food in the country (Africa Agriculture Status Report, 2013; Adebo and Ajiboye, 2014; Grandval and Douillet, 2011). The contributions of Niger Delta Nigeria, tenure or part-time farmers in food production are below expectation given the continental shelf and large volume of drainages in the area (Egbe, 2012). Instead of a rapid increase in farm produce, excess flooding, erosion and industrial effluent has subjected the soil in the area to rapid degradation and thus unproductive (Onyeneke, Mmagu and Aligbe 2017). Many communities in the coastal and inland areas of Niger Delta are plagued with loss of soil nutrient due to rapid erosion and flooding that came with heavy rainfall (Etim and Folarin, 2015; Jumbo-Ibeakuzie, 2008). This has resulted in low levels of crop yield as well as total crop failure (Etim *et al.*, 2015). Abnormal changes in rainfall leading to increasing frequency in flood and intensified leaching in most part of the Niger Delta states in Nigeria such as Rivers, Bayelsa, Imo and Delta have brought long – term implications for a viable and productive agro-system with unbalanced eco-system in their rural communities (Onyeneke *et al.*, 2017; Gobo and Abam 2005).

The Niger Delta region is endowed with natural resources such as crude oil. However, frequent exploration and exploitation of crude oil in this region has resulted in soil pollution which further degrades the soil (Ani *et al.*, 2015). Oil

pollution in Niger Delta is the reason for the changing pattern in agricultural activities to off-farm activities (Akpokodje and Salau, 2015). According to Digha, Ambah and Jacob (2017), oil polluted farmlands are depleted in soil nutrients as organic matter is lost while the soil retains excess water and carbon. Crop yield thus decline with only off-farm activities predominating the area. High oil concentration in the soil may not only reduce the amount of water and oxygen available for plant growth, but also interferes with soil-plant – water relationships, block the soil air spaces, and interfere with micro-organisms-nutrient interactions. There is also direct physical oil contact with plants (coating of root tissues) which adversely affect plant growth and reduce the crop yield (Digha *et al.*, 2017). These are some factors that expose the farmland to adverse vulnerable conditions.

In Nigeria, the traditional and predominant method of clearing farm is through bush burning. However, according to Izah *et al.*, (2017) it poses a great threat to biodiversity in Niger Delta. Bush burning destroys soil organic matter, kills beneficial insects and micro-organisms, depletes soil moisture and destroys the structure of the soil making the soil prone to degradation with concomitant unsustainable for agricultural production (Okoro and Uwem, 2016; Mbagwu, 2003). According to Nwaiwu, Onubuogu and Onwerenmadu (2016), continuous practice of bush burning/clearing by farmers accelerates soil degradation. Burning also releases into the atmosphere, carbon dioxide and carbon monoxide, which accelerate atmospheric temperature (Nwalieji *et al.*, 2012). The soil temperature may rise between 93° to 1004°C due to the different materials burnt and the length of time exposed to heating (Pantami *et al.*, 2010). According to Parry *et al.*, (2004), a high temperature especially with tropical crops can lead to a drastic crop failure and low yields. This implies that as the soil becomes vulnerable to nutrient depletion due to burning, farmers income drops and poverty increases.

Again, the current area of land covered by forest is grossly depleting due to population increase, due to the quest for more lands for other activities different from agriculture and the widespread poverty (Enete and Amusa, 2010). The area of land under forest is about 400 million ha and is depleting at the rate of 0.7% and even more in the south (Enete et al., 2009; Onoja and Unaeze, 2009). The mangrove forest in Niger Delta Nigeria depletes fast due to the use of its resources as fuel wood, stake pole production, fish traps, boat carving, fishing platforms as well as shore line protection bars and finally timber (Mmom *et al.*, 2010). In Cross-River State for example, 29% of the state is under tropical rain forest, rich in biodiversity and economically valuable timber. Unfortunately, the forest reserves have suffered significant loss and degradation over the last couple of years owing to rapid farmland expansion and illegal logging (Enobakhare *et al.*, 2013). Deforestation deprives the earth surface of the shade that it needs to keep moist and rich for cultivation. As a result, farm lands dry up and lose its nutrient over time resulting in declining crop productivity (Asante, 2010).

Crop farmers are vulnerable to any reductions in crop productivity. According to Harvey *et al.*, (2014), smallholder farmers are vulnerable to any shock that affects their agricultural system such as soil degradation. Vulnerability in this context refers to the degree to which a system is susceptible to and is unable to cope with adverse effects of soil degradation (Adger, 2006). According to Nwaiwu (2016) and Lal *et al.*, (1998), soil degradation leads to loss of farmlands, decrease in root depth, available water and nutrient reserves in the soil. Egbule (2014) noted that over five thousand farmlands have been lost to soil degradation in Niger Delta as a result of excessive pressure on marginal lands to meet the food demand of the growing population. Such marginal or nutrient depleted soils are particularly vulnerable to degradation, further lowering their quality and overall productivity. This most likely

will lead to food shortages thus leading to famine and increasing the vulnerability of these farmers to the effects of soil degradation. Given the far-ranging adverse effects of soil degradation, adaptation must be an integral component of an effective strategy to address it.

Adaptation is about building resilience and reducing vulnerability. Adaptation has the potentials to reduce adverse effects of soil degradation and to enhance beneficial impacts. Mitchell and Tanner (2006) defined it as an understanding of how individuals, groups and natural systems can prepare for and respond to changes in their environment. According to Ajayi (2015), adaptation strategies that can sustainably reduce the impact of soil degradation and increase crop yield include contour farming, mulching, crop rotation, strip cropping, dry land farming, organic agriculture and low external input. Others include appropriate tillage practices that facilitate soil and water conservation, improve root system development, maintain a favorable level of soil organic matter content, and reverse degradation in the soil's life-support processes, retaining structures, subsurface drainage and terraces. In addition, the use of credit (financial leverage) is counted on as useful component of adaptation strategy to soil degradation (Rabin, 2010; Mwamba, 2013).

1.2 Statement of Problem

Vulnerability to soil nutrient depletion across the globe and Niger Delta Nigeria in particular has led to wide spread decline in food production in the area. Policy makers and researchers are raising concern on why an area like Niger Delta of Nigeria with a massive natural resource and water bodies is still vulnerable to plant nutrient depletion and cannot produce enough food to sustain itself. Available adaptation strategies are ignored or not effectively used by farmers to reduce soil degradation. According to Young *et al.*, (2015), soil degradation is a serious global environmental issue and about 2 billion hectares of global agricultural land is

degraded. In fact, in all parts of Nigeria lands, there is noticeable evidence of soil degradation and it is seriously associated with the problem of declining agricultural productivity in Niger Delta (Osuji and Nwoye, 2007). Some authors (Olotu *et al.*, 2013; Akinagbe and Umukoro, 2011; Chukwuone, 2015; Amadi, 2013) have suggested that yields of many important food crops in Niger Delta are in constant decline due to soil nutrient depletion. In particular is the concern that yields may further decline for major crops like cassava and maize, which are important sources of food calories (Montagnac *et al.*, 2013; Akerele and Akinleye, 2010). Declining agricultural productivity according to Sadiq, Yakasai, Ahmad, Lapkene and Abubakar (2013) may be improved by increasing size of production. According to Food and Agricultural Organization (2021), large scale commercial production is rare in Nigeria and as a result there is lack of data which masks the performance in crop output (Ariyo and Mortimore, 2011). However, the small scale farmers for which information is more readily available who make up 80% of the total farmers in Nigeria operate on small farmlands that are vulnerable to nutrient depletion and persistent crop failure (Mgbenka, Mbah and Ezeano, 2015; Lowder, Skoet, and Raney, 2016). The analysis of data using a comprehensive and more standardized agricultural census data from literature (i.e secondary data), including at the farm level on output performance of the farmers becomes necessary, thus, necessitating the need to trace the trend in agricultural performance (crop output) over the years.

Oil spills have significant impact on the farmlands upon which many poor Niger Delta communities depend for livelihood. Oil exploration and exploitation activities in Niger Delta, is known to exert adverse effects on soil physio-chemical properties and eco-system. The degraded farmlands in Niger Delta have almost become wasteland due to the discharge of effluent and waste (Bello and Anobeme, 2015). According to Osuji *et al.*, (2007), there is a high level hydrocarbon deposits on the

farmlands affected by oil spills in Niger Delta and severe hydrocarbon contaminants on farmland may alter some physio-chemical properties thus leading to low productivity. There is a serious issue of massive wetland for food production turning to oil wasteland and dumps of hydrocarbon. According to Digha *et al.*, (2017) the oil dumps and wastelands reduce the soil fertility such that most of the essential nutrients are no longer available for plant and crop utilization. This is the major reason for decline in food production and it is raising a policy concern in Niger Delta.

Niger Delta region has the largest wet land in Africa with an advantage of all year round agricultural production. This is due to its location in the rainforest and mangrove forest vegetation zones of Nigeria characterized by rich alluvial soil (Inoni *et al.*, 2006; Akpokodje and Salau, 2015; Ekanem and Nwachukwu, 2015; Izah *et al.*, 2018). According to Epidi *et al.*, (2008), cereals and legumes are cultivated twice every year in Akwa Ibom State of Niger Delta. The poor output performance recorded in recent times was due to soil degradation. Ebewore and Emaziye (2016) noted that a serious problem is facing farmers in Niger Delta areas due to depleted soils. Ehirim (2014) opined that suitable soils for cassava and food staple production in Imo State must not only be free from oil contaminants but also with improved soil practices adopted by the farmers. Poor land practices can lead to wasting away of nutrients through leaching and soil erosion. Soil erosion has been identified as a major reason for loss of plant nutrients (Kumar and Pani, 2012). It has the ability of washing away the top soil and rendering farmlands unsuitable for staple food crop production (Ehirim, 2014). Apart from the loss of nutrients associated with it, there are issues of reduced intensive farming in areas where water run-off is predominant (Ovuka, 2000). It removes the top soil and the organic matter in them, washes away essential nutrients and reduces soil fertility. Decline in the fertility and usability of the soil for crop production in Niger Delta has led to poor output performance of

farmers, thus, increased their vulnerability to shocks. It is a well known fact that soil degradation not only results in decreased food production but it also threatens farmers' livelihood especially in Niger Delta region. The degraded farmlands thus make Niger Delta more vulnerable.

Magombeyi and Taigbenu (2008) stated that success in preventing food shortages will only be achieved if we understand the vulnerability and risk of the majority of small-holder farmers to soil degradation. According to Mwamba (2013), communities or households that are most vulnerable to soil fertility loss may also be those most at risk of hunger and poverty. Again Ohajianya *et al.*, (2016) observed that climate change crisis may lead to the disruption of the rural farmer's livelihood causing a vicious cycle of falling productivity and farm income, which in turn increases the poverty status of these farmers.

Although farmers are meant to adapt to the prevailing soil and weather conditions in their areas, the case is uncertain with the farmers in Niger Delta region of Nigeria. Ehirim *et al.*, (2014) observed that suitable soil for cassava production has high marginal value productivity but that is when farmers adapt to the use of sustainable soil and cropping practices. Adaptation to suitable soil management has been recognized as an important strategy to reduce the impacts of farmer's vulnerability to degraded soils. Some of the adaptation strategies to soil degradation according to Uyigue *et al.*, (2009), Nigerian Environmental Study Team (NEST), (2011) and Ajayi, (2015) include income diversification to non-farm activities, delayed planting, use of fast-maturing varieties, crop rotation, contour farming and terracing, seasonal migration from family residence, using hand irrigation, soil management (use of organic fertilizer), soil conservation practices, planting on mounds, mulching, planting shade trees to reduce the effect of extreme heat etc. However, it

is possible that these adaptation strategies are ignored or not effectively used by farmers to reduce soil degradation in Niger Delta.

This study therefore seeks to determine the forms and perceive level of soil degradation using physical attributes of a degraded soil and their adaptation strategies in the Niger Delta States of Nigeria. To the best of my knowledge, no such study has been carried out in Niger Delta, thus creating an information gap. In the same vein, many studies including Ikehi *et al.*, (2014); Osabuomen *et al.*, (2011); Oladeji (2007) and Ani *et al.*, (2015) carried out a research on environmental degradation, pollution and climate change effect on food crop production, their adaptation strategies, determinants and constraints in Nger Delta. They failed to look at the effect of soil degradation on output of dominant staple crops in Niger Delta, thus creating another information gap. Furthermore, the level or extent of farmers' vulnerability to soil degradation has received widespread debate at the global level as evidenced in the work by oldeman (1991), Eswaran *et al.*, (1998) and Kertesz (2009), but no such work has been done in the Niger-Delta states of Nigeria. It is therefore important to understand and fill these gaps in knowledge.

1.3 Objectives of the Study.

The general objective of the study is to analyze crop farmers' vulnerability to soil degradation and adaptation strategies in the Niger-Delta States of Nigeria.

Specifically, the objectives are to:

- i examine the socio-economic characteristics of the crop farmers in the study area,
- ii identify the forms and perceived levels of soil degradation in the study area,
- iii determine the effect of soil degradation indicators and production factors on the output of dominant staple crops in the study area,

- iv ascertain the level of vulnerability of the crop farmers to soil degradation in the study area,
- v determine the factors influencing the levels of vulnerability of the crop farmers to shock due to soil degradation in the study area,
- vi determine the types of adaptation strategies to soil degradation and their influencing factors in the study area,
- vii ascertain the trend in output of major staple crops namely cassava and maize in the study area from 1995-2016.

1.4 Hypotheses of the Study

- Ho₁: perceived level of adaptation strategies used by crop farmers in the study area are not significantly influenced by their socio - economic factors.
- Ho₂: Soil degradation indicators and production factors have no significant effect on the output of dominant staple crops in the study area.
- Ho₃: Level of vulnerability of the crop farmers to soil degradation in the study area is not significantly influenced by socio-economic factors.

1.5 Justification of the Study

The present inability of food crop production sector to meet the foods demand of Nigerians and the challenge posed by soil degradation emphasized the need for the improvement of food crop farmers. Soil degradation has the potential to severely affect countries highly dependent upon agrarian livelihood. People who depend on farming activities will require a variety of adaptation strategies to mitigate the negative effect of environmental hazards and maintain the livelihood of farming families. Therefore, this study will enable farmers in soil degraded areas to know the different strategies to adapt to protect their farms and crops.

It will serve as reference material to scholars, researchers etc working on soil degradation for further work. It will also provide a guiding tool for policy makers to know the kind of policies that will help protect our environment.

The findings of this study will enable the Federal and State governments of Nigeria to provide a basis for support such as appropriate programs and policies that will enable farmers cope with soil degradation. Furthermore, the results of this study will provide a useful guide to international and local donor agencies interested in soil degradation and their adaptation strategies in their provision of grants and funds for environmental and resource management studies.

1.6 Scope of Study

This study is limited to four states out of the nine states that make up the Niger-Delta. The states include Imo, Edo, Delta and Rivers.

CHAPTER TWO

LITERATURE REVIEW

Literature review is a comprehensive study and interpretation of literature that addresses a specific topic (Aveyard, 2010). This chapter is sequentially arranged and discussed under the following sub-headings:

Conceptual Framework

Theoretical Review

Empirical Framework

Analytical Framework

2.1 Conceptual Framework

2.1.1 The Concept of the Environment

The term environment was derived from a french word “Environia” which means to surround (Deka, 2015). Environment literally means surrounding in which we are living. According to Ehwarieme *et al.*, (2011), an environment can be defined as the surrounding conditions that affect people and other organisms. An environment is a concept which embraces different components. According to Mondal (2012), an environment can be divided into two components physical and biotic environment.

- Physical environment refers to all abiotic factors or conditions like temperature, light, rainfall, soil, air, water, minerals etc.
- Biotic environment includes all biotic factors or living forms like plants, animals, micro-organisms.

2.1.2 Concept of Adaptation and Adaptation Strategies

According to Younus (2012), adaptation is a process by which vulnerable people seek to cope with environmental extremes. It can also be referred to as the outcome of a process that leads to a reduction in harm or risk of harm (Levina and Tirpak,

2006). Mitchell and Tanner (2006) defined it as an understanding of how individuals, groups and natural systems can prepare for and respond to changes in their environment. According to European Commission (2013), adaptation means any adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Based on these four definitions, adaptation can be an outcome, a process, an understanding or an adjustment. Understanding here refers to a planned action. Process is a very broad and open ended term that does not include any particular time or subject references and can easily incorporate steps and adjustment. Adjustment seems to imply a process that leads toward some standard or goal. Expectations from adaptation as an outcome might be much higher than expectations from it as a process. These small differences might create different expectations from different stakeholders depending on the meaning of the term that they decide to use. However according to IPCC (2001), adaptation can be anticipatory (which takes place before impact of degradation are observed), autonomous (triggered by changes in natural systems and market or welfare changes in human systems) and planned (result of a deliberate policy decision, based on awareness that conditions have changed or are about to change and understanding that action is required to return to, maintain, or achieve a desired state). Based on the above, Smit and Wandel (2006) gave a general definition of adaptation as a process, actions or outcome taken by a system (individuals, households or groups) to help communities and ecosystems cope with, manage or adjust to changing environmental conditions, stress, hazard, risk or opportunity.

Adaptation strategies involve a range of actions including behavioral change, technical or hard engineered solutions like construction of disaster reduction strategies such as the establishment of early warning systems etc.

According to Hashimu, (2013) the typology of adaptation options or strategy is divided into four categories. First is micro-level adaptation; these include farm production adjustments such as diversification and intensification of crop production; changing land use and irrigation; and altering the timing of operations. Second are numerous market responses. They include development of crop and flood insurance schemes, innovative investment opportunities in crop shares and futures, credit schemes, and income diversification opportunities. A third subset of adaptation strategy encompasses institutional changes; many that fall within this category require government responses. The latter comprise pricing policy adjustments such as the removal of perverse subsidies, development of income stabilization options, agricultural policy including agricultural support and insurance programs; improvement in agricultural markets, and broader goals, such as the promotion of inter-regional trade in agriculture.

A fourth set of adaptation is technological developments; these consist of the development and promotion of new crop varieties and hybrids and advances in water management techniques (for example, irrigation, conservation tillage). However these categories are considered to produce benefits in short term or long term time dimension. Adaptation strategies are needed at all levels of administration: at local, regional, national and international levels. Some of the common adaptation strategies in agriculture that can be used to control soil degradation include: the use of new crop varieties, species that are more suited to drier conditions, irrigation, crop diversification, mixed crop- livestock farming systems, change of planting dates, diversification from farm to non-farm activities, increased use of soil and water conservation techniques, changed use of capital and labour, shifting to higher ground to avoid flood, and trees planted for shade and shelter (Obayelu *et al.*, 2014).

2.1.3 Concept of Soil Degradation

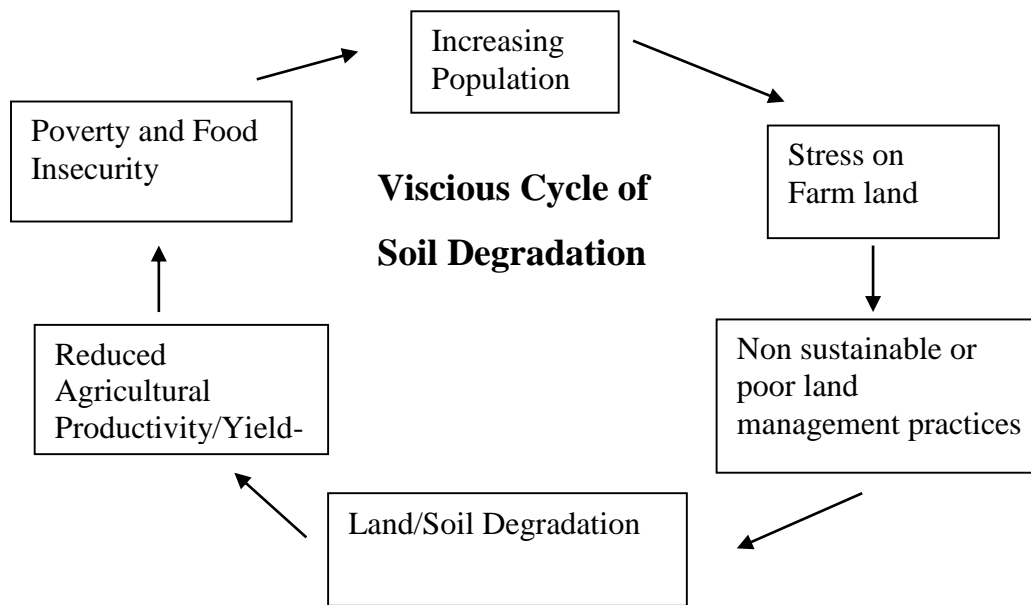
Degradation, according to the Free Dictionary, means a decline to a lower condition, quality or level. Soil degradation, according to Bojo (1996) means the total or partial loss of soil productivity quantitatively, qualitatively or both as a result of such processes as soil erosion, salinization, water logging, depletion of plant nutrients, deterioration of soil structure, desertification and pollution. Soil degradation has been defined as a process that causes deterioration of soil productivity and low soil utility as a result of natural or anthropogenic factors (Ayoub, 1991). Soil degradation can also be defined as a process that leads to decline in the fertility or future productive capacity of soil as a result of natural and human activities (United Nations Environment Programme, 1993). Increasing use of natural resources by rapidly increasing human population has resulted in over exploitation of natural resources. The consequences of such exploitation are clearly seen in soil erosion, loss of biodiversity and pollution of land, air and water bodies. The degradation of the environment from over exploitation has reached a level which is threatening human well – being and survival.

2.1.4 Concept of Vulnerability

Vulnerability means any condition of susceptibility to external shocks that could threaten people's lives and livelihoods, natural resources, properties and infrastructure, economic productivity and a region's prosperity (Uribe *et al.*, 1999). Vulnerability according to Oyekale (2013) is the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. Inter-governmental Panel on Climate Change (IPCC) (2001) defined vulnerability as a function of adaptive capacity, sensitivity and exposure. UNEP (2003) defined vulnerability as the likelihood that an individual or group will be exposed to and adversely affected by a hazard or it can be seen as the insecurity of the well-being of individuals, households or communities in the face of a changing

environment. Smallholder farmers however, are particularly vulnerable to changes in the environment that reduce productivity and negatively affect their weather dependent livelihood systems (Ngigi, 2009). The level of vulnerability of different social groups to soil degradation is determined by both socioeconomic and environmental factors. The variations of these socioeconomic and environmental factors across different social groups are responsible for the differences in their levels of vulnerability to soil degradation.

2.1.5 Conceptual Framework Linking Vulnerability, Soil Degradation, Adaptation and Yield



Increasing population pressure brings about competition for scarce resources which puts stress on farm land. This results to small farms, low production per person and increasing land shortages. Land shortage leads to non-sustainable land management practices which are the direct cause of soil degradation thus making the farmers vulnerable. When rural poor farmers don't have enough land for cultivation, they are forced to clear forest; cultivate steep slopes without conservation, over graze

rangelands and make unbalanced fertilizer application which leads to degradation of the soil. Soil degradation then leads to reduced productivity probably because farmers need higher inputs to maintain crop yields and farm income. This has the effect of increasing the poverty status of the farmers thus leading to a degradation cycle. According to Seyoum *et al.*, (2020) crop yield loss, food insecurity, loss of productive agricultural land resulting in reduction in farm income increased farmers' vulnerability to soil degradation.

2.1.6 Concept of Adaptive Capacity, Sensitivity and Exposure

Adaptive capacity is the ability of farmers to cope with the impacts of soil degradation, which is the ability to make adjustments (NEST, 2011). Adaptive capacity is generally accepted as a desirable property or positive attribute of a system for reducing vulnerability and increasing resilience and as a prerequisite for adaptation to take place (Dixon *et al.*, 2014). Adaptive capacity varies among individuals, communities, socioeconomic groups and regions. Those with the least capacity to adapt are generally the most vulnerable to the negative impacts of soil degradation. Issues of policy, growing populations and low agricultural production contribute to low adaptive capacity and ultimately, vulnerability. Developing countries with growing populations and lower technological capabilities generally have lower adaptive capacity (NEST, 2011). This is especially true for small-scale farmers who are resource-dependent and also dependent on the seasons for their livelihoods. Those individuals and communities who can be flexible in their responses and have a range of choices usually have a greater capacity to deal with change. People are vulnerable to environmental changes due to changes in frequency or duration of those changes or because they are constrained economically, socially or politically from responding adequately to those changes.

Sensitivity is the degree to which a system will be affected by, or responsive to environmental changes. Sensitivity can also be defined as the degree to which a system will respond to an external disturbing force. It includes the ability to resist change and the ability to return to a previous condition after a stress has been removed (Luers, 2005).

Exposure on the other hand is the nature and extent of changes that a place is subjected to with regard to variables such as temperature, precipitation, and extreme weather events (Ibarraran, Malone & Brenkert, 2008).

Exposure according to Madhuri *et al.*, (2014) is the magnitude and duration to which the population is exposed to disaster.

2.2 Theoretical Review

2.2.1 The Environmental / Ecological Justice Theory: This theory deals with the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. It will be achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work. It is also the equitable distribution of environmental risks and benefits; fair and meaningful participation in environmental decision-making; recognition of community ways of life, local knowledge, and cultural difference; and the capability of communities and individuals to function and flourish in society (Bonne & Cadenasso, 2007).

Environmental justice emerged as a concept in the United States in the early 1980s. The term has two distinct uses. The first and more common usage describes a social movement in the United States whose focus is on the fair distribution of

environmental benefits and burdens. Second, it is an interdisciplinary body of social science literature that includes (but is not limited to) theories of the environment, theories of justice, environmental law and governance, environmental policy and planning, development, sustainability, and political ecology. The theory establishes the importance of all persons to contribute towards the protection of our decaying planet earth. This may not be possible without the formulation of quality environmental laws and policies which must be enforceable within the boundary of the policy. The mitigation and adaptation to environmental degradation will only begin when policies and environmental laws are geared towards the reduction of environmental degradation. This theory advocates that issues of environment and ecology should be handled urgently because failure to do that may degenerate into a more deplorable state that may be difficult to proffer solution. The issues of environmental management should transcend just being included in school curriculum but should be preached in religious gathering. This theory believes that it is important to take precautionary actions to avoid the occurrence of future environmental disaster that could be detrimental to man in his environment.

2.2.2 Theory of Production function Frontier

Soil degradation alters the production function and sustainability of agriculture. Therefore the theory of production function was used to explain this study.

Production Function

In economic theory a production function relates physical output of a production process to physical inputs or factors of production. It portrays the input- output relationship in which resources are transformed into products. A production function is the mathematical relationship describing the maximum quantity of output that a producer can produce, from a given amount of inputs given the technology in use

(Coelli, 1995). The production function therefore describes a boundary or frontier representing the limit of output obtainable from each feasible combination of inputs. There are numerous input-output relationships in agriculture because the rate at which input transformed into outputs varies with soil type or nature of the soil, technology etc. Any given input-output relationship specifies the quantities and qualities of resources utilized to produce a particular product. Mathematically, a production function can be expressed as follows:

$$Y = f(X_1, X_2, X_3 \dots X_n/X_{n+1}, X_{n+2}, X_{n+k})$$

Where:

Y = Output

$X_1 \dots X_n$ = Variable inputs

$X_{n+1} \dots X_{n+k}$ = Fixed inputs

In this study, production or yield response functions are estimated with respect to the soil degradation indicators (SDIs), topography of the soil (TS) and type of crop enterprise (TCE) while other inputs such as level of technology (LT), Fertilizer application (FA) and management (M) are assumed constant. The yield response function can be expressed as:

$$Y = f(\text{SDIs, TS, TCE/LT, FA, M})$$

This theory relies on the fact that farmers attempt to maximize their profit and thus they choose the number of inputs (X) that allow them to achieve this goal given the explanatory variables.

Assumptions of Production Function

- i. The production function is defined only for non-negative values of inputs and outputs in terms of relationship

- ii. Every possible combination of inputs is assumed to result in maximum level of output
- iii. The input-output relationship or the production function is single-valued and continuous for which there exist first and second order partial derivatives of the output Y, with respect to each of the input variables
- iv. The production function is characterized by a decreasing marginal product for all factor-product combinations, decreasing rate of technical substitution between any two factors and an increasing rate of product transportation between any two products
- v. The return to scale are assumed to be decreasing ie one percent increase in all the input variables results in less than one percent increase in output
- vi. The exact nature of the firms production is assumed to be determined by a set of technical decisions taken by the producer
- vii. All the products and factors of productions are perfectly divisible
- viii. The parameters determining the firms production function do not change over the time period considered. Moreso, these parameters are not permitted to be random variables.

Types of production function

There are many types of production functions. Some of them are explained below.

a. Cobb-Douglas Production Function

This refers to the production function in which one input can be substituted by other, but to a limited extent. For example capital and labour can be used as a substitute for each other but to a limited extent. It can be expressed as:

$$Q = K^b L^a$$

Where:

Q = Output

K = Capital

L = Labour

b. Leontief Production Function

Leontief used fixed proportion or input having no substitutability between them. It is regarded as the limiting case for constant elasticity of substitution. It is expressed as:

$$Q = (Z_1/a, Z_2/b)$$

Where:

Q = Quantity of output produced

Z₁ = Utilized Quantity of input 1

Z₂ = Utilized Quantity of input 2

a & b = Constants

c. Constant Elasticity of Substitution (CES)

This shows a constant change produced in the output due to change in input production. It can be expressed as:

$$Q = f (a.k^2 + (1-a) L^2)^{1/2}$$

Where:

Q = Quantity of Output

F = Factor Productivity

A = Share Parameter

KL = Quantities of Primary production factor (Capital and Labour)

d. Linear Function:

This is a function in which none of the independent variables is raised to a power greater than one. It is properly known as a linear production function and is simplest

form of all the agricultural production functions. Mathematically, this can be written thus:

$$Y = a + bx_1 + e$$

Where: Y = Output, X = variable inputs, a = Y-intercept, b = Slope of the function
e = error term.

e. Exponential Production Function

According to Olayide, *et al.*, (1982), this function is of the form: $Y = b^x$ which is monotonically increasing provided that the base is greater than one. If it is less than one but greater than zero, then the exponential function will be monotonically increasing. The base usually taken is the number $e = 2.71828$. An exponential function can otherwise be expressed as a logarithm thus: $\text{Log } Y = a + bx_1$. Where the slope is given as $(b.Y)$ and the elasticity expressed as $b/$ using the exponential function.

$$Q = ae^{b_1x_1 + b_2x_2}$$

f. Semi-log model

Another common functional form is the semi-log model (log-lin model) in which the dependent variable is measured in logs and the x variable in levels. This typically applies to economic variables which are related exponentially

$$y = \beta_0 \exp^{\beta_1 x}$$

Taking (natural) logs gives

$$\log_e Y = \text{Log}_e \beta_0 + \beta_1 x \log_e (\exp)$$

$$\text{since } \log_e (\exp) = 1$$

$$\text{Log}_e Y = \text{Log}_e \beta_0 + \beta_1 x$$

This means then that:

$$\frac{d \log y}{dx} = \beta_1 = \frac{dy}{y}$$

$$y/x$$

So $\beta_1 = \% \text{ change in } y / 100$ by a unit change in x and $\% \text{ change in } y = \beta_1 * dx * 100$.

2.2.3 Resilience theory: Based on the concept that there are protective factors (personal, social, familial, and institutional safety nets) that enable individuals to maintain competent functioning in the face of major life stressors. An individual's resilience at any moment is calculated by the ratio between the presence of protective factors & the presence of hazardous circumstances (Tillman Undated). Resilience refers to the process of overcoming the negative effects of risk exposure, coping successfully with traumatic experiences, and avoiding the negative trajectories associated with risks (Fergus & Zimmerman, 2005).

Resilience theorists generally agree that the presence of one or more protective factors can reduce the effects of exposure to adversity. The more protective factors (or "assets") available, the more resilient a young person will be. The term resilience has been used to label three different types of phenomena:

- individuals who have experienced traumatic events but have been able to recover well;
- persons who belong to high-risk groups, but who have more favorable outcomes than expected
- Persons who show positive adaptation despite life stressors.

2.3 Empirical Literature

A number of empirical studies have been independently carried out by researchers on the socio-economic characteristics of crop farmers. A review of some of these studies is as follows:

2.3.1 Age: Large numbers of aged farmers are still found in farming activities in Nigeria today and farmers' productivity is expected to decrease as they age. In the study by Anigbogu *et al.*, (2015) on socio economic factors influencing agricultural production among cooperative farmers in Anambra State it was found that majority of the farmers fall within the age bracket of 51-60 years. This is also in line with the findings of Onwuagba, Oguoma, Onyeagocha, Henri-Ukoha and Nwaiwu (2014); chikaire *et al.*, (2016) that most food crop farmers fall within the age bracket of 51-60 years. This is an indication that farming activities are in the hands of aged people who are at the verge of retirement from active work force.

2.3.2 Household size: Studies have shown that most farmers in Nigeria have large household size. This could serve as an advantage if used as farm labour. Ofuoku, Idoge and Ovwigho (2014) studied child labour in agricultural production and socioeconomic variables among arable farming households in Nigeria. In their finding the mean household size was 11. This also corresponds with the findings of Inoni, Omotor and Adun (2006) that most arable farmers have a mean household size of 11. The implication is that it could serve as a cheap source of farm labour.

2.3.3 Farm size: Agricultural production in Nigeria is still characterized by small farm holders. Anyoha *et al.*, (2013) carried out a study on the socio economic factors influencing climate change adaptation among crop farmers in Umuahia South Area of Abia State, Nigeria. Using descriptive statistics his findings showed that majority of the crop farmers (50%) own less than 1 hectare of land. This implies that most food crop farmers are small scale farmers who do not have enough land to cultivate on.

2.3.4 Education: Formal education enhances adoption of innovation according to Enujeke and Ofuoku (2012). According to the study by Iyagba and Anyanwu (2012)

on problems and prospects of cassava production in Rivers State, the findings showed that most of the crop farmers had one form of formal education or the other with a majority of 50% of them having primary education. The implication is that most of the farmers will resist new innovations.

2.3.5 Forms, Causes and Levels of Soil Degradation

The issue of soil degradation has assumed a global perspective. That is, there is no place in the world today that is not faced with one form of degradation or the other. According to Ballayan (2000); Infonet-Biovision (2010) and ACS Network (2009) the forms of soil degradation include: loss of soil fertility (soil nutrient and organic matter), erosion, excessive flooding, unfavourable changes in salinity, acidity or alkalinity, soil compaction, effects of toxic chemicals. These elements contribute to a significant amount of soil quality depreciation annually. Excessive soil degradation thus gives rise to immediate and long term impacts which translate into serious global environmental problem.

The causes of soil degradation for a particular area can be one or combined effects of many. According to Zia-ur-Rehman (2016) causes of soil degradation can be classified into two categories: biophysical and anthropogenic.

Biophysical factors have direct effect on all ecosystems such as loss of fertile top soil due to water or wind erosion, depletion of nutrients or toxicity due to acidity or alkalinity (salinization) or water logging, heavy metal contamination of soil and spillage of crude oils adversely affect soil micro flora which ultimately affect soil productivity and cause soil degradation. On the other hand anthropogenic factors have indirect effect on ecosystem such as deforestation, extensive cultivation on marginal land, improper cultivation practices like mono-cropping, poor manuring, misuse of fertilizers or excess use of fertilizers, excessive irrigation, over-grazing, fragility of soil, adverse weather and mining may accelerate the process of soil

degradation. Among the major causes of degradation, soil erosion (water erosion) is the most severe, visible and most widespread form of soil degradation (Xinshen and Daniel, 2007) which covers 87% of the affected area. The main cause of water erosion is removal of vegetation, over exploitation of vegetation, over grazing and improper agricultural practices.

Although soil degradation is recognized as a serious and widespread problem, its level or extent of severity is only very roughly known. According to Ogwo and Ogu (2014) the level or extent of soil degradation may vary widely among and even within countries. The level of soil degradation is related in a qualitative manner to the agricultural suitability of the soil, the extent of its declined productivity, possibilities for restoration to full productivity and its original biotic functions. Oldenman (1991), carried out a research on global extent of soil degradation using a 3 point likert type scale of Light, Moderate and Strong+ Extreme. His findings revealed that Africa has a strong + Extreme level of soil degradation. In addition, Kertesz (2009) also carried out a research on the global extent of land degradation and desertification using likert scale and percentages. His findings revealed that out of the 1663 million hectares of land in Africa for agriculture, pasture and forests about 494 million hectares (30%) are degraded while 321 million hectares (19%) are seriously degraded.

2.3.6 Qualitative Indicators or Visual Attributes of a Degraded Soil

According to Van Lynden *et al.*, (2004) indicators are measures that relate to a condition, change of quality, or change in state of something valued. Soil degradation indicators are therefore used to monitor soil changes and to determine whether the quality of soil remains stable or is declining or improving. Qualitative indicators of a degraded soil are often described and recorded through direct physical observation (Van Dan, 2007). The use of local knowledge and experience of farmers

through visual assessment provides a simple way to characterize the status and changes in soil quality. According to Bunemann *et al.*, (2018), the increased use of visual soil assessment is considered to be important in yield gap analysis and land management programs.

According to Pulido *et al.*, (2014), some peasant derived site-specific indicators of a degraded soil include weed abundance, presence of some plant species, stoniness of the soil, surface soil colour, change in colour of leaves, exposed roots, fewer trees, increased distance and time to collect fuel wood, crop yield and performance. Others include wilting of plants, leaf and plant senescence, increased runoff, soil crusting, increased fertilization need, poor resistance of plant to diseases etc (Akhtar *et al.*, 2013; Mohammed, 2012; European Union, 2014; Oklahoma State University 1977). These indicators can be specific for a particular form of soil degradation.

Toxic soil: Toxicity according to Mc Cauley *et al.*, (2011), occurs when a nutrient in the soil is in excess of plant needs and decreases plant growth or quality. According to Moreno *et al.*, (2013) and Masters *et al.*, (2013) a toxic soil can be detected through change in colour of soil from dark brown or black to red due to the presence of un-hydrated iron oxides. In the same vein, Mc cauley *et al.*, (2011) noted that lodging of plants is also an indication of a toxic soil due to the presence of excess nitrogen. Some researchers (Singh and Kalamdhad (2011); Chibuike and Obiora (2013); Fazal *et al.*, (2010)) noted that Change in leaf colour to brown, presence of grasses such as signal grass and decline or late seed germination are indications of a toxic soil.

Decreased vegetative cover: Kusimi and Yiran (2011) stated that decrease in number of trees, increasing distance to firewood location, low quality of firewood and scarcity of grasses for roofing and grazing are indications of decreased vegetative cover due to bush encroachment for farmland extension. Absence of some common

weed species such as Elephant grass is also an indication of a decreased vegetative cover (Bunemman *et al.*, 2016).

Compacted soil: According to Wolkowski and Lowery (2008) exposed and twisted roots and a soil that is hard to till are indicators of a compacted soil which may be due to continuous cropping. This results in the soil particles pressing together, restricting rooting depth and water infiltration. Increase in surface water ponding was identified by Mckenzie (2010) while slow or poor plant emergence and uneven early growth in form of short and tall plants in adjacent rows were identified by Stiegler (1977) as indicators of a compacted soil. This may result due to restricted root growth caused by compacted layers or not having enough oxygen for root respiration.

Flooding and waterlogging: indications of flooding and waterlogging according to Ojeh *et al* (2014) include heavy rain between 5days to a month, submerged farmland after heavy rain and water remaining on farmland 5days to 2weeks after heavy rain. Others include wilting of plants, leaf senescence and height of water level (Akhtar *et al.*, 2013; Mohammed, 2012; Eni *et al.*, 2011).

Leaching of soil nutrient: some of its indicators according to some researchers (Master *et al.*, 2013, Bunemman *et al.*, 2016, Mauro wagner *et al.*, 2002, Huber *et al.*, 2007 and Ferguson *et al.*, 2004) include change in colour of soil from darker organic surface layer to lighter colour, exposed roots, increased rate of rainfall, poor resistance of plants to diseases and poor crop yield.

Decreased water absorption capacity: indications of decreased water absorption capacity are increased runoff, Delay in flowering of plants, poor drainage, stunted growth of crop and increased soil crusting (European Union, 2014; Kowalczyk, 1967; USDA, 2008;).

Decline in soil organic matter content: low density of soil mites according to Maribe *et al.*, (2011) is an indication of low soil organic content. Others include yellowish

of leaf (Pulido and Bocco, 2014), increased fertilization need, soil particles easily loosened by rain drops and carried away by moving water (Mc cauley *et al.*, 2017), presence of some weed species and stone (Omari *et al.*, 2018).

Rural farmers in the tropics exhibit a good understanding of their farmland using these local indicators (Gosai *et al.*, 2011). Thus analyzing these soil degradation indicators based on local perception and adaptation strategies of the farmers will provide information that is essential for sustainable soil management.

2.3.7 Crop Farmers Level of Adaptation Strategies to Soil Degradation.

In agriculture, adaptation efforts focus on implementing measures that help build rural livelihoods that are more resilient to degradation. Uddin *et al.*, (2014) determined crop farmers' level of adaptation strategies to environmental degradation and climate change effects in Bangladesh. He used adaptation strategy index to determine the adaptation strategies which held relative importance over others by rank ordering them using a four point likert rating of High, Medium, Low and No importance. His findings revealed that farmers ranked increased use of irrigation 1 as the best followed by practicing crop diversification 2, integrated farming system 3, use of drought tolerant varieties 4, use of salinity tolerant varieties 5, practicing crop rotation 6, cultivating short duration crops 7, practicing inter-cropping 8, find off farm job 9, move to non- farm activities 10, agro forestry 11, soil conservation techniques 12, zero tillage 13 and crop insurance 14.

Adaptation strategies according to the findings of Kuponiyi *et al* (2010) and Obayelu *et al* (2014) used by farmers to cope with degradation includes water conservation techniques, move to different site, shading and shelter/mulching, early planting, early harvest when dry soil is expected, different planting dates, mixed cropping, mixed farming, zero tillage, applying farm yard manure, increase fertilizer application three days prior to sowing, having access to extension facilities and

credit facilities, adopting new crop varieties, afforestation, crop diversification and diversification to non-farm activities etc. Other adaptation strategies according to Selvaraju (2006) includes early planting, deep planting, planting of cover crops, application of mulch to conserve moisture, planting of drought tolerant, planting of early maturing crops, alley farming, agro forestry etc.

Adaptation strategies used by farming households according to Akinagbe *et al.*, (2011) to minimize the effect of degradation due to erosion includes practicing crop rotation, relay cropping, construction of contour ridges, practicing bush fallow and shifting cultivation, avoidance of bush burning, use of erosion control measures such as terracing, mounting an awareness campaign on the proper use of agricultural land and finally effective stakeholder participation in the land use planning and management.

Apata (2010) observed that adaptation strategies used to check crude oil pollution includes diversification into non-farming activities such as trading of manufactured goods, fish trading, boat building, artisan work, plank selling, paid employment, palm wine tapping, mat weaving, local brewery (local gin), motor cycle operator (okada) etc.

In an attempt to reduce the effects of deforestation on livelihoods, farming households have developed some adaptation strategies such as the use of fuel efficient wood stoves, protection of economic trees, reducing quantity of fire wood consumed, use of alternative energy (kerosene), participation in farm forestry, use of cow dung for cooking and use of corn straw for cooking (Mustapha *et al*, 2012).

The use of these adaptation strategies helps to protect the environment because of the inherent benefits associated with them. According to Young *et al.*, (2015) soil and water conservation technology (such as planting of cover crops, planting legumes, mulching, planting canopy trees etc) and organic fertilizer are

environmentally non-degrading, resource conserving (increased retention of organic matter and decreased risk of soil erosion), socially acceptable, technically appropriate and economically viable thereby promoting productivity and sustainability. Mixed farming on the other hand helps to maintain soil fertility and offers highest return on farm business thereby increasing farm income.

2.3.8 Factors Affecting Crop Farmers Adaptation to Soil

Degradation.

According to Asafu—Adjaye (2008), some of the factors affecting the use of soil conservation measures in Fiji Island using ordered probit model include net farm income, farm size, land type and extension services. Nwaiwu (2015) reported that age, household size, major occupation membership of cooperative, farm size and gender affect adaptation tendency of farmers to soil conservation measures in South-eastern Nigeria using logit multiple regression.

Barungi *et al.*, (2013) noted that some of the factors influencing the adoption of soil erosion control technologies by farmers along the slopes of Mt. Elgon in Eastern Uganda using double-hurdle models were farming as main occupation, ownership of different types of farm tools, sex of farmer, steepness or location of cultivated land, access to extension services, farm size, knowledge regarding cost and benefits associated with use of the technology etc.

Uddin *et al.*, (2014) indicated that socio-economic factors that negatively influence rural farmers' use of adaptation strategies to soil degradation in Bangladesh include age, farm size and family size while education and family income are positively related to farmers' use of adaptation strategies to adjust to soil degradation. He also used adaptation strategy index to identify adaptation strategies which held relative importance over others. This was done by asking farmers to assess different adaptation strategies using a four point rating scale of no importance, low

importance, moderate importance and high importance. The result showed that out of the 14 adaptation strategies, increased used of irrigation was ranked first, and thus the most important factor among farmers' adaptive strategies to environmental degradation

Mustapha *et al.*, (2012) noted in his findings that adaptation measures against environmental degradation caused by deforestation are influenced by age, farming experience and educational status. According to Mustapha *et al.*, (2012), farmers' age and farming experience influenced farmers' knowledge and awareness of activities in the environment. Educated farmers on the other hand can easily access information on deforestation and ways to control it.

According to Apata (2010), determinants of diversification into off farm activities as an adaptation option to crude oil pollution include: age and access to credit which have significant negative effect on diversification, whereas, farming income, education, number of non-farm rural activities, access to extension services and access to market have significant positive effect on livelihood diversification.

According to Ademola and Olujide (2014), some of the challenges that affect farmers adaptation to soil conservation measures include unfavorable land tenure system, lack of incentive, cultural barrier, insufficient fund, unavailability of information, population pressure on land, lack of technical know-how, inadequate soil conservation skills little road access to lands and insufficient farm labour. Some of the problems which constrain farmers' adaptation to environmental degradation and climate change according to the findings of Uddin *et al.*, (2014) and Deressa *et al.*, (2008) include lack of available water (for irrigation and drinking), shortage of land, unpredicted weather, lack of credit/money, lack of market access, shortage of farm inputs, lack of information, poor soil fertility, insecure property rights and shortage of labour. This also conforms with the findings of Ofuoku (2011) and

Mustapha *et al.*, (2012) that adaptation constraints of farmers to environmental degradation includes lack of information, inadequate land, lack of sufficient labour, poor extension service, lack of awareness and lack of capital.

2.3.9 Vulnerability of Crop Farmers to Soil Degradation

Gutu (2013) used vulnerability index analysis to assess individual level of vulnerability to climate change impacts among crop dependent communities of Western Ethiopia. His findings revealed that majority of farming households (47%) fall within the highly vulnerable category, having an index between -17.98 and -1.00 due to small land size, highly fragmented farm, low productivity of land due to fertility lose, high degradation of farmlands due to steep sloping, lower level of experience to adapt to climate change impact. This category of farmers also has less diversified livelihood options, lower level of access to technology, lower level of access of early warning information etc.

Opiyo *et al.*, (2014) used vulnerability index of the integrated approach method to measure household vulnerability to climate-induced stresses in Kenya. He considered 27 socio-economic and biophysical indicators obtained from 302 households to reflect climate vulnerability components: adaptive capacity, exposure and sensitivity. The first Principal component which explained majority of the variations was used to develop weights for different indicators and produce a household vulnerability index (HVI) so as to classify households according to their level of vulnerability. The results showed that 27% of households were highly vulnerable, 44% were moderately vulnerable and 29% of households were less vulnerable to climate- induced stresses.

Tsue *et al.*, (2014) examined the vulnerability levels of 365 farming households in North central Nigeria. Principal Component Analysis (PCA) was used to develop vulnerability index for the individual households to classify households depending

on their level of vulnerability to environmental degradation impacts. Ordered logistic regression model was employed to identify the key determinants of vulnerability to environmental degradation impacts. The households were categorized into three levels as: highly vulnerable (vulnerability index, V_i of 1.24), vulnerable ($V_i=3.35$) and less vulnerable ($V_i=6.18$). The result of households' vulnerability to environmental degradation showed that mean household vulnerability index in the study area was 2.86. Majority of the households (63.2%), fall within the vulnerable group with vulnerability index of 3.35 indicating that they were vulnerable to environmental degradation.

2.3.10 Factors Influencing Level of Vulnerability of Crop Farmers to Soil Degradation

According to Jolejole-foreman *et al.*, (2012) some of the factors that influence farmers vulnerability to land degradation in Ethiopia include; access to information, farming years, income, soil type, slope and elevation, improper irrigation, adaptation method etc.

Adegbilie (2014) investigated the vulnerability of farmers to flood disaster in Akinyele LGA of Oyo State Nigeria which is one of the major causes of soil/land degradation. According to his findings, some of the factors influencing farmers' vulnerability to flood include average income of the farmers, type of soil, access to land, inadequate agricultural extension contact etc.

Further more, the research by Seyoum *et al.*, (2020) in the determinants of farm households' vulnerability to the impact of land degradation in the central OmoGibe Basin of Ethiopia noted that age, sex, marital status, family size, dependency ratio, extension service, social participation, livestock ownership, land tenure security, land size and distance to the nearest main road, perceived reduction in crop land

productivity and plot-level land degradation affected households vulnerability to the impact of land degradation.

More so, according to Olanrewaju and Nurudeen (2021), some of the factors affecting farming households' vulnerability to desertification in rural communities of Northern Katsina state Nigeria include age, farming status, size of households, access to non-farm income, migration and improved seed varieties.

2.3.11 Trends in Output/Yield of Staple Crops in Nigeria.

Philip *et al.*, (2014), observed that the yields of staple crops such as (cassava and maize) during the review period of 1999 – 2009 largely fell far short of their respective realizable potentials. Using trend analysis their finding showed that in South East (SE) about 12, 13.8, 12.8, 12.3, 14.3 and 14.5 mt/ha of cassava were produced in 1999, 2001, 2003, 2005, 2007 and 2009 respectively. In South South(SS) about 10.8, 11.1, 10.7, 10.6, 25.6 and 25.4 mt/ha of cassava were produced in 1999, 2001, 2003, 2005, 2007 and 2009 respectively while in South West (SW) about 12.7, 13.6, 13.6, 14.8, 15.4 and 16.1mt/ha were produced in 1999, 2001, 2003, 2005, 2007 and 2009 respectively. Also according to their finding the yield of maize in SE was 2.08, 2.01, 2.95, 1.85, 1.88 and 1.72 mt/ha in 1999, 2001, 2003, 2005, 2007 and 2009 respectively. In SS it was 1.6, 1.71, 1.6, 1.72, 1.53 and 1.58 mt/ha in 1999, 2001, 2003, 2005, 2007 and 2009 respectively while SW about 1.57, 1.72, 1.82, 1.87, 1.7 and 2.09 mt/ha was produced in 1999, 2001, 2003, 2005, 2007 and 2009 respectively. In spite of the expansion in area planted to maize, the yields have remained low. The decline or low yield of maize during the late 2000s may be due to drought and erratic rainfall (Drought Tolerant Maize Project (DTM) 2014). In another study, it was found that annual yield of yam in Nigeria in mt/ha was about 7.8, 10.5, 5.6, 10.7, 10.8, 9.9, 11.9 and 13.1 in the years 1961, 1980, 1985, 1990, 1995, 2000, 2010 and 2012 respectively (Verter and Becvarova, 2015).

2.3.12 Effect of Degradation on Crop Production

Soil degradation is one of the most serious environmental problems facing human society. Soil degradation diminishes soil quality and thereby, reduces the productivity of agricultural land. Nwaiwu (2016) investigated the level of arable crop farmers' awareness of soil degradation in Imo State using mean scores and rank order, frequency counts and percentages as statistical tools. Soil degradation indicators used were productive capacity of land, loss or change in vegetative cover and soil nutrient, increased vulnerability of the land, poor drainage, flooding and loss of species and eco-system. His findings showed that almost all the farmers (95.9%) were aware of soil degradation which was moderately serious and have been noticed for a long time. His findings also showed that loss or change in vegetative cover and soil nutrient was observed to a great extent which has great effect on crop production.

Idowu and Mayowa (2012) investigated the human perception of land degradation in a section of Niger Delta Nigeria using percentages as statistical tools. Their findings showed that erosion and flooding, salt water intrusion and de-vegetation affected farm lands and farming activities of the people in the area. Obasi (2015) investigated the effect of land degradation on productivity of small scale farmers in Abia State, Nigeria using Chow's test model. Farmers in un-eroded farm land were assigned the value of 1, while farmers in eroded farm lands were assigned the value of 0. The Chow's test showed a significant effect of land degradation (erosion) on productivity of the farmers. Farmers in un-eroded lands had larger land areas of cultivation than farmers cultivating in eroded farms. Farm size, productivity and net return of farmers in un-eroded farms were higher (1.1ha, ₦1.4, ₦65,140) than those in eroded farm lands (0.9ha, ₦1.2, ₦31,125). According to Akinlagbe *et al.*, (2011), on farmers' perception of the effects of land degradation on Agricultural activities

in Ethiope East Local Government Area of Delta State Nigeria, soil erosion is the major cause of reduction in farm yield. Their findings further revealed that soil erosion also led to decrease in farm income, loss of nutrient/organic matter, increase in cost of production as a result of additional money spent in controlling degraded land, decrease in farmland available for cultivation and loss in value of land. These however threatened food security thereby precipitating starvation and poverty.

Subair (2009) investigated the environment – productivity relationship in the South West Nigeria's Agriculture using multiple regression analysis to establish the relationship between agricultural yield and its inputs (such as land, seed and fertilizer) in a deteriorating environment relative to an environmentally friendly location. He noted that in the environmentally friendly location, land was negatively related to output, while other inputs (seed and fertilizer) were positively related. In the polluted area, all other inputs except land were negatively related to output. He finally reported that environmental degradation has a negative effect on crop yield such as cassava and maize.

Hoang and Mitsuyasu (2011) carried out a research on the impact of environmental factors on the productivity and efficiency of rice production in Vietnam's red river delta using Cobb Douglas stochastic production frontier. Eight production inputs such as seed, labour, fertilizers, other fertilizer use, insecticides, herbicides, irrigation cost and other renting cost and four environmental factors denoted as dummies such as soil quality, irrigation, disease and water pollution were included in the function. The result showed that intensive fertilizer use will increase rice yield, while applying insecticide and herbicide exceedingly will lower the yield. Irrigation access and water pollution negatively affected rice yield.

Oil exploration and exploitation has not been of much benefit to the local communities in the Niger Delta. According to the findings of Agbogidi *et al* (2007),

soils treated with crude oil at four weeks after planting maize died within 24 hours while the plant without crude oil treatment remained intact. Ahmadu *et al* (2013), also observed that the major significant effects of oil spillage on cassava production as perceived by the farmers include crop failure, poor yield, rotting tubers and stunted growth with mean scores of 4.80, 4.78, 4.75 and 4.75 respectively. Other effects include increased soil temperature and toxicity, reduction of soil fertility, degradation of farm land and low land productivity with mean scores of 4.73, 4.70, 4.70 and 4.70 respectively. Furthermore, Nwosu *et al*, (2014) observed that crude oil production and its spillage on farm land significantly affected the output of yam planted in crude oil producing communities.

Climate change is one of the most significant degradation factors influencing year to year crop production. According to Kuponiyi *et al.*, (2010), the impacts of climate on crop production includes low yield of crops, stunted growth of crops, ease of spread of pest and diseases that attack crops, drying of seedling after germination and ineffectiveness of agriculture chemicals due to delay of rainfall. Finally, more intense rainfall as a result of climate change may lead to flooding and waterlogged soils, which is also a pathway for crop production to be damaged.

2.4 Analytical Literature

Some empirical studies conducted by researchers have applied a number of analytical tools to their studies. Some of these tools and their applications by these researchers are as follows:

2.4.1 Ordinary Least Square Regression Analysis.

Ordinary least-squares (OLS) regression is a generalized linear modeling technique that may be used to model a single response variable which has been recorded on at least an interval scale. The technique may be applied to single or multiple

explanatory variables and also categorical explanatory variables that have been appropriately coded.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots 2.4$$

The relationship between variables Y and X is described using the equation of the line of best fit with:

α = indicating the value of Y when X is equal to zero (also known as the intercept)

β = indicating the slope of the line (also known as the regression coefficient).

The regression coefficient β = describes the change in Y that is associated with a unit change in X.

X's are the independent variables.

2.4.2 Vulnerability Index Method

Some of the most common methods used in measuring vulnerability include:

Econometric Method, Indicator and Integrated Method (Deressa *et al.*, 2008).

- **Econometric Method:** The econometric method has its roots in the poverty and development literature. A good example is estimating the vulnerability to poverty of rural farm households using econometric method such as the feasible generalized least square (FGLS) method.

This method is based on estimating the probability that a given shock, or set of shocks, moves consumption by households below a given minimum level (e.g. consumption poverty line) or forces the consumption level to stay below the given minimum requirement if it is already below that level.

The econometric equation is thus presented as a Cobb–Douglas (C–D) type function.

Consumption of a household h is given by:

$$\ln C_h = X_h \beta + e_h \dots\dots\dots 2.5$$

Where C_h is per capita consumption expenditure, X_h represents a bundle of observable household characteristics (such as household size, location, educational attainment of the household head etc.) and environmental shocks namely droughts, floods, erosion, oil pollution and deforestation. β is a vector of parameters, and e_h is a mean zero disturbance term.

By assuming that log consumption is normally distributed (i.e. that $\ln C_h$ is normally distributed, Letting $\Phi (\cdot)$ denote the cumulative density of the standard normal distribution therefore probability that a given household is vulnerable is specified as follows:

$$V_h = P_r(\hat{\ln}C_h < \hat{\ln} z/X_h) = \Phi \left[\frac{\ln z - X_h\beta^\wedge}{\sqrt{X_h\theta^\wedge}} \right] \dots 2.6$$

Where $\ln z$ is the log of the minimum consumption/ income level beyond which a household would be called vulnerable.

- **Indicator Method or Biophysical Approach:** which is based on selecting from the whole set of potential indicators and then systematically combining the selected indicators to indicate the level of vulnerability. According to Deressa (2010), the biophysical approach assesses the level of damage that a given environmental stress causes on both social and biological systems. For instance, the yield impacts of climate change can be analyzed by modeling the relationships between crop yields and climatic variables. The model is specified as follows:

$$\delta W = \beta_1\delta R + \beta_2\delta T_{\max} + \beta_3\delta T_{\min} \dots 2.7$$

Here, δW = change in yield

δR = change in rainfall

δT_{\max} = change in maximum temperature.

δT_{\min} = change in minimum temperature.

$\beta_1, \beta_2, \beta_3$ are the coefficients of rainfall, maximum temperature and minimum temperature respectively.

- **Integrated method:** This method combines both the Economic/socioeconomic and indicator/biophysical method to determine vulnerability. According to this method, the different socioeconomic and biophysical indicators are classified into adaptive capacity, sensitivity, and exposure based on the Inter governmental Panel on Climate Change definition of vulnerability (IPCC, 2001). The first stage of analysis is the descriptive analysis of the socioeconomic and environmental characteristics that describe the adaptive capacity, sensitivity, and exposure of the farmers to soil degradation. In the second stage, the vulnerability index is obtained by applying Principal Component Analysis (PCA) on the adaptive, sensitivity, and exposure variables. Based on the STATA output, the vulnerability indicators are grouped into different components with Eigen values greater than one. Then PCA will generate the weights. The component scores of the first component is used to assign weight to the variables. This is done by multiplying each variable by the corresponding component score. The first principal component of a set of variables is the linear index of all the variables that captures the largest amount of information common to all the variables (Deressa, Hassan, and Ringler 2008). In other words, the first principal component explains the majority of the variation in the data set. The direction of relationship among vulnerability indicators is such that positive value is attached to adaptive capacity while negative value is attached to both exposure and sensitivity. This is based on the assumption that greater exposure to negative effects of soil degradation is more sensitive to damages. It is further believed that areas that have higher frequencies of extreme soil degradation like flood, droughts etc. are liable to losses in livelihood (Usman, 2013).

The model for integrated approach is specified as :

$$V = (W_{a1}X_1 + W_{a2}X_2 + W_{a3}X_3 \dots W_{an}X_n) - (W_{s1}Y_1 + W_{s2}Y_2 + W_{e1}Z_1 + W_{e2}Z_2) \dots \dots \dots 2.8$$

(Component scores of adaptive capacity variables \times the standard deviation) – (component scores of sensitivity \times the standard deviation + component scores of exposure \times the standard deviation).

Where V is vulnerability, while Xs, Ys and Zs are adaptive capacity, exposure, and sensitivity, respectively, and W is the first component score of each variable.

In this study, the data will be normalized by converting them into natural logarithms and then analyzed in stages. This will be done in order to combine the variables denominated in different units.

- The first stage of analysis will be the descriptive analysis of the socioeconomic and environmental characteristics that describe the adaptive capacity, sensitivity, and exposure of the farmers to soil degradation.
- Second, the vulnerability indices will be obtained by applying Principal Component Analysis (PCA) on the adaptive, sensitivity, and exposure variables. PCA is frequently used in research that constructs indices for which there are no well-defined weights, such as asset-based indices used for the measurements of wealth across different social groups (Madu, 2012). Therefore, PCA will generate the weights, the assumption being that there is a common factor that explains the variance in the vulnerability. Intuitively, the first principal component of a set of variables is the linear index of all the variables that captures the largest amount of information common to all the variables (Deressa, Hassan, and Ringler, 2008). Accordingly, the first component scores from the PCA will be allowed to define a weighted sum of the individual variables.

- Then vulnerability index will be calculated using normalized value of each variable (using its mean and standard deviation). The factor scores from the PCA will then be multiplied by the standard deviation of the variables.

2.4.3 Ordered Probit Regression Model

The ordered probit model is a widely used approach to estimating models of ordered type which almost employs the probit link function. There is a latent Continuous metric underlying the ordinal responses observed by the analyst. The latent continuous variable Y is a linear combination of some predictors, x , plus a disturbance term that has a standard normal distribution:

$$Y = X_i B + e \dots\dots\dots (2.9)$$

The latent variable, Y_i exhibits itself in ordinal categories, which could be coded as 0,1,2k. The response of category k is thus observed when the underlying continuous response falls in the k-th interval as;

$$\begin{aligned}
 Y^* = 0 & \text{ if } Y^* \leq \delta_0 \\
 Y^* = 1 & \text{ if } \delta_0 \leq Y^* < \delta_1 \\
 Y^* = 2 & \text{ if } \delta_1 \leq Y^* < \delta_2 \dots\dots\dots (2.10)
 \end{aligned}$$

Where Y^* ($i = 0, 1, 2$) are the unobservable threshold parameters that will be estimated together with other parameters in the model. When an intercept coefficient is included in the model, Y^*iB is normalized to a zero value (Green, 2000) and hence only k-1 additional parameters are estimated with X_s . Like the models for binary data, the probabilities for each of the observed ordinal response which in this study had 3 responses (0,1,2) will be given as;

$$\begin{aligned}
 \text{Prob } (Y = 0) &= P (Y^* = 0) = P (B_i X_i + e_i = 0) = \Phi (B_i X_i) \\
 \text{Prob } (Y = 1) &= \Phi (\delta_1 - B_i X_i) - \Phi (B_i X_i) \\
 \text{Prob } (Y = 2) &= 1 - \Phi (\delta_1 - B_i X_i) \dots\dots\dots (2.11)
 \end{aligned}$$

Where, $0 < Y^*_i < Y^*_i < Y^*_i = 1,2,\dots,\dots,\dots,n$ is the cumulative normal distribution function such that the sum total of the above probabilities is equal to one.

2.4.4 Marginal Effects

The ordered probit model does not explain by how much the probability of an individual farmer being in any vulnerability level or choosing a particular adaptation category will change when there is a change in any of the explanatory variables. In other words, it does not show the magnitude of the effect of a change in explanatory variable leading to the calculation of marginal effect. Marginal effects describe the effect of a unit change in the explanatory variable to the change in the probability of a dependent variable. It measures instantaneous rate of change. Marginal effects measure the expected change in probability of a particular choice being made in respect to a unit change in explanatory variables (Greene, 2003; Ehirim, 2014). The signs of the marginal effects and respective coefficients may be different as it depends on the signs and the magnitude of the other coefficients. A positive parameter β_j means that an increase in the independent variable X_i increases by one unit from the mean, the relative probability of being in any vulnerability level or choosing adaptation strategy j relative to the probability of choosing alternative. That is, the increase by a unit of the independent variable X_i from its mean value will increase the probability of being in any vulnerability level or choosing adaptation strategy j by β_j .

2.4.5 Soil Degradation Index

According to Larson and Pierce (1991), soil quality (SQ) can be expressed as a function of its attributes.

$$SQ = f(q_1, \dots, q_n) \dots (2.12)$$

Where :-

q_1 is individual SQ indicators.

SQ is the collective contribution of the indicators.

However, according to Karlen *et al.*, (2001) there is no ideal or universal index for assessing or measuring soil quality or degradation. Rather utilization of the soil quality concept requires that the following steps be followed:-

- Identify critical functions
- Select appropriate indicators
- Develop appropriate scoring or interpretation guidelines
- Combine the information into index values to determine if the resource is being sustained, degraded or aggraded.

According to Amacher *et al.*, (2007), soil quality can be measured using the following formula:

Soil Quality Index (SQI) =

$$\frac{\text{Total Soil Quality indicators indicated}}{\text{Maximum possible Total Soil Quality Indicators}} \times \frac{100}{1}$$

In the context of this study soil degradation therefore is:

Soil Degradation Index (SDI) =

$$\frac{\text{Total Number of Perceived Soil Degradation indicators}}{\text{Maximum Possible Total Number of Soil Degradation Indicators}} \times \frac{100}{1}$$

2.4.6 Trend Analysis

We are often faced with data that seem to indicate increasing or decreasing trends over time. Trend is the general direction the market is taking during a specified period of time. Trends can be both upwards and downwards. While there is no specified minimum amount of time required for a direction to be considered a

trend, the longer the direction is maintained, the more notable the trend. Trend analysis is the process of looking at current trends in order to predict future ones and is considered a form of comparative analysis. This can include attempting to determine whether a current market trend, such as gains in a particular [market sector](#), is likely to continue, as well as whether a trend in one market area could result in a trend in another. Trend analysis can also be used to determine how a particular sector can be affected by internal and external forces such as soil degradation.

In modeling the time trend for this study, the bivariate regression model and line graph were used. Bivariate Regression Analysis involves analysing two variables to establish the strength of the relationship between them. The two variables are frequently denoted as X and Y, with one being an independent variable (or explanatory variable), while the other is a dependent variable (or outcome variable). The bivariate regression model of production is specified thus:

$$Y_i = f(t)$$

Where:

Y_i = Crop output of staple crops

t = time (yrs)

2.4.7 Choice of Model for Present Study

My choice of models includes: Vulnerability Index, Multiple Regression Analysis using OLS, Odered Probit model, Soil Degradation Index and Time Trend Analysis.

2.4.8 Justification for Choice of Models

The Odered Probit model will be appropriate for analyzing objective 6 which is factors influencing adaption strategies to soil degradation : It is assumed that farmers in the current study areas operate under the same policy and degraded environments and face exogenous variables denoted as X_i (age, sex, educational level, farm income, credit facility, extension agent visit, farm size, farming experience, Non-

farm income and household size) and that these conditions determine farmers' decision to choose set of adaptation strategies Y. It is expected that these exogenous variables will be positively and significantly related to farmers' adaptation to soil degradation.

Vulnerability index will be used in this study because of its ability to break down vulnerability index score or factors (using principal component analysis) into subcomponent "drivers" of vulnerability thus allowing a more detailed understanding of social vulnerability factors. According to Dunning and Durden (2013), Social Vulnerability Index is the most widely referenced index for social vulnerability assessments. The indicators to be used for adaptive capacity (xs) include; literacy level, off farm activity, agrochemical supply, fertilizer supply, improved seed supply, irrigation potential, planting trees, crop diversification, access to large farm size, access to farm credit and secured land tenure while the indicators for sensitivity/exposure (ks) will include; household size, sloppy farmland, use of fire wood, bush burning, oil spillage, soil erosion, frequent flooding, deforestation, drought and run-off because they signal a wide variety of conditions and processes that must be operating well if that measure is favorable in terms of environmental vulnerability. It is expected that the adaptive capacity indicators will be negatively related to vulnerability while sensitivity/exposure indicators will be positively related to vulnerability.

Likert scale rating is justified because it will help to rate the responses of the farmers according to their perception on the adaptation strategy that is best suited for them.

The use of soil degradation index is justified because it will enable us to determine the level of soil degradation in the study area.

Trend analysis is justified because it will help to determine if crop output in the study area is increasing, decreasing or stable.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The Niger-Delta States are located in the Atlantic Coast of Southern Nigeria where River Niger divides into numerous tributaries. It is the second largest Delta in the world with a coastline spanning about 450 kilometers terminating at the Imo River entrance. The region spans over 20,000 square kilometers and has been described as the largest wetland in Africa and among the three largest in the world (Uyigüe and Agho, 2007). About 2,370 square kilometers of the Niger Delta area consist of rivers, creeks, estuaries and stagnant swamp that cover about 8600 square kilometers. The Delta, with mangrove swamps spanning about 1900 square kilometers has the largest mangrove swamps in Africa (Awosika, 1995). The region falls within the tropical rain forest zone. The ecosystem of the area is highly diverse and supportive of numerous species of terrestrial and aquatic flora and fauna and human life. It is the richest wetland in the world (Iyayi, 2004). It lies between latitude $4^{\circ} 15'$ and $4^{\circ} 50'$ North of the equator and longitude $5^{\circ} 25'$ and $7^{\circ} 37'$ East of Greenwich (Emaziye, 2013).

Along the coast it stretches from the Benin river in the West to Bonny river in the East while on land, it begins a few miles below Aboh at a point where river Niger bifurcates into river Nun and forcados into the Atlantic West at the South, stretching over 160 miles (Mmom *et al.*, 2010).

The climate of the Niger Delta region varies from the hot equatorial forest type in the southern lowlands to the humid tropical in the northern highlands and the cool montane type in the obudu plateau area. The wet season is relatively long, lasting between seven and eight months of the year, from the months of March to October. While the dry season begins in late November and extends to February or early March, a period of approximately three months.

The main ethnic groups of the region are the Ijaws (the largest ethnic group), the Itsekiris, Yorubas, Efiks, Ibibios and Igbos. Politically, the Niger Delta area cuts across nine states in southern Nigeria which include Abia (1), Akwa Ibom (2), Bayelsa (3), Cross River (4), Delta (5), Edo (6), Imo (7), Ondo (8) and Rivers (9). These states fall within the south-south, south-east and south west geographical area of Nigeria. The total population of the Niger Delta region based on the 2006 population census is 31.2 million distributed among the constituent states (Omuta, 2011). The major traditional occupations include farming and fishing, while secondary occupations include industries like gin distillation, textile weaving and boat carving. Tertiary occupations include trade and commerce, and transportation. Oil and gas account for about 97% of the country's total export. The region is also endowed with several other solid minerals such as granite, barites marble, clay, gypsum, phosphate rock, limestone sand etc.

3.2 Sample Selection

Multi-stage sampling technique was used in this study. There are 9 states that make up the Niger Delta: Akwa Ibom, Bayelsa, Cross River, Delta, Ondo, Rivers, Abia, Edo and Imo. The states were grouped first in their geographical areas South-South (Akwa Ibom, Cross River, Bayelsa, Rivers, Delta, and Edo), South East (Abia and Imo) and South-West (Ondo) and two geographical areas of south-south and south-east were purposively selected because majority of the states fall within their group. Secondly, these states were stratified into two categories namely the coastal states (Akwa Ibom, Bayelsa, Cross River, Delta and Rivers) and inland states (Abia, Edo and Imo) and two states were randomly selected from each stratum giving rise to four states. The third stage was the purposive selection of two agricultural zones from each state, making a total of eight agricultural zones. The purposive selection was based on the Agricultural Zones that have the highest number of crop farmers

and mostly affected by soil degradation as given by the ministry of agriculture annual records, etc. In the fourth stage, two extension blocks were randomly selected from each of the selected agricultural zones to get 16 extension blocks. The fifth stage involved the random sampling of two cells from each of the 16 extension blocks, making a total of 32 cells. The lists of registered crop (cassava – maize based) farmers in the selected cells were compiled with the help of the extension agents to form the sampling frame of 245. The sample size model was used to obtain the sample size of 152. The sample size model is specified as follows;

$$n = \frac{N}{1 + N(e^2)} \dots 3.1$$

Where,

n = sample size for the study

N = Total sampling frame

e = Tolerable error level of 5%

In the sixth and final stage, proportionate sampling technique was used to determine the spread of the sample size of 152 due to unequal sampling frames in the various villages and simple random sampling was then applied to select the sample size of 152 respondents for the study.

3.3 Data Collection

Primary data were collected by using structured questionnaire which were administered to the respondents. The period of primary data collection was 2016. Secondary data were obtained from several sources, including National Bureau of Statistics Agricultural Survey Report, Agricultural Development Projects (ADPs) Annual Records and National Agricultural Extension and Research Liaison Services (NAERLS) National Report.

The types of primary data collected were the socio-economic characteristics of the crop farmers such as age, sex, farm size, farm income, credit access, family size and educational level, etc. forms of soil degradation ravaging the area, adaptation strategies in use by the farmers, annual crop output within the period of 1995 – 2016 sourced from National Bureau of Statistics Agricultural Survey Report, Agricultural Development Projects (ADPs) Annual Records and National Agricultural Extension and Research Liaison Services (NAERLS) National Report. These were supplemented with farmers estimated mean output record for the year 2016.

3.4 Data Analyses

The data were analyzed using descriptive statistics such as mean and percentages. Inferential statistics such as ordered Probit regression model, Vulnerability Index Model, OLS Regression Analysis and Trend analysis were used.

Objectives i, and ii were achieved using descriptive statistics such as mean and percentages.

Objectives iii was determined using OLS Multiple Regression Analyses.

Objective iv was achieved using descriptive statistics and Vulnerability Index Model.

Objective v was achieved using ordered Probit Model

Objective vi was realized using ordered Probit Model. In this study, the seven (7) choice categories of adaptation strategies considered were: (1). Use of improved varieties, (2). Soil and water conservation technologies, (3). Mixed farming, (4). Diversification to non-farm activities, (5). Adjustment of planting periods, (6). Use of soil organic amendment and (7) Use of financial leverage.

Objective vii was achieved using trend analysis.

3.4.1 Model Specification

To accomplish objective ii, the model was specified as:

The crop farmers' perceived level of soil degradation was measured on a 3-point likert type scale of high = 3, moderate = 2 and low = 1 on each of the different soil degradation indicators. The soil degradation indicators and their perceived features are;

Soil Degradation Indicators	Perceived Effects of Soil Degradation Factors (SDF)
Toxicity of the Soil	<ul style="list-style-type: none"> i) Colour changes of the soil from dark brown or black to tan (bleached black or brown) (Moreno <i>et al</i> 2013; Masters <i>et al</i> 2013) ii) Prevalent grasses such as guinea grass and signal grass (Chibuike and Obiora, 2013) iii) Changes in leaf colour to brown (Singh and Kalamdhad, 2011) iv) Delay in seed germination and decline in rate in germination (Fazal <i>et al</i> 2010) v) Lodging of plants (Mc cauley <i>et al</i> 2011)
Flooding/ water logging:	<ul style="list-style-type: none"> i) Perceived persistent rain between 5days to 20days or more (Ojeh <i>et al.</i>, 2014) ii) Water percolation and submergence of farmland for over 5days after heavy rainfall (Ojeh <i>et al.</i>, 2014) iii) Difficulty in carrying out normal cultivation of land due to flood (Mati, 2014) iv) Wilting and Leaf senescence due to flood (Akhtar <i>et al</i>, 2013; Mohammed, 2012) v) Root rot (Ransom, 2013)

- Decreased vegetation cover:**
- i) Absence of some common weed species like elephant grass (Bunamman *et al.*, 2016)
 - ii) Decrease in number of trees near the farm, (Kusimi and Yiran, 2011)
 - iii) Low quality of firewood in surrounding areas compared to decades ago (Kusimi and Yiran, 2011)
 - iv) Scarcity of grasses for roofing and grazing, in surrounding areas (Kusimi and Yiran, 2011)
 - v) Increasing distance to firewood location and decrease in abundance of firewood in surrounding areas (Kusimi and Yiran, 2011)
- Subsurface compaction of soil**
- i) Soil hard to till (Wolkowski and Lowery, 2008)
 - ii) Exposed and twisted roots (Wolkowski *et al.*, 2008)
 - iii) Slow or poor plant emergence, (Stiegler, 1977)
 - iv) Increase in surface water ponding, (Mckenzie, 2010)
 - v) Uneven early growth in form of short and tall plants in adjacent rows. (Stiegler, 1977)
- Decreased water absorption capacity**
- i) Poor drainage (if water remains on farmland 3days after rain), (European Union, 2014)
 - ii) Increased runoff, (European Union, 2014)

Decline in soil organic matter content

- iii) Stunted growth of crop,(Kowalczyk, 1967)
- iv) Delay in flowering of plant, (USDA, 2008)
- v) Increased soil crusting.(USDA, 2008)
- i) Yellowish of leaves, (Pulido and Bocco, 2014)
- ii) Presence of some weed species and stone, (Omari *et al*, 2018)
- iii) Increased fertilization need, (Mc cauley *et al.*, 2017)
- iv) Low density of mites, (Maribe *et al.*,2011)
- v) Soil particles easily loosened by rain drop and carried away by moving water (*Mc cauley et al.*, 2017).

Leaching of soil nutrient:

- i) Exposed roots (Bunemman *et al.*, 2016)
- ii) Change in colour of soil from darker organic surface layer to lighter colour, (Masters *et al.*, 2013)
- iii) Increased rate of rainfall (Mauro Wagner *et al.*,2002)
- iv) Poor yield of Crops (Huber *et al.*, 2007)
- v) Poor resistance of plants to diseases. (Ferguson *et al.*, 2004)

$$(SDI) = \left(\frac{PSDi}{MSDi} \right) 100$$

Where:-

SDI = Soil Degradation Index

MSDi = Maximum Possible Number of Soil Degradation Indicators.

PSDi = Perceived Number of soil Degradation Indicators by the farmers

0-1indicator means that the level of soil degradation is low

2-3 indicators means that the level of soil degradation is moderate

4-5 indicators mean that the level of soil degradation is high.

Estimation of MSDi and PSDi

(MSDi) = 5 for each of the seven degradation Indicators

(PSDi) ≤ 5 for each of the seven degradation Indicators

To accomplish Objective III Multiple Regression Function was used.

To determine the effects of soil degradation indicators and production factors on outputs of dominant staple crops in the study area (objective iii), ordinary least squares multiple regression model was used.

The implicit form of the model was specified as;

$$Q_i = F(W_j, e); j = 1, 2, \dots, 12 \dots \dots \dots 3.2$$

$$Q_i = F(w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9, w_{10}, w_{11}, w_{12}, e) \dots \dots \dots 3.3$$

Explicitly using the four functional forms, we have;

Linear:

$$Q_i = a + b_1w_1 + b_2w_2 + b_3w_3 + b_4w_4 + b_5w_5 + b_6w_6 + b_7w_7 + b_8w_8 + b_9w_9 + b_{10}w_{10} + b_{11}w_{11} + b_{12}w_{12} + e \dots \dots \dots 3.4$$

Exponential:

$$\text{Log } Q_i = a + b_1w_1 + b_2w_2 + b_3w_3 + b_4w_4 + b_5w_5 + b_6w_6 + b_7w_7 + b_8w_8 + b_9w_9 + b_{10}w_{10} + b_{11}w_{11} + b_{12}w_{12} + e \dots \dots \dots 3.5$$

Semi – log:

$$Q_i = a + b_1 \log w_1 + b_2 \log w_2 + b_3 \log w_3 + b_4 \log w_4 + b_5 \log w_5 + b_6 \log w_6 + b_7 \log w_7 + b_8 \log w_8 + b_9 \log w_9 + b_{10} \log w_{10} + b_{11} \log w_{11} + b_{12} \log w_{12} + e \dots \dots \dots 3.6$$

Double – log

$$\text{Log } Q_i = a + b_1 \log w_1 + b_2 \log w_2 + b_3 \log w_3 + b_4 \log w_4 + b_5 \log w_5 + b_6 \log w_6 + b_7 \log w_7 + b_8 \log w_8 + b_9 \log w_9 + b_{10} \log w_{10} + b_{11} \log w_{11} + b_{12} \log w_{12} + e \dots \dots \dots 3.7$$

Where;

- Q_i = Outputs of cassava and maize in tonnes
- i = One for output of cassava in tonnes, and 2 for output of maize in tonnes.
- W_j = Level of soil degradation indicators
- w_1 = Perceived decreased vegetative cover index
- w_2 = Perceived level of leaching of soil nutrients index
- w_3 = Perceived level of decreased water absorption capacity index
- w_4 = Perceived level of sub surface compaction soil index
- w_5 = Perceived flooding/water-logging and soil erosion index
- w_6 = Perceived level of decline in soil organic matter index
- w_7 = Perceived level of soil toxicity index
- w_8 = Labour input (Mandays)
- w_9 = Expenditure on planting materials (₦)
- w_{10} = Quantity of fertilizer (kg)
- w_{11} = Capital (Depreciated values of capital inputs in Naira)
- w_{12} = Farm Size (Ha)
- e = error term

The a priori expectation is that the coefficients of $w_1, w_2, w_3, w_4, w_5, w_6, w_7, < 0, w_8, w_9, w_{10}, w_{11}, w_{12}, > 0$.

The choice of a working functional equation was based on statistical measure of performance such as the Coefficient of Multiple Determination (R^2), the F-Statistics, significance of the individual coefficients and the signs of the regression coefficients whether or not they conform to the a priori expectation.

To accomplish Objective IV the Vulnerability Index Model was used.

Vulnerability was first calculated using the formula by Deressa *et al* (2008)

The vulnerability index is specified as:

$$\text{Vulnerability} = (\text{adaptive capacity}) - (\text{sensitivity} + \text{exposure})$$

The above formula was operationalised using the equation by Madu (2012)

$$VI = (Wa_1X_1 + Wa_2X_2 + Wa_3X_3 \dots Wa_nX_n) - (Wa_1Y_1 + Wa_2Y_2 + Wa_1Z_1 + Wa_2Z_2) \dots \dots \dots 3.8$$

Where :

VI is vulnerability Index

$Wa_1 - Wa_n$ is the principal component factor loading scores

$X_1 - X_n$ are the adaptive capacity variables: Formal education, marital status
 Off farm income, Use of organic manure, Use of improved variety, Practice mixed farming, Use of soil conservation measures, Adjustment of Planting period, Diversification, Access to information, Member of farmers association, Farm size, Farming experience, Average farm income, Extension agent contact, Access to credit.

$Y_1 - Y_n$ are the exposure variables: Increased soil erosion, Increased flooding, Incidence of deforestation, Heavy rainfall.

$Z_1 - Z_n$ are the sensitivity variables: Sloppy farmland, Swampy farmland, Oil spilled farmland, Household dead or Injured by flood, Loss of vegetative Cover, Bush encroachment, female headed household, Infertile soil.

Since the vulnerability indicators (X, Y, Z) don't have the same units of measurement, standardization was used to normalize the actual values or scoring values into 0 to 1 scale to make it more comparable. The normalizing process was executed using the following formula used by Swanson *et al* 2007:

$$1 - \left[\frac{\text{Value to be normalized} - \text{Minimum value}}{\text{Maximum value} - \text{Minimum value}} \right]$$

The normalized values were then used to obtain their means and standard deviations. This was used to calculate the values of X, Y and Z in equation 3.7. For instance:

$$X = W_a \sqrt{\frac{\sum (X_i - \bar{X})^2}{n-1}}$$

W_a is the principle component factor loading scores.

X_i is the normalized value for each vulnerability indicator.

\bar{X} is is the mean of X across the different households

n is the sample size.

The values of the farmers' vulnerability indices were obtained, ranked and classified. The higher the mean index, the lower the vulnerability of farmers to soil degradation (Nwafor Eze *et al.*, 2018). The classification enhanced understanding of the variations in the vulnerability level of the farmers to soil degradation in the study area.

However, in creating the indices, the scale of analysis is important. As quoted by Gutu *et al.* (2013) vulnerability analysis may range from local or household level to regional or global level. The choice of scale is dictated by the methodologies, and data availability. For this study, the scale of analysis is regional because the study area is Niger Delta region. Ranking and classification were performed on the farmer's vulnerability indices to group the farmers in the study area into highly vulnerable, moderately vulnerable and less vulnerable according to their degree of

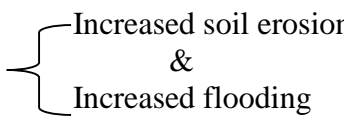
farmers' vulnerability. The ranking and classification enhanced understanding of the variations in the vulnerability levels of the farmers to soil degradation in the study area.

Vulnerability indicators: its unit of measurement and direction.

The element of vulnerability	Vulnerability indicators	Unit of measurement	Direction as it relates to indicators and vulnerability
Adaptive Capacity	Formal education	Years	The higher the level of education the lesser the vulnerability. (Evangelista <i>et al.</i> , 2015)
	Marital status	Dummy (Married 1, otherwise 0)	Those married are less vulnerable
	Off farm income	Dummy (Yes 1, No 0)	The larger the off-farm income the Lesser their vulnerability (Evangelista <i>et al.</i> , 2015 and Zerihun, 2017)
	Use of organic manure	Dummy (Yes 1, No 0)	The more they use organic manure the lesser their vulnerability (Zia-ur-Rehman <i>et al.</i> , 2016)
	Use of improved variety	”	The more they use improved variety the lesser their vulnerability (Sime ad Aune, 2018)
	Practice mixed farming	”	The more they practice mixed farming the lesser the vulnerability (FAO 2005)
	Use of soil conservation measures	”	The more they use it, the the lesser their vulnerability (Zia-ur-Rehman <i>et al.</i> , 2016)
	Adjustment of Planting period	”	The more the adjust their planting period the lesser their Vulnerable (Kinuthia <i>et al.</i> , 2018)
	Diversification	”	As diversification increases Vulnerability decreases

(Evangelista *et al.*, 2015 and Zerihun, 2017)

	Access to information	”	The more the information The lesser the vulnerability (Ndambiri <i>et al.</i> , 2013)
	Belong to any farmers association	”	Membership to associations reduces vulnerability (Donatti <i>et al.</i> , 2019)
	Farm size	>3ha 1 Otherwise 0	The larger the farm the lesser the vulnerability (Negash, 2014)
	Farming experience	>10 years 1 Otherwise 0	The more experienced a farmer is, the less vulnerable he becomes. (Ndambiri, <i>et al.</i> 2013)
	Average farm income	Naira	The higher the farm income the lesser the vulnerability. (Negash, 2011)
	Extension agent contact	No of Times a Year	The more the extension contact the lesser the vulnerability (Desalew <i>et al.</i> , 2017).
	Access to credit	% of loan applied for that was received	The higher the loan received the lesser the vulnerability. (Tsue <i>et al.</i> 2014).
Sensitivity	As perceived by The Farmer	<ul style="list-style-type: none"> — Sloppy farmland — Swampy farmland — Oil spilled farmland 	% of total farmland that is sloppy, swampy or affected by oil spill.
	Household dead or Injured by flood	Number	The more the number of people killed or injured by flood the more the vulnerability. (Dewan, 2015)
	Loss of vegetative Cover	Dummy (Yes 1, No 0)	Increase in loss of vegetative cover increases vulnerability (Zia-ur-Rehman <i>et al.</i> , 2016)
	Bush encroachment	”	Increase in bush encroach

	Household headed by females	”	ment increases vulnerability (FAO 2005) The more the number of households headed by females, the more their vulnerability. (Adeotie <i>et al.</i> , 2016)
	Infertile soil	”	The more infertile the soil is the more the vulnerability. (Zia-ur-Rehman <i>et al.</i> , 2016)
Exposure			
As perceived By the farmers	 Increased soil erosion & Increased flooding	% of total farmland affected by erosion and flooding.	The more the soil is affected by erosion and flooding the more their vulnerability. (Nwafor Eze <i>et al.</i> , 2018)
	Incidence of deforestation	Dummy (Yes 1, Otherwise 0)	The more the incidence of deforestation, the more the vulnerability. (Anyanwu <i>et al.</i> , 2013).
	Heavy rainfall	Dummy (1-2 times a yr =1 3-5 times a yr =2 6-9 times a yr =3 ≥10 times a yr=4)	The more the number of heavy rains in a yr the more the vulnerability (DRPA, 2012)

To accomplish objective v, the Ordered Probit Regression Model was used.

The Ordered Probit (OP) Regression model is specified and estimated with x_i denoting the levels of farmers vulnerability to soil degradation as low = 0, moderate = 1, and high =2.

The factors influencing farmers vulnerability level to soil degradation is therefore specified as follows; low, moderate or high

$$Y_i^{\text{low, moderate or high}} = b_0 + b_1^{\text{OP}} x_1^{\text{OP}} + b_2^{\text{OP}} x_2^{\text{OP}} + b_3^{\text{OP}} x_3^{\text{OP}} + b_4^{\text{OP}} x_4^{\text{OP}} + b_5^{\text{OP}} x_5^{\text{OP}} + b_6^{\text{OP}} x_6^{\text{OP}} + b_7^{\text{OP}} x_7^{\text{OP}} + b_8^{\text{OP}} x_8^{\text{OP}} + b_9^{\text{OP}} x_9^{\text{OP}} + b_{10}^{\text{OP}} x_{10}^{\text{OP}} + b_{11}^{\text{OP}} x_{11}^{\text{OP}} + \mu^{\text{OP}}$$

.....3.9

Where,

- Y_i = Levels of vulnerability. The levels of vulnerability of farmers to soil degradation were ordered as (low = 0, moderate = 1, and high = 2)
- X₁ = Gender (Dummy variable, male = 1, female = 0)
- X₂ = Level of education (Years spent in school)
- X₃ = Age of farmer (years)
- X₄ = Household size (Number of persons in the household)
- X₅ = Annual farm income (₦)
- X₆ = Annual off-farm income (₦)
- X₇ = Farm size (Ha)
- X₈ = Extension contact (Number of visits per annum)
- X₉ = Access to credit (percentage of total loan applied for that was received)
- X₁₀ = Farming experience (years)
- X₁₁ = Marital status (Dummy variable; married = 1, otherwise = 0)
- μ = error term

Marginal effects

It is worth noting that the marginal effects are given as;

$$\frac{\partial \epsilon(Y/X)}{\partial x} = \phi(\beta^1 x) \beta$$

Where;

$\phi(\bullet)$ denotes the standard normal density.

Thus, the marginal effect of x depends not just on β , but on the values of x_i and all other variables in the equation, so to calculate the impact of x_i on Y we chose values for x_i and all other variables. The coefficients of β gave the effect of marginal change in the dependent variable x on the Z – score ($\beta' x$).

Therefore, the marginal effect of ordered probit model (measured as low vulnerability = 0, moderate vulnerability = 1, and high vulnerability = 2) was estimated as;

$$\text{Prob}_j (Y = 1/x, D=2) - \text{Prob}_j (Y = 1/x, D =1) - \text{Prob}_j (Y = 1/x, D = 0)$$

Where;

$\text{Prob}(\cdot)$ = response ordered probability (0, 1, 2).

$$\frac{\partial \epsilon (Y/X)}{\partial x} = \text{Marginal effects of the farmers level of vulnerability}$$

$$\phi(\beta' x)\beta = \text{Vector of explanatory variables}$$

$$\sigma\epsilon = \text{Probability of being in any vulnerability level}$$

$$j = \text{Vulnerability level}$$

$$x = \text{Specific explanatory variable}$$

$$\beta_i = \text{Vector of regression coefficients}$$

$$x_i = (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}) \text{ as defined in equation 3.10}$$

To accomplish objective vi, the ordered Probit Model and descriptive statistics were specified as:

The ordered probit regression model was specified and estimated with Y_i denoting the levels of adaptation strategies employed by the farmers, as less adapting = 0, moderately adapting = 1, and highly adapting = 2.

The factors influencing adaptation strategies used by farmers were therefore specified as follows,

The specification of the ordered probit model is as follows;

$$Y_i = b_0 + b_1^{op} x_1^{op} + b_2^{op} x_2^{op} + b_3^{op} x_3^{op} + b_4^{op} x_4^{op} + b_5^{op} x_5^{op} + b_6^{op} x_6^{op} + b_7^{op} x_7^{op} + b_8^{op} x_8^{op} + b_9^{op} x_9^{op} + b_{10}^{op} x_{10}^{op} + b_{11}^{op} x_{11}^{op} + b_{12}^{op} x_{12}^{op} \dots \dots \dots 3.11$$

Where,

Y_i = Adaptation strategies. The adaptation strategies used by farmers were ordered as (less adapting = 0, moderate adapting = 1, and highly adapting = 2).

X_1 = Gender (Dummy variable, male = 1, female = 0)

X_2 = Level of education (Number of years spent in school)

X_3 = Age of farmer (years)

X_4 = Household size (Number of persons in the household)

X_5 = Annual farm income (₦)

X_6 = Annual off-farm income (₦)

X_7 = Farm size (Ha)

X_8 = Extension contact (Number of visits per annum)

X_9 = Access to credit (percentage of total loan received out of total loan applied for)

X_{10} = Farming experience (years)

X_{11} = Marital status (Dummy variable; married = 1, otherwise = 0)

X_{12} = Nature of soil degradation (measured on a 3-point liker type scale of loss of vegetative cover = 1, flooding = 2, and decline in fertility

$$y' = \text{error term} = 3)$$

Marginal Effects

The marginal effects are given as follows;

$$\frac{\partial \epsilon (Y/X)}{\partial x} = d (\beta, x)\beta \dots\dots\dots 3.12$$

Where;

$y'(\cdot)$ denotes standard normal density.

Therefore, the marginal effects of Y depend not just on β , but on the values of x_i and all other variables in the equation, so to determine the influence of x_i on y' we choose values for x_i and all other variables. The coefficients of β gave the effects of marginal change in the dependent variable Y on the Z – score ($\beta' x$). Therefore, the marginal effect of ordered probit model (measured as less adapting = 0, moderate adapting = 1, and highly adapting = 2) was estimated as;

$$\text{Prob}_j (Y = 1/x, D=2) - \text{Prob}_j (Y = 1/x, D =1) - \text{Prob}_j (Y = 1/x, D = 0)$$

Where;

Prob(.) response ordered probability (0, 1, 2)

$$\frac{\partial \epsilon (Y/X)}{\partial x} = \text{Marginal effects of the farmers adaptation strategies}$$

$$Q (\beta' x)\beta = \text{Vector of explanatory variables}$$

$$\partial \epsilon = \text{Probability of using any adaptation strategy}$$

$$j = \text{Adaptation strategy}$$

$$x = \text{Specific explanatory variable}$$

$$\beta_i = \text{Vector of regression coefficients}$$

$$x_i = (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}) \text{ as defined in equation } \dots\dots\dots 3.13$$

To accomplish Objective VII Trend Analysis was used.

In modelling time trend for this study, the bivariate regression model and line graph were used.

The bivariate regression model for production was specified as follows;

Thus;

$$Y_i = f(t) \quad \dots 3.14$$

Where:

Y_i = Crop output of staple crops

Where $i = 1$ for cassava

$i = 2$ for maize

t = time (yrs) 1995-2016.

3.4.2 Hypotheses Testing

a. Test of Hypothesis 1 & 3

The Chi square likelihood ratios obtained from the results of the ordered probit regression was used to test hypothesis 1 and 3 at 5% level of significance.

b. Test of Hypothesis 2

The t-ratios obtained from the results of the Multiple Regression estimates of objective iii were compared with tabulated t-values to test hypothesis 2.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1a Socio-Economic characteristics of the farmers

The distribution of the farmers according to socioeconomic characteristics is presented in Table 4.1. The socioeconomic characteristics of the farmers examined were age, sex, educational level, household size, farm income, non-farm income, farm size, member of farmers association, number of visits by extension agents, access to credit, marital status and years of farming experience.

4.1.1 Age of the farmer

The distribution of the farmers according to age is presented in Table 4.1

Table 4.1 Distribution of the farmers according to age

Age (Yrs)	Frequency	Percentage
15-30	5	3.3
31-46	41	27.0
47-62	90	59.2
63-78	16	10.5
Total	152	100

Mean 51years

Source: Field data, 2017

The percentage distribution of the farmers according to age shows that majority (59.2%) fall within 47-62 years, 27.0% fall within 31-46 years, 10.5% fall within 63-78 years of age, while 3.3% of the farmers fall within the age bracket of 15-30 years, with mean age of 51 years. This indicates that young people were not much involved in farming activity in the area. This is in line with the findings of Ahmadu and Egbodion (2013) who confirmed the low involvement of the youth in agricultural production in Niger Delta who instead seek for white collar jobs. This

may be due to its unattractiveness in terms of low income which is worsened by soil degradation. However older farmers tend to have more experience which increases the probability of making use of adaptation measures to soil degradation (Atinkut and Mebrat, 2016). Age is seen as one of the most important factors that determine the productive ability of a farmer. Increase in the age of a farmer has been related to increase in skill and experience. However, as their physical strength is decreasing, production declines resulting in low income.

4.1.2 Sex of the farmer

The distribution of the farmers according to sex is presented in Table 4.2.

Table 4.2 Distribution of the farmers according to sex

Sex	Frequency	Percentage
Male	98	64.5
Female	54	35.5
Total	152	100

Source: Field data, 2017

Table 4.2 shows that most (64.5 %) of the farmers are males, while 35.5% are females showing that majority of the farmers in the study area are males. This could stem from the fact that men have more access to productive resources and services than the women such as land, credit, other farm inputs and extension services (FAO, 2011). Thus, they are more likely to use adaptation measures than the female farmers. This is because they are likely to meet the investment demands of soil management techniques. Gender plays a vital role in agricultural production and household food security. It has been observed to be the key determinant of the distribution of responsibilities and resources between men and women.

4.1.3 Marital status of the farmers

The distribution of the farmers according to marital status is presented in Table 4.3.

Table 4.3 Distribution of the farmers according to marital status

Marital status	Frequency	Percentage
Married	126	82.9
Single	5	3.3
Divorced	2	1.3
Widowed	18	11.8
Separated	1	0.7
Total	152	100

Source: Field data, 2017

From the findings in table 4.3, most (82.9%) of the farmers are married, 11.8% are widowed, 3.3% are single, 1.3% are divorced, while 0.7% are separated. The very high percentage of the married crop farmers could be attributed to the fact that respondents require helping hands to carry out the tedious nature of manual farming which dominates the farming system in the area. This is also an indication that most farmers depends on family members as cheap source of labour (Ohikere and Ejeh, 2012). According to Senkoro (2010) married farmers are more productive because they make use of labour through out the year and are more likely to use soil and water conservation practices making them less vulnerable to soil degradation.

4.1.4 Number of years spent in school by the farmers

The distribution of the farmers according to number of years spent in school is presented in Table 4.4.

Table 4.4 Distribution of the farmers according to number of years spent in school

Level of Education (Years spent in school)	Frequency	Percentage
0 (No formal Education)	31	20.4
1-6	23	15.1
7-12	23	15.1
13-18	47	31.0
19-24	28	18.4
Total	152	100

Mean = 11 years

Source: Field data, 2017

Table 4.4 shows that majority (31.0%) of the farmers spent between 13-18 years in school, 20.4% did not attend any formal education, 15.1% spent between 1-6 years in school, 15.1% spent between 7-12 years in school, while 18.4% spent between 19-24 years in school with mean of 11 years spent in school. This is an indication that majority of the farmers were literate which is expected to have a positive influence on adoption of improved technologies such as improved varieties, soil organic amendment, soil and water conservation technology etc. This is in support of Oluwatusin and Shittu (2014) who reported that farmers adoption of improved technology is influenced by their level of education. Thus, respondents level of education will assist them to seek information on soil degradation. Education is an important source of information for farm-level management activities. It is also regarded as an important determinant of adoption and implementation of innovation.

4.1.5 Household size of the farmers

The distribution of the farmers according to household size is presented in Table 4.5.

Table 4.5 Distribution of the farmers according to household size

Household size (No of persons)	Frequency	Percentage
1-3	28	18.4
4-6	62	40.7
7-9	39	25.7
10-12	20	13.2
13-15	3	2.0
Total	152	100

Mean = 6 persons

Source: Field data, 2017

The percentage distribution of the farmers according to household size shows that majority (40.8%) of the farmers have family size of between 4-6 persons, 25.7% with family size of 7-9 persons, 18.4% have family size of between 1-3 persons, 13.2% with family size of 10-12 persons, while 2.0% with family size of 13-15 persons with mean family size of 6 persons. This shows that the farmers have large family size which will serve as a source of cheap labor and is expected to influence production positively. According to Olarinde *et al.*, (2014), farm households with large family size will serve as source of cheap labor and are better able to take on various adaptation management practices in response to soil degradation compared to those with limited labor. It is believed that household size constitutes a major source of family labor needed for agricultural production. It is measured by number of members in a household.

4.1.6 Farm size of the farmers

The distribution of the farmers according to farm size is presented in Table 4.6.

Table 4.6 Distribution of the farmers according to farm size

Farm size (Ha)	Frequency	Percentage
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0.1-1.0	107	70.0
1.1-2.0	30	20.0
2.1-3.0	11	7.0
3.1-4.0	4	3.0
Total	152	100

Mean = 0.9ha

Source: Field data, 2017

From the findings in table 4.6, it was found that majority (70.3%) of the farmers has farm size of less than 1ha indicating that this set of farmers operates on marginal farms. According to Apata *et al.*, (2011), marginal farms are farms of less than 1 ha. 19.7% have farm size of 1.1-2ha, 7.2% of the farmers have farm size of between 2.1-3ha while 2.6% of the farmers have farm size of 3.1-4ha with mean farm size of 0.9ha. Having mean farm size of 0.9ha is an indication that most of the farmers in the study area are smallholder farmers whose farm sizes may further be reduced by soil degradation, which invariably affects output quantity negatively. This supports the finding of Obasi *et al.*, (2013), who stated that large fraction of the agricultural output in Nigeria are in the hands of smallholder farmers whose average holding is less than 3 hectares. The implication is that these small holder farmers are more likely to be vulnerable to the effect of soil degradation than large holders. This is because according to Liverman (1990) and Haghjou *et al.*, (2014), small holder farmers are less likely to invest in soil conservation measures (whether mechanical or non-mechanical) and their lower levels of investment reflect their poverty level.

4.1.7 Farming experience of the farmers

The distribution of the farmers according to farming experience is presented in Table 4.7.

Table 4.7 Distribution of the farmers according to farming experience

Farming experience (Years)	Frequency	Percentage
1-10	27	17.8
11-20	49	32.2
21-30	56	36.8
31-40	20	13.2
Total	152	100

Mean = 20years

Source: Field data, 2017

The result in table 4.7 shows that majority (36.8%) of the farmers have farming experience of 21-30 years, 32.2% have farming experience of between 11-20 years, 17.8% of the farmers have farming experience between 1-10 years, while 13.2% have farming experience of between 31-40 years with mean farming experience of 20years. This shows that they are elderly farmers who are well experienced. According to Komba *et al.*, (2012) the more experienced a farmer is, the more knowledgeable about farming he or she is.

4.1.8 Membership of farmers association

The distribution of the farmers according of membership to farmers association is presented in Table 4.8.

Table 4.8 Distribution of the farmers according of membership to farmers association

Member to farmer's association	Frequency	Percentage
Yes	86	56.6
No	66	43.4
Total	152	100

Source: Field data, 2017

Table 4.8 above shows that majority (56.6%) of the farmers belong to farmers association, while 43.4% do not belong to any farmers association. Membership of farmers association is seen as a strategy used to promote collective action in order to strengthen the lives of farmers by rendering services such as provision of farm inputs, credit facility or loan, agricultural extension, education of members etc.

The implication is that this will enhance their access to information and farm resources such as agro-inputs, credit, even extension contact etc. This will encourage the use of appropriate technology and good adaptation strategies to soil degradation thereby increasing agricultural productivity and income (Adesope *et al.*, 2012; Yamusa *et al.*, 2014).

4.1.9 Number of times visited by extension agents per year

The distribution of the farmers according to number of times visited by extension agents per year is presented in Table 4.9.

Table 4.9 Distribution of the farmers according to number of times visited by extension agents

Number of visits by extension agents	Frequency	Percentage
0	15	9.9
1-6	47	30.9
7-12	75	49.3
13-18	-	-
19-24	15	9.9
Total	152	100

Mean = 7 visits/year.

Source: Field data, 2017

The result in table 4.9 shows that majority (49.3%) of the farmers were visited 7-12 times a year by extension agents. 30.9% were visited 1-6 times a year, 9.9% were visited 19-24 times a year while 9.9% were not visited by extension agents. This shows that majority of the farmers have access to extension agents. Extension agents are agricultural experts, employed by government to teach farmers improved methods of farming and innovations and assisting them to organize and solve their problems. The implication is that farmers will invest in and implement sustainable technologies and farm practices to check soil degradation if they have the right information and motivation through these extension agents thereby exploiting their full potentials in agriculture. According to Demeke (2003), unless there is an adequate mechanism for transmitting information such as the extension agents, the adoption of any new agricultural practices or technologies would not be successful.

4.1b Socio-Economic Activities

4.1.10 Access to Bank credit

The distribution of the farmers according to access to Bank credit is presented in Table 4.10.

Table 4.10 Distribution of the farmers according to access to Bank credit

Access to Bank credit	Frequency	Percentage
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Yes	24	15.8
No	128	84.2
Total	152	100

Source: Field data, 2017

From table 4.10, majority (84.2%) of the farmers don't have access to bank credit facilities, while 15.8% of the farmers have access to bank credit. The implication is that lack of agricultural credit will limit the farmers' ability to obtain the resources required to deploy appropriate adaptation practices making them more vulnerable to soil degradation. Availability of credit enhances probability of a farmer to adapt strategies that reduce the negative impact of soil degradation and relieves the farmer of his financial constraints. Huda *et al.*, (2016) stated that lack of agricultural credit makes the farmers economically too insolvent to undertake any adaptation strategy.

4.1.11 Source of credit

The distribution of the farmers according to source of credit is presented in Table 4.11.

Table 4.11 Distribution of the farmers according to source of credit

Source of credit	Frequency*	Percentage
Family/friends	40	26.3
Commercial bank	24	15.8

Personal savings	117	77.0
Others (Esusu/cooperative/ Age grade)	16	10.5

***Multiple responses were recorded**

Source: Field data, 2017

Table 4.11 shows that majority (77%) source their credit from personal savings, 26.3% of the farmers source their credit from family/friends, 15.8% source their credit from bank, while 10.5% source their credit from other means such as Esusu, Age grade etc. This shows that most of the farmers don't have access to bank loan instead they depend on their meager income from which they make little savings. This is because according to Awotide *et al.*, (2015) rural borrowers are not an attractive proposition for formal financial institutes because they cannot meet the minimum requirements and are perceived as high risk borrowers. Consequently, this will influence the adoption of agricultural innovations.

4.1.12 Amount of bank loan applied for within 2016

The distribution of the farmers according to amount of bank loan applied for in 2016 is presented in Table 4.12.

Table 4.12 Distribution of the farmers according to amount of bank loan applied for within 2016

Amount of bank loan Applied (₦)	Frequency	Percentage
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No application for loan	128	84.2
≤100000	1	0.7
101000-300000	7	4.6
301000-500000	11	7.2
501000-700000	5	3.3
Total	152	100

Source: Field data, 2017.

The distribution of the farmers according to amount of loan applied shows that most (84.2%) of the farmers did not apply for any loan from the bank, 7.2% applied for loan of between 301000-500000 naira, 4.6% of the farmers applied for loan of between 101000-300000 naira, 3.3% applied for loan of between 501000-700000 naira while 0.7% of the farmers applied for < 100000 naira. This indicates that majority of the farmers don't have access to formal credit facility.

4.1.13 Amount of bank loan received within 2016

The distribution of the farmers according to amount of bank loan received in 2016 is presented in Table 4.13.

Table 4.13 Distribution of the farmers according to amount of bank loan received within 2016

Amount of loan Received (₦)	Frequency	Percentage
--	------------------	-------------------

Non receipt of loan	128	84.21
≤100000	3	1.97
101000-300000	11	7.24
301000-500000	10	6.58
Total	152	100

Source: Field data, 2017.

The distribution of the farmers according to amount of loan received from the bank shows 84.21% of the farmers did not receive any loan. 7.24% of the farmers received loan of between 101000-300000 naira, 6.58% of the farmers received loan of between 301000-500000 naira while 1.97% received loan of less than or equal to 100000 naira. This indicates that majority of the farmers have limited access to formal credit facility.

4.1.14 Percentage of bank loan received

The distribution of the farmers according to percentage of bank loan received is presented in Table 4.14.

Table 4.14 Distribution of the farmers according to percentage of bank loan received.

Percentage of loan received	Frequency	Percentage
0	128	84.2

25	5	3.3
50	1	0.7
75	7	4.6
100	11	7.2
Total	152	100

Source: Field data, 2017.

The findings from table 4.14 shows that 7.2% received 100% of the loan applied for, 4.6% received 75% of the loan applied for, 3.3% of the farmers received 25% of the loan they applied for, while 0.7% of the farmers received 50% of the loan they applied for. This result shows that 24 farmers out of the actual number of respondents which is 152 have access to formal credit. This is an indication that most farmers do not have access to formal credit facility.

4.1.15 Off- farm activities

The distribution of the farmers according to Off-farm activities is presented in Table 4.15.

Table 4.15 Distribution of the farmers according to off-farm activities engaged in.

Non-farm activities	Frequency*	Percentage
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Trading	67	44.1
Civil service work	20	13.2
Fishing	11	7.2
Commercial driving	10	6.6
Others	19	12.5
No off farm activities	38	25.0

***Multiple responses were recorded**

Source: Field data, 2017

The result shows that majority (44.1%) of the farmers are involved in trading, 25.0% are not engaged in off-farm activity. 13.2% are civil servants, 12.5% are involved in other activities such as mat weaving etc, 7.2% are engaged in fishing, while 6.6% are commercial drivers. This indicates that most of the farmers are part-time farmers who are engaged in off-farm activities which can contribute significantly to their total income in order to make ends meet (Tijani *et al.*, 2010). Off-farm activity is an important means of raising financial capital of farming households thereby reducing income variability or risk.

4.1.16 Income from Off- farm activities

The distribution of the farmers according to income from non-farm activities is presented in Table 4.16.

Table 4.16 Distribution of the farmers according to average income from other activities per Year

Off-farm income	Frequency	Percentage
≤100000	50	32.9
101000-300000	45	29.6

301000-500000	16	10.5
501000-700000	2	1.3
701000-900000	1	0.7
No off farm income	38	25
Total	152	100

Mean: ₦131296.05

Source: Field data, 2017

Percentage distribution of the farmers according to average income from off farm activities shows that majority (32.9%) earn less than 100000 naira, 29.6% earn about 101000-300000 naira, 25% are not engaged in any off farm activity, 10.5% earn about 301000-500000 naira, 1.3% earn about 501000-700000, while 0.7% earn about 701000-900000 with mean off-farm income of about ₦131000. This shows that with earnings from off-farm income farmers will be able to overcome working capital constraints associated with small scale agricultural production. Off-farm income is an income generated by farmers from any non-agricultural income generating enterprises such as artisanal activities, transportation, civil service work or any other informal businesses. Off-farm income according to Diiro (2013) is expected to induce technology adoption and provide farmers with capital for purchasing productivity enhancing inputs such as improved seed and fertilizers.

4.1.17 Access to Information.

The distribution of the farmers according to access to information is presented in Table 4.17.

Table 4.17 Distribution of the farmers according to access to information

Access to information	Frequency	Percentage
Yes	147	96.7
No	5	3.3

Total	152	100
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Source: Field data, 2017

Table 4.17 shows that majority (96.7%) of the farmers have access to information, while 3.3% don't have access to information. This indicates that they have access to information in the study area. Farmer's access to information increases his/her awareness to soil degradation which will enable them to adopt suitable strategies that best suits their soil conditions. According to Njagi *et al.*, (2017) non-adoption of available innovations among small scale farmers could be attributed to socio-economic factors such as information barriers that render adoption of innovations unprofitable.

4.1.18 Sources of Agricultural Information

The distribution of the farmers according to sources of Agricultural information is presented in Table 4.18.

Table 4.18 Distribution of the farmers according to sources of Agricultural information

Sources of Information	Frequency*	Percentage
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Radio	81	53.3
Extension agent	89	58.6
Television	38	25.0
Internet	28	18.4
Friends	82	53.9
Others	9	5.9

***Multiple responses were recorded**

Source: Field data, 2017.

Majority (58.6%) of the farmers source their information from extension agents, 53.9% source their information from friends, 53.3% of the farmers source their information from the use of radio, 25% source their information from television, 18.4% source their information from internet, while 5.9% from other sources. This shows that many of the farmers have access to extension agents in the study area. According to Lwoga *et al.*, (2011), extension officers are important sources of information and knowledge, though farmers are dissatisfied with the frequency of their interactions with extension agents which is common here in Nigeria.

4.2 Forms and levels of soil degradation in the study area

The distribution of the farmers according to forms and levels of soil degradation in the study area is presented in Table 4.20 and 4.21. The forms of soil degradation examined were soil toxicity, flooding & water logging, decreased vegetative cover, subsurface compaction of soil, decreased water absorption capacity, decline in soil organic matter content and leaching of soil nutrient.

4.2.1 Forms of soil degradation in the study area

The distribution of the farmers according to forms of soil degradation experienced in the study area is presented in Table 4.19.

Table 4.19 Distribution of the farmers according to forms of soil degradation experienced in the study area

Forms of soil Degradation	Freq*	Percentage
Soil toxicity	43	4.3
Flooding & water logging	249	25.0
Decreased vegetative cover	153	15.4
Subsurface compaction of soil	84	8.4
Decreased water absorption capacity	72	7.2
Decline in soil organic matter content	183	18.4
Leaching of soil nutrients	211	21.2

***Multiple responses were recorded**

Source: Field data, 2017.

Table 4.19 shows that most (25.0%) of the farmers experienced flooding and water logging, 21.2% experienced leaching of soil nutrients, 18.4% of the farmers experienced decline in soil organic matter content, 15.4 % experienced decreased vegetative cover on their farms, 8.4% of the farmers experienced subsurface compaction of soil in the farmlands, 7.2% experienced decreased water absorption capacity while 4.3% of the farmers experienced soil toxicity. This is an indication that soil degradation is indeed a major issue in the study area. According to Uyigue and Agho (2007); Subair (2009); Etuonovbe (2009) and Ogboi *et al.*, (2013), the Niger Delta region is faced with myriads of environmental problems such as deforestation, bush burning, soil toxicity resulting from gas flaring and oil exploration, coastal erosion and flooding etc, which have paralysed agricultural activities.

4.2.2 Perceived Level of soil degradation in the study area

The distribution of the farmers according to perceived level of soil degradation in the study area is presented in Table 4.20

Table 4.20 Distribution of the farmers according to perceived level of soil degradation in the study area

Soil degradation forms	High	Moderate	Low	Σfx	n	\bar{X}	Decision
	(3)	(2)	(1)				
Soil toxicity	9	61	82	231	152	1.5	Low
Flooding & water							
Logging	108	30	14	398	152	2.6	High
Decreased vegetative							
cover	64	65	23	345	152	2.3	High
Subsurface compaction							
of soil	12	65	75	241	152	1.6	Low
Decreased water							
absorption capacity	22	66	64	262	152	1.7	Low
Decline in soil organic							
matter content	88	52	12	380	152	2.5	High
Leaching of soil							
nutrient	91	37	24	371	152	2.4	High
Total						14.6	7
Mean Score						2.1	High

Source: Field Data, 2017

Note: Σfx = Sum (frequency of responses (f) * X variables; high 3, moderate 2 and low 1)

Table 4.20 shows that the respondents' perceived level of soil toxicity, subsurface compaction of soil and decreased water absorption capacity is low, while the level of flooding and water logging, decreased vegetative cover, decline in soil organic matter content and leaching of soil nutrient is high in the study area. The respondents' perceived soil degradation has a mean score of 2.1 indicating that the overall level of soil degradation in the study area is high.

4.3 Effects of Perceived Level of Soil Degradation on the Output of Staple Crops

4.3.1 Effects on Cassava Output

Table 4.21 shows the multiple regression result in four functional forms on the effects of level of soil degradation on cassava output.

Table 4.21 Estimated Multiple Regression Results of the Effects of Soil Degradation Indicators and Production Factors on Cassava Output

Explanatory variables	Linear function	Semi – log function	Double – log function	Exponential function
Constant	304.1134	285.4055	241.6016	185.2006
Loss of vegetative cover (x_1)	-13.0916 (-3.1903)*	-2.8713 (-1.4442)	-0.0664 (-3.1174)*	-0.0064 (-3.3684)*
Leaching of soil nutrients (x_2)	-10.3317 (-1.1343)	-4.1604 (-3.0335)*	-0.0713 (-2.4502)**	-0.0071 (-3.0869)*
Decreased water absorption (x_3)	-14.0946 (-4.4509)*	-3.3702 (-1.2213)	-0.0829 (-2.9821)*	-0.0039 (-1.8571)

Sub – surface compaction (x_4)	-13.1137 (-1.0945)	-2.9112 (-1.5714)	-0.0912 (-2.9804)*	-0.0082 (-3.2801)*
Flooding (x_5)	-10.8219 (-1.0945)	-3.0615 (-2.9712)	-0.0717 (-1.1014)	-0.0049 (-1.8148)
Decline in soil organic matter (x_6)	-11.3717 (-3.7257)*	-4.1922 (1-3282)	-0.0883 (-3.8899)*	-0.0093 (-3.5769)*
Soil toxicity (x_7)	14.2608 (1.0893)	2.8217 (1.4149)	0.0491 (1.4149)	0.0091 (3.1379)*
Labour (x_8)	13.1426 (1.0939)	3.9422 (1.3715)	0.0688 (3.1852)*	0.0078 (3.3913)*
Planting material (x_9)	10.4417 (3.4118)*	4.1902 (1.3599)	0.0654 (2.8811)*	0.0077 (3.3478)*
Fertilizer (x_{10})	16.1945 (1.0802)	3.1165 (2.9362)*	0.0713 (3.0471)*	0.0082 (1.2239)
Capital (x_{11})	13.0615 (1.0912)	3.5814 (1.3199)	0.0841 (1.0809)	0.0067 (1.2885)
Farm size (x_{12})	12.0619 (2.4118)**	4.2206 (2.8924)*	0.0855 (3.5774)*	0.0076 (2.6207)*
R ²	0.4833	0.4038	0.8539	0.6469
F – value	10.8266*	7.8438*	67.7698*	21.2238*
Sample size (n)	152	152	152	152

Figures in Parenthesis are t – ratios

** Significant at 5% , * Significant at 1%

Source: Field Data, 2017

Based on the values of R², F-statistics and the apriori expectation, the double log function was chosen as the lead equation. Results showed that the coefficient of multiple determinations (R²) was 0.8539. This implies that 85.39% variability in cassava output was explained by the model, while the remaining 14.61% was accounted for by the variables not included in the model. Results showed that loss of vegetative cover, decreased soil and water absorption, sub-surface compaction and decline in soil organic matter, labour; planting material, fertilizer and farm size were statistically significant at 1%, while leaching of soil nutrients was significant

at 5% level, implying that these soil degradation indicators and production factors significantly affect cassava output in the study area.

The coefficients of flooding, soil toxicity and capital were not significant at 5% level, implying that these soil degradation indicators and production factor do not significantly affect cassava output in the study area.

Results showed that loss of vegetative cover (-0.0664) was negative and statistically significant at 1% level. This implies that an increase in loss of vegetative cover per hectare decreases the output of cassava by 0.0664 tons. This is inline with the apriori expectation. Vegetative cover acts as a soil stabilizer and prevent water and soil erosion. Woody vegetation protects the soil better and lasts longer than annual plants. Their roots deepen and improve the soil, while its shade facilitates ecosystem metabolism. On the other hand, cover crops also improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. The vegetative covers are essential for ensuring the continuity of agricultural activities. This is an indication that increased loss of vegetative cover decreases the output of cassava since the soil stabilization functions are impaired. According to Rehman *et al.*, (2015), loss of vegetative cover can drastically affect the surface runoff which is not only the greatest source of soil and water loss, but also important water for crop production. He further explained that soil losses continually lead to critical degradation of soil characteristics, decreased soil productivity due to deterioration in soil fertility and consequently decreased crop production.

The leaching of soil nutrients (-0.0713) was also negative and statistically significant at 5% level, which conforms to the apriori expectation. This implies that an increased leaching of soil nutrients per hectare decreased the cassava output by 0.0713 tons. Leaching carries away some of the nutrients such as nitrogen and phosphorous, that

plants use. The implication is that as too much nitrate content is removed from the soil, the soil pH drops greatly and become over-acidic. Soil acidification on the other hand, yields numerous negative consequences especially in cassava production, as it leads to poorly developed root systems. According to Tadele (2017), most African soils are inherently low in fertility due to high leaching; hence they are deficient in major nutrients such as nitrogen and phosphorus causing substantial yield losses to crop plants. Little wonder Pongsivapai *et al.*, (2016) remarked that leaching of plant nutrient is one of the major problems affecting cassava yield.

The coefficient of decreased soil and water absorption (-0.0829) was negative and significant at 1% level. This is also inline with the apriori expectation. This implies that an increase in declined soil and water absorption per hectare decreases the output of cassava by 0.0829 tons. This could be linked to the fact that when the soil moisture decreases below the wilting point, plant roots exert more pressure, and the rate of absorption decreases. On the other hand, when the soil is completely saturated with water, then soil temperature and aeration are poor and this condition also affects the absorption of water. This in turn reduces the yield and output performance, as higher CO₂ concentrates around the roots and results in poor oxygen availability to the plant. This was also observed by Pitts (2016) that too little soil moisture can result in yield loss and plant death and too much of it causes root disease and wasted water.

The coefficient of sub-surface compaction (-0.0912) was significant at 5% level and had a negative effect on the output of cassava which conform to the apriori expectation. This shows that as an increase in sub-surface compaction per hectare decreases the output of cassava by 0.0912 tons. This could be attributed to impeded root growth as a result of the compacted soil which restricts the growth of cassava roots, as roots develop maximum pressure above which they are not able to expand

in the soil. Hence, yield loss and decrease in output. This is in line with Singh (2015) that increase in soil compaction decreases crop yield and increases soil degradation.

The coefficient of declined soil organic matter (-0.0883) was negative and statistically significant at 1% level and also conform to the apriori expectation. This implies that an increase in declined soil organic matter per hectare decreases the cassava output by 0.0883 tons. This could be linked to the reduction in the nutritional and biological functions of soil organic matter which reduces the plant growth and hence the output of cassava. According to Albrecht (2014), decline in soil organic matter content reduces the efficiency of soil for crop production.

The coefficient of labour (0.0688) input was positive and statistically significant at 1% level, and this conforms to a priori expectation. It implies that a 10% increase in labour input per hectare increases cassava output by 6.88 tons. This could be due to the timely applications of maintenance inputs and completion of cassava production activities early enough due to more labour inputs and time allocated to production. According to Onyenweaku and Ohajianya (2005), increases in farm labour input leads to increase in crops output due to timeliness in farm operations.

The coefficient of planting material (0.0654) was positive and significant at 1% level, which implies that a 10% increase in planting material per hectare leads to a 6.54 increase in cassava output per ton. This could be because planting material use is directly proportional to crops output. This finding agrees with those of Likita (2005), who reported that more use of planting materials, especially improved varieties, lead to increase in outputs.

Fertilizer (0.0713) was positive and statistically significant at 1% level, which implies that a 10% increase in quantity of fertilizer per hectare leads to 7.13% increase in cassava output per ton. This is linked to the fact that fertilizer, a

maintenance input, improves yield of crops when appropriately applied both in quantity and time. This result corroborates those of Onyenweaku, Igwe and Mbanasor (2004) who found in their study in yam production in Nasarawa State, that increased use of maintenance inputs such as fertilizer leads to increase in yam input.

The coefficient of farm size (0.0855) was positive and significant at 1% level, implying that a 10% increase in farm size per hectare would lead to increase of 8.55% in cassava output per ton. This could be because expansion of land hectarage cultivated means use of more production inputs that would lead to increased output. This finding is similar to those of Tanko (2003) on arable crops production in kebbi State, and Ohajianya and Onyenweaku (2002) on rice production in Ebonyi State, who found in their studies that cultivation of large hectarage of farmland leads to increase in crops production.

4.3.2 Effects on Maize output

Table 4.22 shows the multiple regression result in four functional forms on the effects of level of soil degradation on maize output.

Table 4.22 **Estimated Multiple Regression Results of the Effects of Soil Degradation Indicators and Production Factors on Maize Output**

Explanatory variables	Linear function	Semi – log function	Double – log function	Exponential function
Constant	339.1054	296.0522	241.4522	201.6866
Loss of vegetative cover (x_1)	-10.3619 (-1.1302)	-4.0829 (-3.4489)*	-0.0665 (-2.9955)*	-0.0071 (-1.2241)
Leaching of soil nutrients (x_2)	-14.6613 (4.7561)*	-3.1164 (-1.1743)	-0.0922 (-3.1684)*	-0.0063 (-1.3404)
Decreased water absorption (x_3)	10.3906 (3.3381)*	5.2267 (3.5624)*	0.0387 (1.4073)	0.0092 (3.2857)*
Sub – surface compaction (x_4)	-11.0556 (-1.1169)	-2.8216 (1-4224)	-0.0521 (-3.1012)*	-0.0049 (-3.7692)*
Flooding (x_5)	-10.2219 (-1.1169)	-3.1944 (-1.3379)	-0.0522 (-1.2639)	-0.0055 (-1.3415)
Decline in soil organic matter (x_6)	-14.0056 (-4.5085)*	-3.8022 (1.3045)	-0.0617 (-2.5602)**	-0.0067 (-3.0455)*
Soil toxicity (x_7)	11.2219 (1.0777)	4.0926 (3.7081)*	0.0538 (1.2933)	0.0082 (3.2801)*
Labour (x_8)	13.1726 (1.0994)	3.4415 (1.2774)	0.0617 (2.4387)**	0.0049 (1.3611)
Planting material (x_9)	13.9314 (3.3725)*	4.0926 (1.3609)	0.0419 (3.1037)*	0.0068 (1.1929)
Fertilizer (x_{10})	10.8826 (1.1938)	3.0526 (1.4504)	0.0952 (2.3051)**	0.0077 (3.6667)*
Capital (x_{11})	12.5061 (3.3092)*	4.1164 (3.1315)*	0.0813 (1.1648)	0.0085 (2.9311)*
Farm size (x_{12})	11.0068 (2.5827)*	5.1309 (2.8169)*	0.0744 (3.3972)*	0.0058 (3.0526)*
R ²	0.5122	0.3937	0.7925	0.6342
F – value	12.1605*	7.5214*	44.2342*	20.0951*
Sample size (n)	152	152	152	152

Figures in Parenthesis are t – ratios. ** Significant at 5% , * Significant at 1%. Source: Field Data, 2017.

The double log function was chosen as the lead equation based on the values of R^2 , F-statistics and the apriori expectation. The coefficient of multiple determination (R^2) was 0.7925. This implies that 79.25% variability in maize output was explained by the model, while the remaining 20.05% was accounted for by the variables not included in the model. The coefficients of loss of vegetative cover, leaching of soil nutrients, sub – surface compaction, decline in soil organic matter, planting material and farm size were statistically significant at 1% level, while the coefficients of labour and fertilizer were significant at 5% level, implying that these soil degradation indicators and production factors significantly affect maize output in the study area, while the coefficients of decreased water absorption, flooding, soil fertility and capital were not statistically significant at 5% level, which implies that these factors do not significantly affect maize output in the study area.

Results showed that loss of vegetative cover (-0.665) was negative and statistically significant at 1% level. This is inline with the apriori expectation and it implies that an increase in loss of vegetative cover per hectare decreases the output of maize by 0.665 tons. This is an indication that increased loss of vegetative cover decreases the output of maize since the vegetative cover protects the soil and acts as soil cover that improves the soil fertility and hence productivity. According to Rehman *et al.*, (2015), increase in loss of vegetative cover leads to decreased soil productivity and crop production.

The leaching of soil nutrients (-0.0922) was also negative and statistically significant at 1% level which is inline with the apriori expectation. This implies that an increased leaching of soil nutrients per hectare decreased the maize output by 0.0922 tons. This is an indication that leaching reduces the uptake of soluble nutrients by plants, and hence decreases the yield performance of maize. According to Tadele

(2017), leaching reduces soil fertility due to nutrient loss resulting in crop yield losses.

The coefficient of sub-surface compaction (-0.0521) was significant at 1% level and had a negative effect on the output of maize. This is inline with the apriori expectation and it shows that as an increase in sub-surface compaction per hectare decreases the output of maize by 0.0521 tons. This could be attributed to the fact that compressed soil particles reduces the pore space available for air and water in the soil which are needed for plant growth and good yield performance. Chen and Weil (2011) reported that soil compaction may restrict deep root growth and adversely affect plant access to subsoil water which may result in drought stress that limit maize growth and yield.

The coefficient of declined soil organic matter (-0.0617) was negative and statistically significant at 5% level which is inline with the apriori expectation. This implies that an increase in declined soil organic matter per hectare decreases the maize output by 0.0617 tons. Reduction in soil organic matter affects the soil structure, moisture holding capacity, diversity and activity of soil organisms; and hence affects the output performance of maize. This agrees with the finding of Albrecht (2014) that decline in organic matter content results in decline in maize yields, and therefore lowers earnings on the farmer's investments.

The coefficient of labour input (0.0617) was positive and significant at 5% level, implying that a 10% increase in labour input per hectare increases maize output by 6.17 tons. This could be because increased use of labour especially family labour which is relatively cheaper leads to increase in crops output. This finding is in line with those of Okwuowulu *et al.*, (2002) in Cocoyam minisett and productivity, that increases in farm labour use leads to increased farm output.

The coefficient of planting material (0.0419) was positive and statistically significant at 1% level, implying that a 10% increase in use of planting material per hectare would increase maize output by 4.19 tons. This result agrees with those of Ohajianya *et al.*, (2007) in their study on cassava production in Imo State that increases in the use of planting materials lead to increased crops production.

The coefficient of fertilizer (0.0952) was positive and significant at 5% level, implying that increase in the use of fertilizer increases crops production. This implies that a 10% increase in fertilizer use in maize production per hectare leads to increase of 9.52 tons in maize output. This finding agrees with those of Chen, Huffman and Rozelle (2003), who found in their study on farm size and productivity in Chinese agriculture, that increase in fertilizer use increase crops output.

The coefficient of farm size (0.0744) was positive and significant at 1%, which implies that a 10% increase in farm size cultivated leads to a 7.44 tons increase in maize output. This result is similar to that of Nagash (2000) who reported in their study on farm size and productivity in Ethiopian smallholder agriculture, that increase in farm size cultivated translates to increased crops output.

The F-values for cassava output (67.7698) and maize output (44.2342) were statistically significant at both 1% level as shown in Tables 4.21 and 4.22. Therefore, the hypothesis II which stated that soil degradation indicators and production factors have no significant effect on the output of dominant staple crops in the area was rejected. The study however accepted the alternative hypothesis and concluded that perceived level of soil degradation has significant effect on the output of cassava and maize crops in the area.

4.4 Vulnerability of Crop farmers to Soil Degradation

Table 4.23 shows the factor loading of the first principal component of the vulnerability indicators. The indicators (household level variables) were used to measure the adaptive, sensitivity and exposure of farmers in the coastal and in land areas to soil degradation. The matrix of data for the total sample (N = 152) were used to generate the principal component for each variable (indicator). The study generated twenty-six (26) components with eigen values greater than one (1) and accounting for 53.52% of the total variation in the data set. The first component had an eigen value of 8.835 and accounted for 33.98% of the total variance; while the second and third components had eigen values of 2.94168 and 2.13887, and accounted for 11.31% and 8.23% respectively. The first principal component which explained majority of the variation was used to compute the vulnerability index. It was found that majority of the factor scores shown in table 4.25 were positively related to the indicators of adaptive capacity, and negatively associated with most indicators categorized for exposure and sensitivity. As a result, indicators of adaptive capacity which were positively associated with the first principal component analysis, and indicators of sensitivity and exposure, which were negatively associated with the principal component analysis were used for the computation of vulnerability indices. Hence, 15 indicators were considered for the study.

Table 4.23: Factor loading of the First Principal Component of the Vulnerability indicators

Variable	First Component
Access to information	0.2638
Farmers' Association	0.0597
Number of years spent in school	-0.0489
Access to credit	0.0690
Number of extension visits	0.2784
Farm Income	-0.0449
Off farm Activities	0.2924
Farm size >3 ha	-0.0158
Marital status	0.2720
Improved variety	0.2751
Soil and water conservation	0.2851
Mixed farming	0.2809
Diversification to nonfarm	0.2845
Adjustment of planting period	0.2493
Soil Organic Amendment	0.2666
Swampy farmland	0.1826
Sloppy farmland	0.1679
Farms affected by oil spillage	0.2015
Loss of vegetative cover	-0.0263
Bush Encroachment	0.2501
Female Headed Household	-0.0529
Infertile Soil	0.0247
Number of households dead or injured	0.0634
Farms affected by Increased soil erosion	-0.0194
Farms affected by increased flooding	0.0808
Incidence of Deforestation	0.2252

Number of observation = 152

Number of Comp = 26

Eigenvalue = 8.83584

Proportion of variance = 0.3398

Rho = 0.5352. **Source: Computed Results, 2017.**

Results showed that the mean vulnerability index in the coastal and inland areas was 0.259098, as shown in Table 4.24, indicating that crop farmers in the coastal and Inland area of the Niger Delta are vulnerable to soil degradation. However, a hierarchical cluster analysis was carried out to further determine the level of vulnerability in the coastal and inland areas of the Niger Delta as shown in Table 4.26.

Table 4.24: Mean Vulnerability Index for Crop Farmers in the Coastal and Inland Areas

Items	Index (N=152)
Adaptive	0.768209
Sensitivity/exposure	-0.509111
Vulnerability Index	0.259098

Source: Computed Results, 2017

The vulnerability index was clustered around three major points, namely highly vulnerable, vulnerable and less vulnerable with average vulnerability index of 0.118, 0.209 and 0.422, respectively, as shown in Table 4.25. Farmers in the first cluster were characterized by low vulnerability index (0.118), and hence were considered to be highly vulnerable to soil degradation. The cluster had 29.92% of farmers in the inland area and 44.05% in the coastal area. This implies that farmers in the coastal were highly vulnerable to soil degradation than their counterparts in the inland areas of the Niger Delta. This could be linked to loss of vegetative cover and increased soil erosion resulting from the topography of the area (Tsue *et al.*, 2014), and the operations of multinational oil companies in the area (Oyekale, 2008). Loss of vegetative cover in the coastal area could also be attributed to the oil spills and dredge mud from these multinational companies. According to Demeke (2003) and Desalew *et al.*, (2017) soil degradation is highly prevalent in areas vulnerable to various soil conditions such as soil erosion and sparse vegetative cover.

The farmers in the second cluster had an average vulnerability index of 0.209, and were considered moderately vulnerable to soil degradation. Results showed that about 60.42% of farmers in the inland area and 51.14% of farmers in coastal area are moderately vulnerable to soil degradation. This cluster is the major vulnerable group. This shows that farmers in both inland and coastal areas of the Niger Delta

are vulnerable to soil degradation. The third cluster had vulnerability index of 0.422, with 9.66% of farmers in the inland area and 4.81% in the coastal areas. This implies that farmers in the inland areas are less vulnerable to soil degradation than their counterparts in the coastal areas. This could be attributed to the fact that farmers in the inland area indulge more in soil and water conservation practices, mixed farming and soil organic amendment. Aja *et al.*, (2015) noted that most of these soil conservation methods such as mulching, use of organic fertilizer, mixed farming and cropping etc are compatible with the inland environment in terms of availability of materials, financial and labour cost, ease of application etc. According to Tadele (2017) conservation practices reduced water run-off, increased water infiltration and reduced soil erosion among others. Also, White *et al.*, (2012) and Mohammed-Salem (1993) reported that organic amendments often improve the productivity of soils and the nutritional value of crops grown, while mixed farming helps to replenish soil fertility on arable fields as a result of nutrient loss from soil degradation and provide cash income for farm households. The cash income will enable them invest more in soil conservation practices thereby preserving environmental quality.

Table 4.25: Cluster Analysis for Percentage Vulnerability in the Coastal and Inland Area

Clusters by Vulnerability	Total Sample (N=152)	Inland (n = 83)	Coastal (n= 69)
Highly Vulnerable (0.118)	25.06	29.92	44.05
Vulnerable (0.209)	68.69	60.42	51.14
Less Vulnerable (0.422)	6.25	9.66	4.81
Total	100.0	100.0	100.0

Source: Computed Results, 2017

4.4.1 Level of Vulnerability in the Study Area

The distribution of the farmers according to level of vulnerability in the study area is presented in Table 4.26.

Table 4.26 Distribution of the farmers according to Level of Vulnerability (n=152)

Vulnerability Indicators	Level of Vulnerability			Total Score	Mean
	Highly Vulnerable(3)	Vulnerable (2)	Less Vulnerable (1)		
Sloppy farmland	11 (21.2)	53 (34.9)	88(57.9)	277	1.49*
Oil Spilled farmland	39 (25.7)	62 (40.8)	51 (33.5)	292	1.92**
Heavy rainfall Farmland	93 (61.2)	47 (30.9)	12 (7.9)	385	2.53***
encroachment	16 (10.5)	43 (28.3)	93 (61.2)	227	1.49*
Loss of vegetative cover	91 (59.9)	49(32.2)	12 (7.9)	383	2.52***
Soil infertility	87 (57.2)	53 (34.9)	12(7.9)	379	2.49**
Swampy farmland	18 (11.8)	54 (35.5)	80 (52.7)	242	1.59*
Flooded farmland	74 (48.7)	51 (33.6)	27 (17.7)	351	2.31**
Soil erosion prone farmland	90 (59.2)	49 (32.2)	13 (8.6)	381	2.51***
Total Mean Score or level of vulnerability					18.85 2.09**

Benchmark = 2.0

*** Highly Vulnerable

** Vulnerable

* Less Vulnerable

Figures in parenthesis are percentages of responses. Source: Field data, 2017.

Table 4.27 shows that farmers are less vulnerable to sloppy farm land, swampy farmland and farm land encroachment probably due to the adaptation measures put in place which makes them feel safe. It also revealed that they are highly vulnerable to heavy rainfall, loss of vegetative cover and soil erosion prone farm land which is very unsuitable for crop yield and vulnerable to soil infertility, oil spilled farmland and flooded farmland which is also unsuitable for crop yield. It has a mean score of

2.09 indicating that the farmers are generally vulnerable to soil degradation in the study area.

4.5. Factors Influencing the Levels of Farmers' Vulnerability to Soil Degradation

The factors influencing the levels of farmers' vulnerability to soil degradation in the study area were determined using the ordered probit model regression analysis. The results of ordered probit model regression for factors influencing the levels of farmers' vulnerability to soil degradation are presented in Table 4.27.

Table 4.27 Results of Ordered Probit Regression for Factors Influencing the Levels of Farmer's Vulnerability to Soil Degradation

Explanatory variable	Parameter	Coefficient	t-ratio
Intercept	b ₀	20.1609	4.9516*
Gender (x ₁)	b ₁	-0.0981	-3.0752*
Level of education (x ₂)	b ₂	-0.1083	-3.4057*
Age (x ₃)	b ₃	-0.1847	-3.5315*
Household size (x ₄)	b ₄	-0.0943	-1.1542
Farm income (x ₅)	b ₅	0.1192	3.7722*
Off – farm income (x ₆)	b ₆	0.0349	3.2315*
Farm size (x ₇)	b ₇	0.1604	2.6081*
Extension contact (x ₈)	b ₈	-0.1792	-2.4786**
Credit access (x ₉)	b ₉	-0.0191	-1.0324
Farming experience (x ₁₀)	b ₁₀	0.0843	2.0611**
Marital status (x ₁₁)	b ₁₁	-0.0395	-1.2421
Log likelihood		-129.3106	
Chi-square		72.1043	

** Significant at 5%

* Significant at 1%

Source: Field Data, 2017

The goodness of fit measured by the high Chi-square value of 72.1043 showed that the choice of explanatory variables included in the ordered probit model explained the variations in levels of vulnerability of farmers to soil degradation. Results of the ordered probit model show that gender (x_1), level of education (x_2), age (x_3), farm income (x_5), off – farm income (x_6), and farm size (x_7) were found to be statistically significant at 1% level, while the coefficients of extension contact (x_8) and farming experience (x_{10}) were statistically significant at 5% level, implying that these are the factors influencing the levels of farmers’ vulnerability to soil degradation in the study area.

The coefficients of household size (x_4), credit access (x_9) and marital status (x_{11}) were not statistically significant at 5% level, implying that these factors do not significantly influence the levels of farmers’ vulnerability to soil degradation in the study area. Therefore, hypothesis 3, which stated that levels of vulnerability of the crop farmers to soil degradation in the study area is not significantly influenced by socioeconomic factors is hereby rejected with respect to the significant variables, and accepted with respect to the non-significant variable. The coefficient of gender (x_1) was negative and significant, which implies that the female crop farmers had higher vulnerability to soil degradation than their male counterparts.

The coefficients of level of education, age, extension contact were negative and significant, implying that decreases in the magnitude of these factors lead to high vulnerability of the crop farmers. The coefficients of farm income, off-farm income, and farm size were positive and significant. This direct relationship implies that increases in the magnitude of these factors lead to less vulnerability of farmers to soil degradation in the study area.

4.5.1 Marginal Effects of Factors Influencing level of Vulnerability of Farmers to Soil Degradation

Table 4.28 shows the marginal effects of the estimated results of the ordered probit model analysis on factors influencing the level of farmer's vulnerability to soil degradation.

Table 4.28 Results of Marginal Effects of Ordered Probit Regression for Factors Influencing the Level of Farmer's Vulnerability to Soil Degradation

Explanatory variables	Marginal effect ($\partial y/\partial x$)	P (z>x) (P-value)
Gender (x ₁)	-0.0074	0.0126*
Level of education (x ₂)	-0.0521	0.0131*
Age (x ₃)	-0.0418	0.0125*
Household size (x ₄)	-0.0392	0.2912
Farm income (x ₅)	0.0513	0.0116*
Off – farm income (x ₆)	0.0329	0.0135*
Farm size (x ₇)	0.0441	0.0141*
Extension contact (x ₈)	-0.0312	0.0522**
Credit access (x ₉)	-0.0438	0.2832
Farming experience (x ₁₀)	0.0522	0.0516**
Marital status (x ₁₁)	-0.0349	0.2714

** Significant at 5%

* Significant at 1%

Source: Field Data, 2017

The study computed the marginal effects of each explanatory variable since the parameter estimates of the model only provide the direction of the effect of the independent variables on the dependent variable; and not the actual magnitude of change and probabilities.

Gender had negative and significant influence on farmers' vulnerability to soil degradation at 1% level for (-0.0074). The marginal effect shows that an increase in male-headed farmers by one percent decreases the probability of being vulnerable by 0.074%. This implies that male farmers in the area have a lesser probability of being vulnerable to soil degradation than female-headed farmers and this is inline with the apriori expectation. This could be because according to Odendo *et al.* (2009) and United Nations Women Watch (2009) male farmers have more access to resources and information giving them greater capacity to adopt new technologies and soil management techniques than women who face social, economic and political barriers that limit their coping capacity. This probably increases the vulnerability of these women farmers to soil degradation than men.

The marginal effect of age variable was negative and statistically significant at 1% level. This shows that an increase in age by one year decreases the probabilities of being less and moderately vulnerable to soil degradation by 0.418%. This is an indication that increases in farmer's age decreases the chances of being vulnerable to soil degradation. This is not in line with the apriori expectation and could be attributed to loss of strength and physical capacity to carry out farm activities as farm lands become prone to soil degradation. According to Opiyor *et al.*, (2014) elderly farmers lack the capacity in preparing strategies to cushion the effect of adverse environmental conditions thus making them more vulnerable to soil degradation.

The marginal effect of farm income was positive and statistically significant at 1% (0.0513). This shows that an increase in farm income by one percent increases the

probabilities of being vulnerable by 0.513%. This is an indication that increase in farm income decreases the chances of being vulnerable to soil degradation and this conforms to the apriori expectation. This could be attributed to the fact that as farm income increases, farmers purchasing power increases and in turn affords the farmers the opportunity to adopt improve soil management practices. This finding is consistent with Negash (2011) that income has a positive relationship with soil conservation measures, changes in planting date and use of crop diversification as adaptation measures to soil degradation. Adapting to these soil degradation measures by these farmers reduces their chances of being vulnerable to soil degradation.

The marginal effect of off-farm income was positive and statistically significant at 1%. This shows that an increase in off-farm income decreases the probability of being vulnerable to soil degradation. This is not in line with the apriori expectation and could be attributed to the fact that farmers focused majorly on off-farm activities while paying less attention to on-farm activities as their earnings from off-farm activities increase. Off-farm income generating activities according to Ndambiri *et al.*, (2013) may sometimes present a constraint to adoption of agricultural technology because they compete with on-farm activities, thus hindering on-farm adaptation by farmers. This could however increase their vulnerability to soil degradation.

The marginal effect of farm size was positive and statistically significant at 1% level (0.0441). This implies that an increase in farm size increases the probabilities of being vulnerable to soil degradation by 0.441%. This implies that the larger the farm size the less vulnerable the farmer is to soil degradation and this conforms to the apriori expectation. This could be linked to the increased farm productivity and marginal income of the farmer which aid purchasing power and adaptability as farm

size increases. An increase in farm size increases the likelihood of adapting to soil degradation using multiple cropping and soil conservation (Negash, 2014).

The marginal effects of extension visits was negative and statistically significant at 5% level (-0.0312) to soil degradation. This implies that an increase in the number of extension contacts by one visit decreases the probability of being less vulnerable by 1.16% and decreases the probabilities of being vulnerable by 0.312%. This is inline with the apriori expectation and it is an indication that extension contacts to farmers have positive influence to farmer's vulnerability to soil degradation as the extension agents extend to farmers the best and sustainable soil management practices that mitigate farmer's vulnerability. This corresponds with the findings of Desalew *et al.*, (2017) that increase in extension agent contact will provide farmers with information on the benefits of SWC, the techniques of implementation, and maintenance that will mitigate farmers' vulnerability to soil degradation.

The marginal effect of level of education was negative and statistically significant at 1% level (-0.0521). This shows that an increase in level of education decreased the probability to be vulnerable to soil degradation by 0.521%. This implies that higher education reduces farmer's vulnerability to soil degradation and this conforms to the apriori expectation. This supports the findings of Tsue *et al.*, (2014) that farming households having more access to education are more likely to be less vulnerable to soil degradation since it will enable them to have more access to mitigation strategies.

The marginal effects of farming experience was positive and statistically significant at 5% (0.0522). This implies that an increase in farming experience by one year increases the probabilities of being less vulnerable by 1.05% and decreases the probabilities of being moderately and highly vulnerable to soil degradation by 1.79%

and 1.45% respectively. This is an indication that farming experience decreases farmer's vulnerability to soil degradation. This is inline with the apriori expectation as increase in years of experience improves farmer's technical know-how in agricultural production and hence soil management practices. This finding is related to that of Ndambiri *et al.*, (2013) who stated that since experienced farmers have more knowledge and information on soil management practices it will enhance their probability of uptake of adaptations strategies thereby decreasing their vulnerability to soil degradation.

4.6 Crop farmer's adaptation strategy to soil degradation in the study area

The distribution of the farmers according to adaptation strategy used in the study area is presented below. The adaptation strategies examined were use of improved varieties, soil and water conservation technology such as mulching, planting cover crops etc, mixed farming, diversification to non-farm activity, use of financial leverage, adjustment of planting period, soil organic amendment and the use of agro chemicals such as fertilizer, pesticides and herbicides.

4.6.1 Adaptation strategies to soil degradation in the study area

The distribution of the farmers according to adaptation strategy used in the study area is presented in Table 4.29

Table 4.29 Distribution of the farmers according to adaptation strategy used in the study area in 2016.

Adaptation strategy used	Freq*	Percentage
Use of Improved Varieties	109	71.7
Soil and Water Conservation Technology (Mulching, Planting Cover crops etc)	127	83.6
Mixed farming	78	51.3
Diversification to non-farm Activity	78	51.3
Adjustment of planting Period	45	29.6
Soil organic amendment	40	26.3
Use of financial leverage	24	15.8
Non use of adaptation	11	7.2

***Multiple responses were recorded**

Source: Field data, 2017.

The percentage distribution of the farmers according to adaptation strategy used to cope with soil degradation in the study area shows that majority of the farmers (83.6%) within the period of 2016, used soil and water conservation technology such as mulching, planting cover crops etc, followed by use of improved varieties, mixed farming and diversification to non-farm activity, with percentages of 71.7, 51.3 and 51.3 respectively, while adjustment of planting period, soil organic amendment and use of financial leverage, were the least used with percentages of 29.6, 26.3 and 15.8 respectively. About 7.2% did not use any adaptation strategy

4.6.2 Perceived Level of Adaptation Strategies in the Study Area

The distribution of the farmers according to perceived level of adaptation strategy in the study area is presented in Table 4.30.

Table 4.30 Distribution of the farmers according to Perceived Level of Adaptation Strategies used in the Study Area (n=152)

Adaptation Strategies	Perceived Level of Adaptation Strategies			Total	Mean
	High (3)	Moderate (2)	Low (1)		
Use of improved crop varieties	109(71.7)	34 (22.4)	9(5.9)	404	2.66***
SWCT (mulching, Planting Cover Crops, etc)	127 (83.6)	25 (16.4)	0(0)	431	2.84***
Mixed farming	78 (51.3)	59 (38.8)	15 (9.9)	367	2.41**
Diversification to non-farm activity	78 (51.3)	64 (42.1)	10 (6.6)	372	2.45**
Adjustment of planting period	45(29.6)	53(34.9)	54(35.5)	295	1.94*
Soil Organic amendment	40 (26.3)	51 (33.6)	61 (40.1)	283	1.86*
Use of financial leverage	24(15.8)	35 (23.0)	93 (61.2)	235	1.55*
Total					15.71
Mean Score or perceived level of adaptation strategies					2.24**

Benchmark = 2

*** High

** Moderate

* Low

Figures in parenthesis are percentages of responses. Source: Field Data, 2017.

Table 4.30 shows that the perceived level of adaptation to soil degradation using soil organic amendment, adjustment of planting period and financial leverage is low, use of mixed farming and diversification to non-farm activity is moderate while the perceived level of adaptation with the use of improved varieties, soil and water conservation technology is high and the best suited to cope with soil degradation in

the study area. However, a mean score of 2.24 indicates that the general level of adaptation to soil degradation in the study area is moderate.

4.6.3 Factors Influencing Levels of Farmers Adaptation Strategies to Soil Degradation

The factors influencing levels of farmers' adaptation strategies to soil degradation in the study area were determined using the ordered probit model regression analysis. The results of ordered probit model regression analysis are shown in Table 4.31.

Table 4.31 Results of Ordered Probit Regression for Factors Influencing the Levels of Farmer's Adaptation Strategies to Soil Degradation

Explanatory variable	Parameter	Coefficient	t-ratio
Intercept	b ₀	26.1729	6.4364
Gender (x ₁)	b ₁	-0.1605	-1.4279
Level of education (x ₂)	b ₂	0.3418	3.3088*
Age (x ₃)	b ₃	-0.2605	-2.5895*
Household size (x ₄)	b ₄	0.0613	1.1766
Farm income (x ₅)	b ₅	0.4122	3.2818*
Off – farm income (x ₆)	b ₆	0.3006	2.9327*
Farm size (x ₇)	b ₇	0.0833	2.6958*
Extension contact (x ₈)	b ₈	0.0421	1.1021
Credit access (x ₉)	b ₉	0.0739	1.2255
Farming experience (x ₁₀)	b ₁₀	0.3816	3.6622*
Marital status (x ₁₁)	b ₁₁	0.0137	1.3431
Nature of soil degradation (x ₁₂)	b ₁₂	-0.0839	3.2646
Log likelihood		-117.0925	
Chi-square		73.4603	

* Significant at 1%

Source: Field Data, 2017

The goodness of fit measured by the high Chi-square value of 73.4603 showed that the choice of explanatory variables included in the ordered probit model explained the variations in levels of adaptation strategies of crop farmers to soil degradation. Results of the ordered probit model show that level of education (x_2), age (x_3), farm income (x_5), off – farm income (x_6), farm size (x_7), farming experience (x_{10}) and nature of soil degradation (x_{11}) were found to be statistically significant at 1% level, implying that these are the socioeconomic factors influencing the levels of farmers adaptation strategies to soil degradation in the study area.

The coefficient of gender (x_1), household size (x_4), extension contact (x_8), credit access (x_9) and marital status (x_{11}) were not statistically significant at 5% level, implying that these are not the socioeconomic factors influencing levels of farmers' adaptation strategies to soil degradation in the study area. Therefore, hypothesis 1, which stated that perceived levels of adaptation strategies used by crop farmers in the study area are not significantly influenced by their socioeconomic factors, is hereby rejected with respect to the significant variables and accepted with respect to the non-significant factors.

The coefficients of level of education, farm income, off – farm income, farm size, farming experience and nature of soil degradation were positive and significant. This direct relationship implies that increases in the magnitude of these variables lead to increases in the adaptation strategies used by the crop farmers. The coefficient of age was negative and significant. This inverse relationship implies that the older farmers use less adaptation strategies to soil degradation than the young and more active crop farmers.

4.6.4 Marginal Effects of Factors influencing the perceived level of Adaptation strategies to Soil Degradation

Table 4.32 shows the marginal effects of the estimated results of the ordered probit analysis.

Table 4.32 Results of Marginal Effects of Ordered Probit Regression for Factors Influencing the Level of Farmer’s Adaptation Strategies to Soil Degradation

Explanatory variables	Marginal effect ($\partial y/\partial x$)	P (z>x) (P-value)
Gender (x ₁)	-0.0081	0.2843
Level of education (x ₂)	0.0637	0.0127*
Age (x ₃)	-0.0422	0.0134*
Household size (x ₄)	0.0416	0.3216
Farm income (x ₅)	0.0667	0.0138*
Off – farm income (x ₆)	0.0426	0.0122*
Farm size (x ₇)	0.0521	0.0142*
Extension contact (x ₈)	0.0382	0.2903
Credit access (x ₉)	0.0426	0.3042
Farming experience (x ₁₀)	0.0493	0.0133*
Marital status (x ₁₁)	0.0537	0.2887
Nature of soil degradation (x ₁₂)	0.0356	0.0126*

* Significant at 1%

Source: Field Data, 2017

The study computed the marginal effects of each explanatory variable since the parameter estimates of the model only provide the direction of the effect of the independent variables on the dependent variable; and not the actual magnitude of change and probabilities.

Marginal effects of level of education significantly influenced at 1% level the chances of adapting (0.0637) to soil degradation. This implies that an increase in educational attainment of farmers by one percent increases the probability of adapting to soil degradation by 0.637%. This implies that higher education gives farmers the ability to adapt and respond to soil degradation problems much faster than their counterparts with lower education which conforms to the apriori expectation.

This corresponds with the findings of Uddin *et al.*, (2014) and Oluwatusin and Shittu (2014) that educated farmers have more reasoning capacity and respond faster to changes in the environment and hence may be more likely to adopt new technologies than others. In addition educated farmers have better understanding about the consequences of soil degradation and the resulting benefits of adopting soil management techniques. This will enable the farmers to spend more time and money on soil conservation technologies (Desalew and Aklilu, 2017).

Age negatively and significantly influenced at 1% level the chances of adapting (-0.0422) and highly adapting (0.0067) to soil degradation. This implies that an increase in age by one year decreases the probability of adapting to soil degradation by 0.442%. This is an indication that as farmers get older, they are more likely to adapt less to soil degradation due to loss of strength and other aging barriers or highly adapt to soil degradation due to the technical know-how and experience gathered over the years. The influence of increase in age on adaptation option is mixed claimed. Etwire *et al.*, (2013) argued that most elderly farmers do not usually have

the physical strength and wealth to invest in various soil management practices while Taruvinga *et al.*, (2016) revealed that as farmers get older it increases their probability of making use of adaptation strategies or adopting new techniques as a result of broad social network and earned experiences over the years.

Farm income positively and significantly influenced at 1% level farmer's adaptation level to soil degradation (0.0667). This shows that an increase in farm income increases the probability of adapting to soil degradation by 0.667%. It is normally hypothesized that increase in income increases adoption of innovative technology by farmers. In fact according to Tazeze *et al.*, (2012) as farm income increases farmers tend to invest more on adaptation strategies such as improved seed varieties, soil and water conservation technology etc. However contradicting finding was reported in the study by Feleke *et al.*, (2016) where farm income is negatively associated with adopting adaptation measures. They concluded that farmers with higher income may be less risk averse and may not be willing to invest in adaptation measures against soil degradation. In another study by Levi *et al.*, (2017), it was also found that performance negatively influences farm investment in agricultural technology. They revealed that when performance is high, farmers prefer not to invest in order to avoid adjustment costs. It can then be concluded from this finding that increase in income has both negative and positive effect on adoption of adaptation measures to soil degradation.

The marginal effect of farm size was positive and significant at 1% level for adapting to soil degradation (0.0521). This implies that an increase in farm size by one hectare increases the probability of adapting to soil degradation by 0.521%. This is an indication that farmers highly adapt to soil degradation as farm size increases and this is inline with the a priori expectation. The same result was also found by Haghjou *et al.*, (2014) that if land area increases, the probability of adoption rises.

This may be because according to Chomba (2004) large farm size enables a farmer to be more flexible in using various soil conservation practices like improved fallow and crop rotation etc.

The marginal effect of off-farm income was positive and significant at 1% level for adapting to soil degradation (0.0426). This implies that an increase in off-farm income by one percent increases the probability of adapting to soil degradation by 0.426%. This is attributed to an increase in the purchasing power due to the extra income. This is an indication that farmers with higher amount of off-farm income would highly adapt to soil degradation. This finding is consistent with that of Berihun *et al.*, (2014) and conforms to the apriori expectation that farm households who have high off-farm income have higher probability of adopting agricultural technologies than those with no off-farm income.

Farming experience positively and significantly influenced at 1% level the chances of adapting (0.0493) to soil degradation. This implies that an increase in farming experience by one year increases the probabilities of adapting to soil degradation by 0.493%. Koskei *et al.*, (2012) argued that farming experience is an indicator of age. This is because according to Olumba and Rahji (2014), as farmers get older they acquire more experience which will in turn increase their understanding thereby increase their level of adoption of technologies. Whereas according to Howley *et al.*, (2012) as farmers get older they become less energetic and more skeptical in adoption of innovative technologies. This is in spite of the experiences gained over the years.

The marginal effect of nature of soil degradation was positive and statistically significant at 1% level with a value of (0.0356). This implies that increase of 1% in nature of soil degradation increases the chances of adapting to soil degradation by

0.356%. This finding further suggests that if the soil degradation is severe in magnitude, the tendency of crop farmers adapting to soil degradation is decreased.

4.7 Trend in output of major staple crops, namely cassava and maize (1995-2016)

Table 4.33 and 4.34 showed that there is fluctuation in both cassava and maize output from 1995-2016. This confirms the findings of Orimoloye and Ibrahim (2017) that there is a fluctuating trend in maize and cassava output. This could be as a result of the effect of soil degradation on the crops. According to the findings of Bakker *et al.*, (2007), soil degradation causes variability in crop yield. The highest average output of cassava (1998.94 tons) was obtained in 2012, while the lowest (788.50 tons) was obtained in 2003. The table also showed that Imo state produced the highest mean output of cassava (2586.34 tons), while Edo produced the least from 1995-2016. On the other hand, table 4.34 showed that the highest average output of maize (162.16 tons) was obtained in 2003, while the lowest (75.60 tons) was obtained in 2008. The table also revealed that Imo state produced the highest mean output of maize (78.86 tons), while Edo produced the least (149.30 tons) from 1995-2016.

Table 4.33: Output of Cassava (Thousand Metric tons) (1995-2016)

Year	Edo	Imo	Rivers	Delta	Average
1995	457.00	1827.00	2080.00	828.00	1298.00
1996	469.00	1877.00	1592.00	803.00	1185.25
1997	598.00	812.50	1507.00	782.00	924.88
1998	604.00	2359.00	1756.00	756.00	1368.75
1999	603.00	2460.00	1663.00	795.00	1380.25
2000	601.00	2208.00	1745.00	795.00	1337.25
2001	658.00	2344.00	1936.00	818.00	1439.00
2002	630.00	2952.00	1402.00	872.00	1464.00
2003	602.00	2251.00	1351.00	903.00	788.50
2004	603.00	2285.00	1405.00	902.00	1298.75
2005	621.00	2332.00	962.00	961.00	1219.00
2006	630.00	2315.00	1251.00	1333.00	1382.25
2008	696.01	3086.50	1835.45	1734.30	1838.07
2009	696.05	3563.67	1850.00	1768.25	1969.49
2010	504.43	2181.93	2004.19	1810.60	1625.29
2011	696.07	3626.33	1947.75	1725.41	1998.89
2012	696.07	3626.38	1948.02	1725.27	1998.94
2013	699.10	3696.40	1248.00	1425.30	1767.20
2014	700.30	3697.60	1249.20	1426.50	1768.40
2015	701.30	3698.60	1250.20	1427.50	1769.40
2016	702.20	3699.50	1251.10	1428.40	1770.30
Average	598.50	2586.34	1510.63	1102.89	

Source: NBS 2007, Agricultural Performance Survey 2009, 2012, 2013

Table 4.34: Output of Maize (Thousand Metric tons) (1995-2016)

Year	Edo	Imo	Rivers	Delta	Average
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1995	57.90	116.15	170.30	83.34	106.92
1996	67.10	141.12	130.37	92.56	107.79
1997	65.10	62.30	168.26	98.65	98.58
1998	70.50	141.05	141.80	81.01	108.59
1999	83.70	145.09	146.02	82.17	114.25
2000	86.50	137.22	147.93	86.83	114.62
2001	88.50	146.56	143.78	108.67	121.88
2002	85.70	229.51	101.18	100.45	129.21
2003	73.10	372.41	90.14	113.00	162.16
2004	80.23	153.75	93.99	113.67	110.41
2005	86.23	154.83	97.71	132.68	117.86
2006	86.90	151.30	103.28	195.00	134.12
2008	5.70	0.00	83.00	213.68	75.60
2009	74.20	170.37	82.00	150.52	119.27
2010	151.69	87.98	56.10	203.94	124.93
2011	74.25	171.78	96.10	164.52	126.66
2012	94.29	172.68	99.90	167.37	133.56
2013	101.40	183.20	124.00	179.20	146.95
2014	101.53	183.33	124.10	179.33	147.07
2015	100.63	182.43	123.20	178.43	146.17
2016	99.83	181.63	122.40	177.63	145.37
Average	78.86	149.30	111.16	131.94	

Source: NBS 2007, Agricultural Performance Survey 2009, 2012, 2013.

4.7.1 Trend in Maize Output (Mt)

Table 4.35 and Figure 4.1 show the result of the trend analysis of output of maize (thousand metric tons (1995-2016)).

Table 4.35 Trend Analysis of Output of Maize (Thousand Metric Tons (1995-2016))

Maize Output	value
Mean (MT)	123.92
Standard Deviation (MT)	13.08
Maximum (MT)	162.16
Minimum (MT)	75.60
Trend (MT /year)	2.869*
Correlation coefficient (r)	0.374 *

*Significant at 1%

Source: NBS, 2016

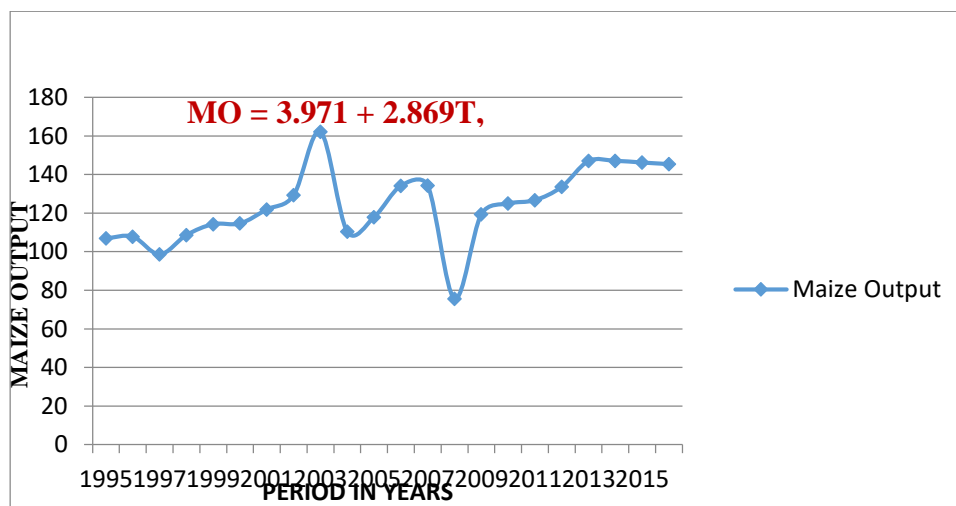


Fig. 4.1 Analysis of Trend of Output of Maize (Thousand Metric Tons (1995-2016))

The result of the analysis in table 4.35 showed that the mean annual output of maize in the study area is 123.92 metric tons with minimum and maximum quantities of 75.60mt and 162.16mt respectively. Figure 4.1 presents a fluctuating trend with correlation coefficients i.e. r values of 0.374 which was significant at 1% level,

thereby indicating a positive relationship between the output of crops and the trend factor (period of production). It can be generally concluded that the trend of maize output over the period of study 1995-2016, is relatively weak or below average at 37%. The weak positive relationship shows a fluctuating performance of maize output in the study area as can be seen in the line graph of fig.4.1 with troughs and peaks which could be attributed to soil degradation ravaging the area over the same period. This is in line with De long *et al.*, (2015) who stated that cropland degradation significantly reduces crop productivity and threatens future food security.

4.7.2 Trend in Cassava Output (Mt)

Table 4.36 and Figure 4.2 show the result of the trend analysis of output of cassava (thousand metric tons (1995-2016)).

Table 4.36 Trend Analysis of Output of Cassava (Thousand Metric Tons (1995-2016))

Cassava Output	value
Mean (MT)	1498.70
Standard Deviation (MT)	316.19
Maximum (MT)	1998.94
Minimum (MT)	788.50
Trend (MT /year)	3.056*
Correlation coefficient (r)	0.463 *

*Significant at 1%

Source: NBS, 2016

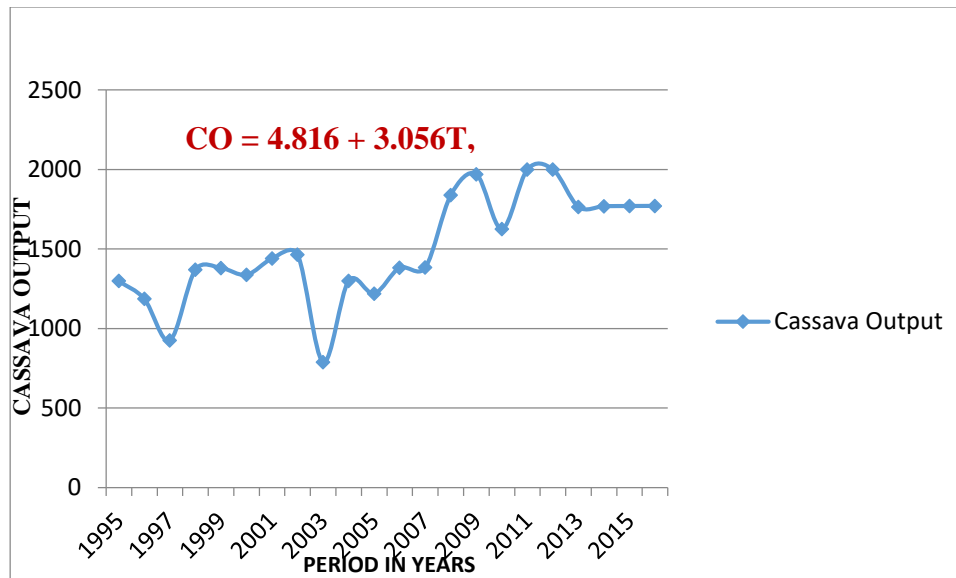


Fig. 4.2 Analysis of Trend of Output of Cassava (Thousand Metric Tons (1995-2016))

The result of the analysis in table 4.36 showed that the mean annual output of cassava in the study area is 1498.70 metric tons with minimum and maximum quantities of 788.50mt and 1998.94 respectively. Figure 4.2 also presents a fluctuating trend with correlation coefficients i.e. r values of 0.463 which was significant at 1% level, thereby indicating a positive relationship between the output of crops and the trend factor (period of production). It can be generally concluded that the trend of cassava output over the period of study 1995-2016, is below average at 46%. The weak positive relationship shows a fluctuating performance of cassava output in the study area as can be seen in the line graph of fig.4.2 with troughs and peaks which could also be attributed to soil degradation ravaging the area over the same period. According to Ohajianya and Asiabaka (2016) despite the fact that cassava grows in marginally suitable fertility condition, its productivity declines with the quality of farmland. This corresponds with Wolka *et al.*, (2013) that soil degradation causes fluctuation in crop productivity which may be caused by incorrect implementation or use of soil conservation structures or adaptation strategies and decline in soil quality.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study was conducted to analyse crop farmers' vulnerability to soil degradation and adaptation strategies in the Niger-Delta States of Nigeria. The study was guided by the following specific objectives: to examine the socio-economic characteristics of the crop farmers in the study area; to identify the forms and perceived levels of soil degradation in the study area; to determine the effects of soil degradation indicators and production factors on the output of dominant staple crops in the study area; to ascertain the level of vulnerability of the crop farmers to soil degradation in the study area; to determine the factors influencing the levels of vulnerability of the crop farmers to shock due to soil degradation in the study area; to determine the types of adaptation strategies to soil degradation and their influencing factors in the study area and ascertain the trend in output of major staple crops namely cassava and maize in the study area from 1995-2016.

The study was guided by three hypotheses as follows: Adaptation strategies used by crop farmers in the study area are not significantly influenced by their socio - economic factors; soil degradation indicators and production factors have no significant effect on the output of dominant staple crops in the study area; and level of vulnerability of the crop farmers to soil degradation in the study area is not significantly influenced by their socio-economic factors. Multi-stage sampling techniques were adopted in the selection of 152 cassava-maize based farmers and data were collected using structured questionnaire within the period 2016. The analytical tools used include: Descriptive Statistics, Ordered Probit Regression Model, Vulnerability Index Model, OLS Regression Analysis, Trend Analysis.

Results showed that most (59.2%) of the farmers were in the age bracket of 47-62 years with mean age of 51 years. Majority (82.9%) of them are male farmers who are married. Most of them attained appreciable level of education with mean household size of 6 persons. The farmers have a mean farm size of 0.9ha. Many (36.8%) of the farmers are experienced with mean farming experience of 20 years. Majority (56.6%) belonged to farmers association and had access to extension agents. Results also showed that few of the respondents (15.8%) had access to bank credit while majority (77%) sourced their credit from personal savings. Most (44.1%) of the respondents are involved in off-farm activities such as trading and earn less than 100000 naira from their off-farm activities. Majority (96.7%) of the farmers had access to information which they source from extension agents.

Forms of soil degradation experienced in the study were soil toxicity, flooding & water logging, decreased vegetative cover, subsurface compaction of soil, decreased water absorption capacity, decline in soil organic matter content and leaching of soil nutrient. Result showed that the general level of soil degradation in the study area is high with a mean of 2.1. Results also showed that the level of flooding and water logging, decreased vegetative cover, decline in soil organic matter content and leaching of soil nutrient were high, while the level of the other 3 forms of soil degradation were low. The regression result of the effects of soil degradation and production factors on cassava output showed that loss of vegetative cover, decreased soil and water absorption, sub-surface compaction and decline in soil organic matter, labour; planting material, fertilizer and farm size were statistically significant at 1%, while leaching of soil nutrients was significant at 5% level, implying that these soil degradation indicators and production factors significantly affect cassava output in the study area.

The regression result of the effects of soil degradation and production factors on maize output showed that loss of vegetative cover, leaching of soil nutrients, sub – surface compaction, decline in soil organic matter, planting material and farm size were statistically significant at 1% level, while the coefficients of labour and fertilizer were significant at 5% level, implying that these soil degradation indicators and production factors significantly affect maize output in the study area,

It was found from the result of the vulnerability analysis that crop farmers in the coastal and inland areas of the Niger Delta are vulnerable to soil degradation with mean vulnerability index of 0.259098. The result of the cluster analysis carried out to further determine the level of vulnerability in the coastal and inland areas of the Niger Delta showed that farmers in the coastal areas were highly vulnerable to soil degradation than their counterparts in the inland areas of the Niger Delta and fall within the vulnerability index of 0.118. The cluster had 29.92% of farmers in the inland area and 44.05% in the coastal area. The result also showed that farmers in the inland areas are less vulnerable to soil degradation than their counterparts in the coastal areas and fall within the vulnerability index of 0.422. The cluster had 9.66% of the farmers in the inland areas and 4.81% in the coastal areas. A 3- point likert scale of highly vulnerable, vulnerable and less vulnerable was used to determine the level of vulnerability of the farmers to 9 different vulnerability indicators. The result showed that farmers are less vulnerable to sloppy farm land, swampy farmland and farm land encroachment probably due to the adaptation measures put in place. It also revealed that they are highly vulnerable to heavy rainfall, loss of vegetative cover and soil erosion prone farm land which is very unsuitable for crop yield and vulnerable to soil infertility, oil spilled farmland and flooded farmland which is also unsuitable for crop yield. It has a mean score of 2.09 indicating that the farmers are generally vulnerable to soil degradation in the study area.

Results of the ordered probit model show that gender (x_1), level of education (x_2), age (x_3), farm income (x_5), off – farm income (x_6), and farm size (x_7) were found to be statistically significant at 1% level, while the coefficients of extension contact (x_8) and farming experience (x_{10}) were statistically significant at 5% level, implying that these are the factors influencing the levels of farmers' vulnerability to soil degradation in the study area.

Farmers in the study area used different adaptation strategies to cushion the effect of soil degradation, but majority (83.6%) used Soil and Water Conservation Technology (such as Mulching, Planting Cover crops etc). Results also revealed that the perceived level of adaptation to soil degradation in the study area is moderate with a mean score of 2.24

Results of the ordered probit model show that level of education (x_2), age (x_3), farm income (x_5), off – farm income (x_6), farm size (x_7), farming experience (x_{10}) and nature of soil degradation (x_{11}) were found to be statistically significant at 1% level, implying that these are the socioeconomic factors influencing the levels of farmers adaptation strategies to soil degradation in the study area.

The result of the trend of output of cassava and maize in the study area from 1995-2016 revealed that there is fluctuation in both cassava and maize output during this period with some lows and highs which may be attributed to the effect of soil degradation.

The result of hypotheses 1, 2, and 3 did not conform to the stated hypotheses leading to the acceptance of the alternative hypotheses.

5.2 Conclusion

The study has shown that farmers in Niger Delta are vulnerable to soil degradation which affects crop output. However, those in coastal areas are more vulnerable than

those in inland areas probably because they are less adapting than those in inland areas. Furthermore, the study showed that the level of soil degradation in the study area is high. Soil degradation indicators and production factors significantly affect cassava and maize output in the study area. The study also showed that farmers in the study area have moderate level of adaptation to soil degradation.

5.3 Recommendations.

Based on the findings of this study, the following recommendations were made:

- ❖ Farmers should invest their labour and limited financial resources in the use of indigenous adaptation measures such as soil and water conservation technology, adjustment of planting period or dates and soil organic amendments so as to reduce their vulnerability to soil degradation. This is because according to our findings, they are significant and positively related to cassava and maize output in the study area.
- ❖ The government, public and private sectors, international bodies, etc, should take these practices to scale by investing in knowledge management, communication and outreach programmes in order to help restore the quality of our soil for sustainable environment.
- ❖ Research scientists and agriculturists should develop and promote geographically adapted strategies that will help farmers adapt more to the type of soil degradation prevalent in their areas.

5.4 Contribution of This Study to Knowledge

The study's main contribution is using the physical attributes of a degraded soil based on farmer's local knowledge to measure their perceived level of soil

degradation on their farmlands and its effect on output of dominant staple crops in Niger Delta. It also found out that the level of flooding and water logging, leaching of soil nutrient, decreased vegetative cover and decline in soil organic matter content were high and they all affected crop (cassava and maize) output negatively.

5.5 Suggestions for Further Studies

The following areas were suggested for further study as they were not covered in this research study:

- A comparative analysis of the effect of soil degradation on output of irrigated and rainfed cropland
- Analysis on the economic returns of different adaptation strategies of crop farmers
- An analysis of long term effect of adaptation strategies on soil degradation indicators

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Owerri.
19th Dec 2016.

Dear Respondent,

REQUEST FOR KIND RESPONSE TO QUESTIONS

I am a Ph.D student of the above named Department and University currently undertaking a research work titled Analysis of Crop Farmers Vulnerability to Soil Degradation and Adaptation Strategies in the Niger Delta States of Nigeria.

You have been chosen as one of the respondents to supply the required information for this study. I therefore solicit your cooperation to respond as objectively as possible to the questions contained in this questionnaire. The research is for academic purposes and all information supplied by you will be treated in strict confidence.

Thank you for your anticipated patience and cooperation.

Yours Faithfully

.....
Ijeoma Rose.

Offor

Questionnaire on Analysis of Crop Farmers Vulnerability to Soil Degradation and Adaptation Strategies in the Niger Delta States of Nigeria.

Please answer the following questions and tick \checkmark where appropriate

Section A: Socio-Economic Characteristics

1. Name of your state.....

2. Name of your LGA.....
3. Name of your community
4. Name of your village.....
5. Age
6. Sex Male Female
7. Marital status Married Single Divorced Widowed Separated
8. Level of Education No formal education Primary Secondary
Tertiary
9. Number of years spent in school
10. Household size
11. Annual Farm income (₦)
12. Farm size (Ha)
13. Farming Experience (Years)
14. Do you belong to any farmers association or cooperative? Yes No
15. Have you been visited by an extension agent before? Yes No
16. If yes, how often did they visit in a year?.....
17. Do you have access to credit facility? Yes No
18. If yes, what is the source of your credit?
Family/friends Commercial bank loan Savings
Others specify
19. If the answer to No. 18 above is commercial bank loan, how much loan did you apply for within the period of 2016?
.....
20. How much loan did you receive
21. What duration was the loan?
< 1 year 1 year 2 years 3 years 4 years > 4 years
22. What percentage of the loan applied for did you receive?
0% 25% 50 % 75% 100%
23. What was the interest rate at that time?

5% 10% 15% 20% 25% 30% others specify

24. Are you engaged in off farm activities? Yes No

25. If yes to question 23 above what other activities are you engaged in?

Trading Civil service work Fishing Commercial driving
Others specify.....

26. How much did you realize on the average from your off farm job or activity within the period of 2016 in ₦?

27. Do you have access to information? Yes No

28. If yes which of the following are your sources of information?

Radio Extension agents Television Internet Friends
Others specify.....

Section B: Soil Degradation

29. Do you know what soil degradation is? Yes No

30. If yes, how do you identify a degraded soil or land?

Color of soil Decrease in depth of soil Ease of tillage
Presence of particular weed species Discoloration of plant leaf
Stunted crops Texture of soil Poor crop yield
Other specify

31. What are the perceived causes of soil degradation in your farm?

Flood Oil exploration Salt water intrusion
Loss of vegetative cover Sand excavation Soil erosion
Toxicity hazards Canalization for pipelines
Others specify

32. Which of the following forms of soil degradation did you experience within the period of 2016?

<u>Forms of soil degradation</u>	
Soil toxicity	
Flooding and water logging	

Decreased vegetative cover
 Subsurface compaction of soil
 Decreased water absorption capacity
 Decline in soil organic matter content
 leaching of soil nutrient

33. How did you identify the level of the following forms of soil degradation experienced in your farm?

Forms of Soil Degradation	Indicators
• Soil toxicity	(a) Change in colour of soil from dark brown or black to red or tan (bleached black or brown) <input type="checkbox"/> (b) Presence of grasses such as guinea grass and signal grass <input type="checkbox"/> (c) Change in colour of leaves to brown <input type="checkbox"/> (d) Decline or late seed germination <input type="checkbox"/> (e) Lodging of plants (tall plants with weak or bended stem) <input type="checkbox"/>
• Flooding and Water logging	(a) Heavy rain between 5days – 1month <input type="checkbox"/> (b) Submerged farmland after heavy rain <input type="checkbox"/> (c) Water remained on farmland 5days to 2weeks after heavy rain <input type="checkbox"/> (d) Wilting of plants <input type="checkbox"/> (e) Leaf senescence (early death of leaf during growing season) <input type="checkbox"/>
• Decreased Vegetative cover	(a) Absence of some common weed species <input type="checkbox"/> Like Elephant grass (b) Decrease in number of trees near the farm <input type="checkbox"/> (c) Increasing distance to firewood location and decrease in abundance of firewood <input type="checkbox"/> (d) Low quality of firewood compared to decades ago <input type="checkbox"/> (e) Scarcity of grasses for roofing and grazing <input type="checkbox"/>

- Subsurface Compaction of Soil
 - (a) Soil hard to till
 - (b) Exposed and twisted roots
 - (c) Slow or poor plant emergence
 - (d) Increase in surface water ponding
 - (e) Uneven early growth in form of short and tall plants in adjacent rows

- Decreased water absorption capacity
 - (a) Poor drainage (if water remains on farmland 3 days after rain)
 - (b) Increased runoff
 - (c) Stunted growth of crop
 - (d) Delay in flowering of plant
 - (e) Increased soil crusting

- Decline in soil organic matter content
 - (a) Yellowish of leaves
 - (b) Presence of some weed species and stones
 - (c) Increased fertilization need
 - (d) Presence of ant hill
 - (e) Soil particles easily loosened by rain drop and carried away by moving water

- Leaching of soil Nutrient
 - (a) Exposed roots
 - (b) Change in colour of soil from darker organic surface layer to lighter colour
 - (c) Increased rate of rainfall
 - (d) Poor yield of crops
 - (e) Poor resistance of plants to diseases

34. How did soil degradation affect your farm within the period of 2016?

Effect of soil degradation on farmland	
Reduction in crop output	
Decrease in farm income	

- Loss of nutrient/ organic matter
- Destruction of soil structure
- Increase in cost of production
- Loss in value of land
- Decrease in farmland available for cultivation
- Increased population pressure on land

Section C: Adaptation strategies to soil Degradation

35. Did you make use of any adaptation strategy to check soil degradation?

Yes No

36. If yes what type of adaptation strategy did you use to cope with the effect of soil degradation within the period of 2016?

Adaptation Strategy	
Use of improved varieties	
Mulching	
Mixed farming	
Diversification to non -farm activity	
Planting cover crops	
Use of financial leverage	
Soil organic amendment	
Adjustment of planting period	
Use of agro-chemicals (fertilizers, pesticides, herbicides)	
Others specify	

37. What is the level of use of the following adaptation strategies to soil degradation?

Types of adaptation	High (3)	Moderate (2)	low (1)
	163		

-
- Use of improved Varieties
 - Diversification to non-Farm activity
 - Mulching
 - Planting cover crops
 - Use of financial Leverage
 - Use of soil organic Amendment
 - Mixed farming
 - Adjustment of Planting period
 - Use of agro-Chemicals (fertilizer Pesticides, herbicides)

38. What effect did the adaptation strategy used have on output performance of the crop planted within the period of 2016?

Effect of Adaptation Strategy on Output		
Increased output		
Decreased output		
No effect on output		

Section D: Cost and Return of the Farmers

39. What type of farm enterprise are you engaged in?
 Maize Cassava Both others specify
40. If cassava how many bundles of cassava stem on the average do you use on your farm per hectare?
41. How much is one bundle of cassava stem?
42. If maize how many cobs of maize on the average do you use on your farm per hectare?
43. How much is one cob of maize?

44. How many 50kg bags of fertilizer on the average do you use on your farm per hectare?

45. How much is one 50kg bag of fertilizer?.....

46. What type of labour do you use? Family labour Hired labour

47. If hired labour how many labourers do you use for the following farm activities

Farm activities	No of labourers
Clearing/ cutting/making mounds	
Planting	
Weeding	
Harvesting	

48. How many labour days does it take the labourers to finish the following farm activities?

Farm activities	Labour days
Clearing/cutting/making mounds	
Planting	
Weeding	
Harvesting	

49. How much on the average do you pay each hired labour for the following farm activities per day?

Farm activities	Amount (₦)
-Clearing/cutting/ making mounds	
-Planting	
-Weeding	
-Harvesting	

50. Provide information on the following items used in production for one year?

Items	Quantity (Number used)	Price (₦)	Life span (Years)
Cutlass			
Hoe			

Basin
Wheel barrow

51. How many 50kg bags of cassava do you harvest from your farm on the average?
52. How much did you sell one 50kg bag of cassava?.....
53. How many 50kg bags of maize did you harvest from your farm on the average?
54. How much did you sell one 50kg bag of maize?
55. What is the trend of maize output over the years in your area?
Increasing Decreasing Stagnant
56. What is the trend of cassava output over the years in your area?
Increasing Decreasing Stagnant

Section E: Vulnerability of the Farmer

57. What is the topography of your farmland? Level sloppy swampy

58. What portion of your farmland is sloppy or swampy?

Farmland	Non	One-third	Half	Three-quarter	Whole farmland
Sloppy farm					
Swampy farm					

59. Which of the following have you experience on your farmland?

Oil spillage Increased flooding Increased soil erosion

60. What portion of your farmland is affected by the following causes of soil degradation?

Causes of soil Degradation	Non	One-third	Half	Three-quarter	Whole farmland
-Oil spillage					
-Increased flooding					
-Increased soil erosion					

61. How often did you experience heavy rainfall within the period of 2016?

Once or twice a year ?.....

62. Is bush encroachment prominent in your area? Yes No

63. Did you experience loss of vegetative cover? Yes No

64. How many members of your family have been lost or injured due to flooding? Non 1 3 5 7 10

65. Is deforestation prominent in your area? Yes No

66. Is your farm land infertile due to soil degradation? Yes No

67. Indicate your level of vulnerability to the following vulnerability indicators?

Vulnerability indicators	Level of Vulnerability		
	Highly Vulnerable (3)	Vulnerable (2)	Less Vulnerable (1)
Sloppy farmland			
Oil Spilled farmland			
Heavy rainfall			
Farmland encroachment			
Loss of vegetative cover			
Soil infertility			
Swampy farmland			
Flooded farmland			
Soil erosion prone farmland			

68. Is the head of the household female? Yes No

STUDY TIME TABLE

The study timetable entails the stages and time spent in completing the programme. These are stated below;

Activity	Duration
Course work	April 2012-January 2014

Selection and approval of research topic	January 2014 – March 2014
Collection of research materials and proposal writing	March 2014- June 2016
Submission of proposal for candidacy	June 2016- September 2016
Candidacy	September 2016
Structuring of questionnaire	September 2016 - December 2016
Approval of Questionnaire by my supervisors	December 2016
Distribution of questionnaire	December 2016 - January 2017
Retrieval of questionnaire	March 2017
Analysis of field data	March 2017-February 2018
Submission of research findings for presentation at departmental/school level	February 2018 – May 2018
Presentation of research findings at departmental/school level	May 2018
Preparation for post graduate school internal defense	May 2018 - November 2019
Post graduate school internal defense	April, 2021
Final correction and preparation for external defense	April 2021
External defense	7 th February, 2022.