SUITABILITY ANALYSIS OF ERO RESERVOIR AND ITS ENVIRONS FOR AQUACULTURE DEVELOPMENT IN EKITI STATE, NIGERIA.

BY

NUHU, HAUWA

FAQ/12/0465

NOVEMBER, 2017

SUITABILITY ANALYSIS OF ERO RESERVOIR AND ITS ENVIRONS FOR AQUACULTURE DEVELOPMENT IN EKITI STATE, NIGERIA.

BY

NUHU, HAUWA

FAQ/12/0465

PROJECT SUBMITTED TO THE DEPARTMENT OF FISHERIES AND AQUACULTURE, FACULTY OF AGRICULTURE, FEDERAL UNIVERSITY, OYE-EKITI, IN PARTIAL FULFILMENT FOR THE AWARD OF BACHELOR OF FISHERIES AND AQUACULTURE

Declaration

I, Nuhu Hauwa, do hereby declare to the Senate of the Federal University of Oye- Ekiti that this project is my own original work done within the period of January to October 2017 and it has neither been submitted before nor being currently submitted in any other institution. All citations and sources of information are clearly acknowledged by means of references.

_______________ 19th/12/2017

Nuhu, Hauwa Date

Certification

This project titled Suitability Analysis of Ero Reservoir and Its Environs for Aquaculture Development in Ekiti State, Nigeria by Nuhu Hauwa, meets the regulation governing the award of the degree of Bachelor in Fisheries and Aquaculture of the Federal University Oye- Ekiti, Ekiti State.

13th December, 2017.

---------------------------- ----------------------------

Mr B. P. Omobepade Date

Supervisor

22/03/2018

---------------------------- ----------------------------

Dr. T. O. Babalola Date

Head of Department

Dedication

This report project is dedicated to the unlimited God who has been there right from the beginning to this very point. I also dedicate this work to Pastor and Prophetess yemi Agbeyo, for their encouragement, financial support and prayers.

Acknowledgements

All glory to God almighty, Honour and Adoration for the gift of life, good health, protection, grace, love, strength, wisdom and knowledge for making it possible for me to complete my undergraduate programme. The success and final outcome of this project required a lot of guidance and assistance from many people and I am extremely privileged to have got this all along the completion of my project

. All that I have done is only due to such supervision and assistance and I would not forget to thank them. I owe my deep gratitude to my project supervisor (Mr. B.P Omobepade) who took the keen interest on this project work and guided me all along, till the completion of my project work by providing all the necessary information and assistance.

I specially want to appreciate my guidance Pastor and Prophetess yemi Agbeyo, for their love, care, support and constant prayers throughout the period of my study, Mummy and Daddy as I call you, I really appreciate, and may you live to reap the fruit of your labour in Jesus name (Amen). To my wonderful mummy in person of Mrs Agnes Nuhu and my aunty, Mrs Akhere Abumere, for always been there for me and her words of encouragement. To my wonderful siblings and wonderful cousin sisters and brothers,(Ighalo David, Agbeyo Daniel, Nuhu Halima and Baruwa Rasheed and my other wonderful brothers and sisters), I thank you for all the kind gestures and ceaseless concern during the course of my study. My Acknowledgement also goes to Mr Sesean Edun, for his concern. I also want to appreciate the lectures and administrative staff in the department of Fisheries and Aquaculture. I am thankful to and fortunate enough to get constant encouragement, support and guidance from all my department mates, I would like to extend my sincere esteems to Mr Saheed of the Department of Agricultural Economics and Extension, for his timely support.

Finally, I would like to thank the executives and members of the Redeemed Christian Fellowship (Ikole campus), for their prayers, encouragement and unconditional love accorded me at the time of need.

Table of content

Contents Page

List of Tables

Page

List of Figures Page

List of Appendices

Chapter One

1.1. Introduction

Developing strategies for aquaculture development entails assessing different areas by which fish production can be increased and sustained. Capture fisheries worldwide are generally perceived as being in crisis. The world capture fisheries have continued to decrease due to overfishing of natural stock, loss of biodiversity and climate change. Aquaculture is often seen as a solution to meet the increasing demand for fish and to offset the declining production from capture fisheries (Nguyen and Tran, 2012).

Fish demand in Ekiti State is about 30, 825 metric tonnes per annum (Federal Department Fisheries, 2010). While production from artisanal fisheries stands at 100.50mt per annum, aquaculture production stands at 108 .67mt, making a total of 209.17mt and a short fall of 30615.83 tonnes per annum (Ekiti State Department of Fisheries, 2009). Equally due to the landlocked nature of the State i.e. neither enclosed by land with neither sea nor ocean surrounding for fishing purposes, therefore there is need to intensify more aquacultural practices so as to bridge the gap between fish demand and supply in Ekiti State and boost the economic profile of the State. To make an impact on the economy, the culture of fresh or marine organisms must be competitive with other type of food-producing industry, including farming and fishing. Job creations, supply of high quality animal protein, income and revenue generation are many of the economic implications of the aquaculture subsector (Nguyen and Tran, 2012).

Oyase and Jemerigbe (2016) believed that the first essential requirement for social and economic justice is adequate food production. A nation should be able to feed her population to occupy a place of pride in the community of nations. Nigeria is a country richly blessed with abundant natural and human resources that if properly harnessed can feed its people and export the surpluses to other countries to generate more revenue. Yet, she is experiencing persistent food crisis both in terms of quantity and quality (Amao *et al.*, 2006). This is a big issue Government have not been able to solve owing to the inability of government to adequately discover areas that can adequately provide employment for the youth; which aquaculture is part. Aquaculture is the only means by which more uniform products are produced on a stable basis thereby increasing the marketability of fish and shellfish. Aquaculture and fisheries play important roles in the global economy, in poverty alleviation, in fostering food security and in recreation (Nguyen and Tran, 2012).

Site selection is a key factor in any aquaculture operation, affecting both success and sustainability (Andi *et al.*, 2013). This could be achieved through the use of geographical information systems (FAO, 2007). Wikipedia (2017) defined geographical information system as a system designed to capture, store, manipulate, analyze, manage and present spatial or geographic data.

1.2. Justification

Nigeria economy entered into recession when the gross domestic product contracted by -2.06% in the second quarter of 2016 (Nigeria Bureau of Statistics, 2016). Increased job loses; inflation, poverty rate and unemployment have characterized this period in Nigeria. This was as a result of declining oil prices which have reduced foreign earnings from the sector by over 50% (Leadership Newspaper, 2016) NBS (2016) reported that Nigeria's unemployment rate rose to 13.3% at the end of the second quarter of 2016. This trend will continue to increase except drastic measures are put in place to harness various areas by which jobs can be created. Considering this, a nation's path to economic development and recovery can only be achieved by utilizing her natural resources of which water is part. Nigeria is yet to fully utilize these potentials for economic attainment inspite of the vast water and land resources available for fish production (Ehui and Tsigas, 2009).

Fish production in Nigeria has not been able to meet the quantity demanded due to increase in population, overfishing of natural stock and inadequate large scale aquaculture. In 2014, Nigeria fish output from aquaculture and captured fisheries was 922,682 metric tonnes in 2014 (FAO, 2014) which is grossly inadequate to meet the demand. Though, import has helped to meet to some extent fish demand shortage of the nation, however, huge food importation is having negative effect on the GDP of the nation. Kamal-Ahmed *et al.* (2013) opined that for a country to have an increased GDP, her net exports must be positive whereas if they are negative the GDP will decrease. Nigeria imported over 1 billion USD worth of fish in 2014 (FAO 2014). However, countries with high comparative advantage like China, Norway, Thailand, Vietnam and USA had positive contribution to their GDPs owing to large export in 2014 (FAO 2014). Currently, Ekiti with a gross domestic product of US$ 2,848 ranked 33rd position in Nigeria; hence all avenues must assess to improve the economic profile of the state (Wikipedia 2017). To achieve an economic growth for the State, there is need to create more avenues for income and revenue generation. This could be attained through intensification of fish production in available inland waters so as to make Ekiti State relevant in the fish value chain in Nigeria. Practicing of aquaculture will provide additional job opportunities, as people will be involved in the entire business chain — researchers, breeders, fish food manufacturers, equipment manufacturers, marinas, storage facilities, processors, transportation and marketing companies as well as restaurants.

Reservoirs and dams are constructed in Nigeria primarily for the purpose of providing water for domestic, power generation, drainage control and irrigation purposes; they equally serve as habitats for aquatic resources exploited for food, commercial and recreational purposes. However, there is little or no emphasis on their utilization for aquaculture development compared with most perennial dams in developed world that are used for onshore fish culture or used in raising fish offshore (De Silva and Amarasinghe, 2008). In Ekiti State, Ero dam is the largest of the dams in the state with capacity to produce 104,000 metric cubic of water per day. Other dams in the State are Little Ose (84,999 metric cubic/day) Itapaji Dam (51,750 metric cubic/day), Ureje Dam (9930 metric cubic/day), Ayede Dam (45,600 metric cubic/day) and Ogbese river (currently being developed into a dam) (Folayan, 2010). Hence, developments of commercial aquaculture around Ero Reservoir will not only increase fish output, create more jobs, pay more wages and salaries but it can also stimulate output in other sectors in the reservoir host communities and its environments (Folayan, 2010).

Land suitability analysis for aquaculture needs to be conducted for the principle of consideration in the decision of the suitable land use. Land has varied physical, social, economic, and geographical values which influences land use Rossiter (2007). Thus, land suitability analysis is a strategic planning tool of land use that can predict the expected benefits and constraints of productive land use and environmental degradation that might occur due to the use of land (Andi *et al.*, 2013). While development and implementation of aquaculture site selection (zonation) strategies is now an established concept, the tools and methodologies for achieving such goals are still under development (FAO, 2007). The success of aquaculture is dependent on the site that has suitable qualities of soil, topography, hydrological indices, water and infrastructure facilities. Aashok *et al.*, (2014), stated that the application of geoinformatics may provide various ways of handling, analysis and interpretation of data, as well as decision making process for aquaculture development. .Tools such as geographical information system (GIS) have several advantages for aquaculture development programs. It not only provides a visual inventory of the physical, biological, and economical characteristics of the environment, it also allows rational management without complex and time-consuming manipulations. In 2007, the use of GIS, remote sensing and mapping was promoted through implementation of GIS at the least cost and the use of data that are freely available via download from the Internet to improve the sustainability aquaculture with a major focus on developing countries (FAO, 2007). Despite this, its use in aquaculture is very limited and only few studies are reported in the literature for Nigeria particularly the development of inland water aquaculture in Ero Reservoir in Ekiti State, Nigeria. There is equally little or no information on the suitability study of inland waters in Ekiti State particularly Ero Reservoir and its environs for aquaculture development in the State.

1.3. Research Objectives

The general objective of this research is to carry out a suitability analysis of Ero reservoirs and its environs for aquaculture development in Ekiti State, Nigeria. Towards this, the specific objectives are to:

i. describe the vegetation around the reservoir and their suitability for aquaculture;
ii. determine the physiochemical parameters of soil around the reservoir and their suitability for aquaculture;

iii. describe the topographic of environs around the reservoir and their suitability for aquaculture;

iv. describe some hydrological parameters for the study area;

v. produce Suitability map for aquaculture development in the study area.

1.4. Research Hypotheses

The following null hypotheses were set for this research:

H_o1: The vegetation around Ero reservoir is not suitable for aquaculture.

Ha1: The vegetation around Ero reservoir is suitable for aquaculture.

H_o2: The topography of the study area is not suitable for aquaculture.

H_a2: The topography of the study area is suitable for aquaculture.

H_o3: Physiochemical parameters of soil around the reservoir is not suitable for aquaculture, H_a3: Physicochemical parameters of soil around the reservoir are suitable for aquaculture

H_o4: Hydrological indices such as rainfall, runoff, water index and moisture stress index of the reservoir and its around are not suitable for aquaculture.

H_a4: Hydrological indices such as rainfall, runoff, water index and moisture stress index of the reservoir and its around are not suitable for aquaculture.

H_o5: Ero reservoir and its environ is not for aquaculture development

H_a5: Ero reservoir and its environ is for aquaculture development

Chapter Two

2.0 Literature Review

2.1. Definition of Aquaculture

Aquaculture can be defined as the process of raising aquatic organisms up to final commercial production within properly partitioned aquatic areas, controlling the environmental factors and administering the life history of the organism positively and it has to be considered as an independent industry from the fisheries hitherto (Ridge, 2010). It could also be defined as the farming of fish, crustaceans, molluscs, aquatic plants, algae, and other aquatic organisms (Nicholas, 2016). Aquaculture involves cultivating freshwater and saltwater populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish (Wikipedia 2017). The Food and Agricultural Organization (2008) introduced a definition of aquaculture which reduces its confusion with capture fisheries: it states that aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc.

2.2. History and Status of Global Aquaculture

Aquaculture is believed to have started from China around 2500 BC. When the waters subsided after river floods, some fish, mainly carp, were trapped in lakes. Early Aquaculturists fed their brood using nymphs and silkworm faeces, and ate them. A fortunate genetic mutation of carp led to the emergence of goldfish during the Tang dynasty. Japanese cultivated seaweed by providing bamboo poles and, later, nets and oyster shells to serve as anchoring surfaces for spores. Romans bred fish in ponds and farmed oysters in coastal lagoons before 100 CE. The 15th-century fishponds of the

Trebon Basin in the Czech Republic are maintained as a United Nations Education and Scientific Organization World Heritage Site(According to FAO (2014) Global fish production has grown steadily in the last five decades, with food fish supply increasing at an average annual rate of 3.2 percent, outpacing world population growth at 1.6 percent. World per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (preliminary estimate). This impressive development has been driven by a combination of population growth, rising incomes and urbanization, and facilitated by the strong expansion of fish production and more efficient distribution channels. China has been responsible for most of the growth in fish availability, owing to the dramatic expansion in its fish production, particularly from aquaculture. Its per capita apparent fish consumption also increased an average annual rate of 6.0 percent in the period 1990–2010 to about 35.1 kg in 2010. Annual per capita fish supply in the rest of the world was about 15.4 kg in 2010 (11.4 kg in the 1960s and 13.5 kg in the 1990s), (Kathryn, 2008).

2.3. History of Aquaculture in Nigeria

Aquaculture development in Nigeria has followed a similar development path from the colonial era, during which more than 2,000 small-scale subsistence-level ponds were built, with some growth continuing in rural areas Miller *et al.* (2011). However, production has been insignificant in national food supply terms. Nigeria's strongly growing population, at some 150 million, as well as its very high demand for fish, has now placed it on a much stronger market-driven path, based on the commercial production in peri-urban areas, (Miller and Atanda2011).This has shown a remarkable 20 per cent increase in growth per year for the past six years, with high growth in small-to-medium-scale enterprise and a number of large-scale intensively managed fish farms. Together with Egypt and South Africa, Nigeria is now one of the most significant and strongly growing aquaculture producers in the region (FAO, 2014). As noted by Nicholas. (2016), Nigeria's fast growth in aquaculture is a replication of that observed in other regions where the market has been a key factor in driving growth.

A further phase of expansion is now being developed with government youth employment programmes, some 20 per cent focusing on fish-farmer training, to promote wider social engagement and to attempt to stem the exodus from rural areas. It is reported that 30 per cent of new investments in agriculture programmes are in fish farming with bankers now more informed and willing to consider loans in this sub-sector. With high demand for fresh fish and consumer preference for fresh water catfish (*Clarias gariepenus*), the Nigerian private sector launched fish farming in earnest around 2000, with the rehabilitation of many abandoned fish farms and new investments in others,(Ozigbo *et al.*, 2014).

2.4 Definition of Reservoir

Wikipedia (2017) defined a reservoir as a barrier that stops or restricts the flow of water or underground streams. Reservoirs created by dams not only suppress floods but also provide water for activities such as irrigation, human consumption, industrial use, aquaculture, and navigability. Encyclopaedia Britannica(2017) defined reservoir is an open-air storage area (usually formed by masonry or earthwork) where water is collected and kept in quantity so that it may be drawn off for use.

2.5 Roles of Reservoir

Although the amounts of water resources are enough for the entire world, the distribution of them in time and space shows uneven pattern,(Tortajada*et al.*, 2012).The water need is increasing with heavy industrial and agricultural requirements, while available water in the world remains as a fixed source.

Economic growth, socio-cultural, and environmental developments are being realized following these changes. In order to achieve sustainable management of water resources, these changes have to be taken into consideration in water-related development projects, (Rita and Malik, 2008).The reservoirs play an important role in the developmental process of a Nation and also have an integral role in fisheries and livelihood security of local communities. With the increase in population growth, reservoirs are becoming important provider of animal protein and for generation of employment in particular to poorer sectors of the people (De Silva and Amarasinghe 2008).

Reservoirs have many uses from generation of electricity to irrigation purpose and also providing habitat to fishes and other aquatic life and in turn also help to provide feed and create revenue for fish communities(Jiashou *et al.,* 2007).Reservoirs are rarely and or never created for fishery purposes, however, the secondary use of the impounded waters for fisheries is becoming an increasingly important activity, particularly in Asia, the region that is purported to have the highest reservoir amongst all continents. Near shore aquaculture siting requires the integration of a range of physical, environmental, and social factorsReservoir fish production is also gradually becoming a significant contributor to total inland production, and often provides a relatively affordable source of fresh and good quality animal protein source to many rural communities, as well many livelihood opportunities directly and indirectly. Reservoir fishery activities in the recent past are also seen as a means of providing alternate livelihood opportunities to people that are displaced by the impoundment. Such livelihoods could entail engagement in capture fisheries and or aquaculture activities such as cage culture. In addition, nations are beginning to take note of the vast reservoir resources that are of a non-perennial nature in the Asian region for development of culture based fisheries,(De Silva and Amarasinghe2008).

This development, a low cost community activity, is thought to provide significant subsidiary income to downstream farmers and contribute to their nutrition. Notably in the region the reservoir fish fauna, fisheries production and management methods, amongst others factors differ widely. The differences in fish yield between reservoirs and/or between countries cannot be easily understood and are unlikely to be determined by individual parameters or characteristics such as the reservoir fish fauna, water quality criteria, hydrological regimes, morphometric, management patterns and so forth, (Nguyen *et al.*, 2007). However, it is possible that there is a great deal to be learnt from management practices of each country.

2.6. Under-Utilization of Reservoirs in Nigeria

Dams are constructed to augment shortfall of water supply, especially during dry season but, unfortunately, several dams built across the country have been abandoned by governments. Investigations byDaily Trust (2016), has revealed that most dams established in Nigeria for irrigation or for potable water, are not serving the purpose for which they are meant for because they are either not functional or under-utilized. Generally, Dams are constructed to augment shortfall of water supply, especially during dry season but, unfortunately, several dams built across the country have been abandoned by governments. Leadership newspaper (2012), has revealed that most dams established in Nigeria for irrigation or for potable water, are not serving the purpose for which they are meant for because they are either not functional or underutilized. Many reservoirs constructed by Federal and State Government are under-utilized for public water supply and other axillary function such as dry season farming and aquaculture. However, they are mostly used for irrigation farming most especially in the Northern part of the country with little/no consideration for the utilization of such environment for aquaculture development.

2.7. Global Use of Reservoir for Aquaculture Development in Some Countries

2.7.1. Reservoir Fisheries in China

China has a long history of reservoir fisheries activities. The earliest stocking activity of fish seed collected from rivers took place in Dong Qian Hu reservoir which was impounded some 1000 years ago in Zhejiang province (Shi, 2007). Many reservoirs have been constructed in China since the 1950s for various purposes and are also used as important resources for fisheries development,(Xing *et al.*, 2007).Presently, reservoir fisheries have become an important component of the fisheries industry in China, and make a substantial contribution to people's fish supplies and rural livelihoods. China is currently in a new development stage (Bureau Statistics, 2007). Environmental conservation and wise use of resources are of major concern in development activities. Over the last 60 years when most progress was made in reservoir fisheries development in China, the most important change was the transition from extensive culture to semi-intensive and intensive culture, (*Jiashou et al* 2007). Chen, (2006)reported that In the 1950s, the capture of naturally occurring fish populations was the main component of reservoir fisheries.harnessing the rivers for irrigation and hydro-electric power generation has been the main focus of developmental activities in ever since the country gained independence. Consequently, a number of small, medium and large river valley projects have come into existence during the last four and a half decades with the primary objectives of storing the river water for irrigation, power generation and a host of other activities. The Ministry of Agriculture, Government of China has classified reservoirs as small medium and large for the purpose of fisheries management.

2.7.2. Reservoir Fisheries in Orissa State, South Eastern India

Unlike rivers, which are under increasing threat of environmental degradation, reservoirs in India offer ample scope for fish yield optimization through effective management (Vass, 2007)

Orissa State has about 256000 hectare of reservoir waters 197,000 hectare, of the reservoirs are suitable for fish production. These reservoirs were constructed primarily for water storage, irrigation, flood control and for generating electricity include three large reservoirs, accounting for 119400 ha, and six medium sized reservoirs, ranging from 1094 ha to 3500 ha each, the reservoir support mainly small-scale fisheries and are rich in their diversity of fish species(Misira, 2007).

In addition to the native fish species the introduction of catla, rohu, mgria and exotic grass carps are common. Most of the reservoirs provide excellent habitats for raising fish. However, some are infested with weeds and are not productive. Department of fisheries, 2008 reported that Stocking of Indian major carp fry in some of the reservoirs to boost fish production began in 1985- 86.Fry have been stocked by the Orissa fish seed Development Corporation (OFSDC) and by the Department of Fisheries in a few reservoirs. The reservoirs are under the administration control of the irrigation Department. However, the fishing rights of 65 reservoirs, totaling 147807 ha, have been to the Department of Fisheries .Thirty a reservoir, having a total area of 64525 ha, where placed under control of OFSDC, but during 1992-1993, the number was reduced to 23 totaling 33899 ha. The state Government urge the use of small irrigation reservoirs for fisheries development will bring a new era in fish production. Hopefully, in the next few years, the State will witness a high production of fish from production (Vass, 2007).

2.7.3. Reservoir Fisheries of Thailand

Thailand has a coastline of 2,614 km and 3,750 km^2 of inland water area (TDRI, 2009). Inland fisheries have been long recognized and operated in the major rivers, Floodplains, canals, swamps, wetlands, lakes and reservoirs (Bhukaswan, 2007). Fisheries resources in Thailand are regarded as a public wealth and fishing is a long standing tradition in the country, considered an integral part of the heritage and culture, particularly in rural areas of Thailand (Coates, 2007). Fish yield from inland fisheries contributes about 7.3 % to the country's overall fish landings and provides about 3 kg caput-1 yr-1 (De Silva and Funge-Smith, 2007). Reservoirs in Thailand are ubiquitous countrywide, especially in the North and North eastern regions. They have been impounded for either hydropower or irrigation purposes, and fisheries are considered a secondary benefit from the impoundments. However, there are to Thai reservoirs, which were impounded and used primarily for fisheries (Virapat and Mattson, 2008). Virapat *et al.* (2009) gave an estimated inventory of 28,956 reservoirs in Thailand ranging from 0.01 ha to more than 1000 ha.

According to Virapat and Mattson (2001) however, there are 27,779 Thai reservoirs. Virapat *et al.* (2009) estimated that fish production from these reservoirs to be between 122,314 and 318,909 t per year. The inland fisheries are essentially artisanal and are based mainly on the indigenous species (80-90 %) such as carps, minnows, snakeheads and catfishes (Virapat and Mattson, 2005). The rest constitute the introduced species such as tilapias as well as Indian and Chinese major carps.

2.8 Aquaculture Site Selection

The success or failure of any aquaculture venture largely depends on the right selection of the site for it. In choosing a site several factors other than the physical aspect of the site are to be considered (Kutty, 2007).Site selection for aquaculture involves the assessment of numerous physical variables. From an aquaculture point of view, site selection or location decisions are important initially in the actual securing of production sites or sites from which to function, (Rosha and De Susan, 2007) .Site selection affects both success and sustainability of an aquaculture operation. The prospects for securing a suitable site will vary greatly depending on existing land/water rights, land use planning controls, availability for purchase or rent, conflicting demands for access, etc.(Hishamunda *etal.*,2009).The fish farmer will then be concerned with securing sites qualitative environmental legislation exists. It is important that sites or locations which allow for economic viability are secured. This could be in areas where optimum sustainable yields can be where environmental parameters can be optimized, preferably in areas where pollution controls or maintained or in areas where there is at least a reasonable potential for realizing production profits (Richard 2016). Sites must also be reserved if future food yields are to be maintained and improved and in order to help the diversification of local employment. Since production requires so many critical physical and economic parameters, and with so many interests competing for the water/land interface "space", the fish producer will need to complete hard for any potential locations. The success of a fish farm project therefore largely depends on one's project site conditions. The site conditions determine if one's fish farm will competitively produce (Andi *et al.,* 2013). Correct selection of a site assists in designing a fish farm hence reduces costs to a fish farmer.Cayelan *et al*(2012), believed that Site selection also takes into account the biological trait of the targeted specie and the intended capacity that will achieve optimal and cost effective production.

2.8.1. Soil Quality

Soil quality is an important factor in fish pond productivity as it controls pond bottom stability, pH and salinity of overlying water and concentrations of plant nutrients required for the growth of phytoplankton, which is the base of food chain of the fish (Adhikari, 2007).Soils vary greatly in large scale because soils result from complex physical interactions which themselves take place in areas having different topographic, geologic, climatic, vegetation and human influences (FAO,2008). A good understanding of soil and its characteristics is one of the most important factors for aquaculture site selection, development and management (Boyd and Queiroz, 2014). This is particularly the case in pond farms, where soil quality has a great influence on construction and maintenance costs and on productivity.

The soil properties most relevant for pond construction are slope, texture and pH, (William, 2008).The site must have soils that hold water and can be compacted (Hajek and Boyd, 2007). If pond levees are constructed with soil that has high water permeability (leakage or seepage), the cost of pumping water could become prohibitive. Excessive seepage often results from improper site selection. Therefore, soil properties should be clearly investigated and identified during site selection (Yoo and Boyd,2007). The amount of seepage will depend on the soil composition and on the structure of the pond bottom. However there are some other factors that are also important for soil evaluation such as effective soil depth, gravel and stones percentages, salinity and pH,(FAO, 2008).Sandy clays to clay loam soils are best for pond construction and they should contain no less than 35%

clay. Soils with high sand and silt compositions may erode easily and present a piping hazard - soil-water flow along pipes-, which could wash out a levee though anti-seep collars can help minimize that problem (William 2008). Soils classified between sandy loam and sand does not contain enough clay for pond construction.

Texture classifications are based on per cent compositions of clay, silt and sand (FAO, 2008). It is the particle size that determines how soil is classified. Soil distribution, particle form and composition, uniformity and layer thickness are equally important (Boyd, 2010). Suitable soils should be close to the surface and extend deep enough so that construction, harvest activity or routine pond maintenance will not cut into a water permeable layer, causing a leak,(Yoo and Boyd,2007).Soils therefore should be good enough for construction of dikes, ease of piping, and high degree of compaction, allowable flow velocities in canals and intake basins, avoiding losses through seepage at the bottom and on the dike, avoiding erosion and to reduce seepage, (Ujwala2008).Soil suitability is therefore important from both engineering and a productivity view point.

2.8.1.Topography

Pond layouts should account for the existing site topography in order to minimize pond construction costs, make use of gravity for water conveyance to and from the ponds and enable water exchange, waste dispersal and efficient drainage during harvesting, (Andi *et al*.,2013). This should also be considered for facilities such as feed stores and office. Location of these facilities should facilitate the work, save energy and work. In excessively flat areas problems such as flooding, the inability to provide for gravity flow of water and poor drainage may occur. Additionally, sluggish water flows found in flat areas are associated with low dissolved oxygen levels, high summer water temperatures and near coastal areas' saline intrusions. Areas having steep slopes may be difficult to operate, (Rajchandar and Karuppasamy, 2012). Areas of steep relief may also cause problems with other production functions such as transport accessibility, isolation from markets, high rainfall and run-off, etc. Extensive earth moving machinery may be required on land with slopes greater than these thus increasing construction costs. Some innovative farmers use terracing - stair stepping - for pond layouts in hollows or on land with slopes greater than 2%, (Kutty, 2007). However, much money is required to accomplish this task. Therefore assessment of slopes is a very important aspect in aquaculture. Areas with low slope, 1 to 5 percent, are suitable for pond construction, but slopes of 2 percent or less are most preferred. Moderate slopes simplify delivery of water and gravity drainage of ponds, (William, 2008). Topography around ponds should allow gravity drainage of the pond in any season. Water heights in external ditches and adjacent water bodies should be lower than the pond drain, even under expected high-water conditions. It is also important that ponds have an adequate drainage area for harvest and this can only be realized where the slopes are moderate.

2.9. Methods for Identifying Sites Suitable for Aquaculture

Two techniques can be used to create a database of areas suitable for aquaculture development

2.9.1. Conventional Method

This method use manpower (human beings) to demarcate the areas suitable for aquaculture. The method is not very competent because it is slow, uses a lot of money and it covers a very small area, which is, only the sampled area (William,2008). For example, the method used to identify the soil suitability is quite cumbersome since one has to keep rolling out balls of soil in the area and check if the ball can easily roll. Various soils will be different when rolled out into a ball shape, (Water resources department, pune, 2009).This form of identification is quite tedious and uses a lot of time, It is believed that this approach will save time and money for farmers which they could use to consult experts.

2.9.2 Geographic Information Systems (GIS)

Geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface, (James and Jose, 2007).By relating seemingly unrelated data, GIS can help individuals and organizations better understand spatial patterns and relationships (National Geographic Society, 2012). GIS technology is a crucial part of spatial data infrastructure, which the White House defines as "the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data".GIS, Acronym for Geographic Information System, is an integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analysed (Pennstate, 2015).

GIS, Remote Sensing and Mapping have a task to play in all geographic and spatial aspects of the development and management of marine (Kairo *et al.*, 2007). GIS is used to manipulate and analyze spatial and attribute data from all sources. It is also used to produce reports in map, database, and statistics, field calculation, and analysis and text format to facilitate decision-making (Araya, *et al*.,2010).

With interests such as offshore renewable energy, sand and gravel extraction, national security, fishing, and nature conservation all pushing for more space, exclusive uses of marine areas are being replaced by a search for more integrated solutions (Halpern *et al.*,2008; Katsanevakis *et al.*, 2011). Geographic Information Systems (GIS) has been widely advocated as one such place-based, integrated tool for managing human activities in the marine environment (Douvere2008; Douvere and Ehler2010; Collie *et al*,.2013).

Chapter Three

3.0 Research Methodology

3.1 Study Area

The survey was conducted in Ero Reservoir and its environs in Ekiti State Nigeria. The reservoir is located on longitude (005°15'E and latitude of 7°40'N) in Moba Local Government area of Ekiti state. It's a large dam that was commissioned in 1987, it supplies presently serves Iludun, Iye, Ikun, Oye, Ero, Eda-Oniyo and its environs. Its source is from river Ero, its height above sea level is 616. The height of the dam is 22m, the reservoir has a capacity of 20MCM. The main purpose of the dam is to provide for water supply and to control flood. The direct user of the reservoir is the Ekiti State Water Corporation.

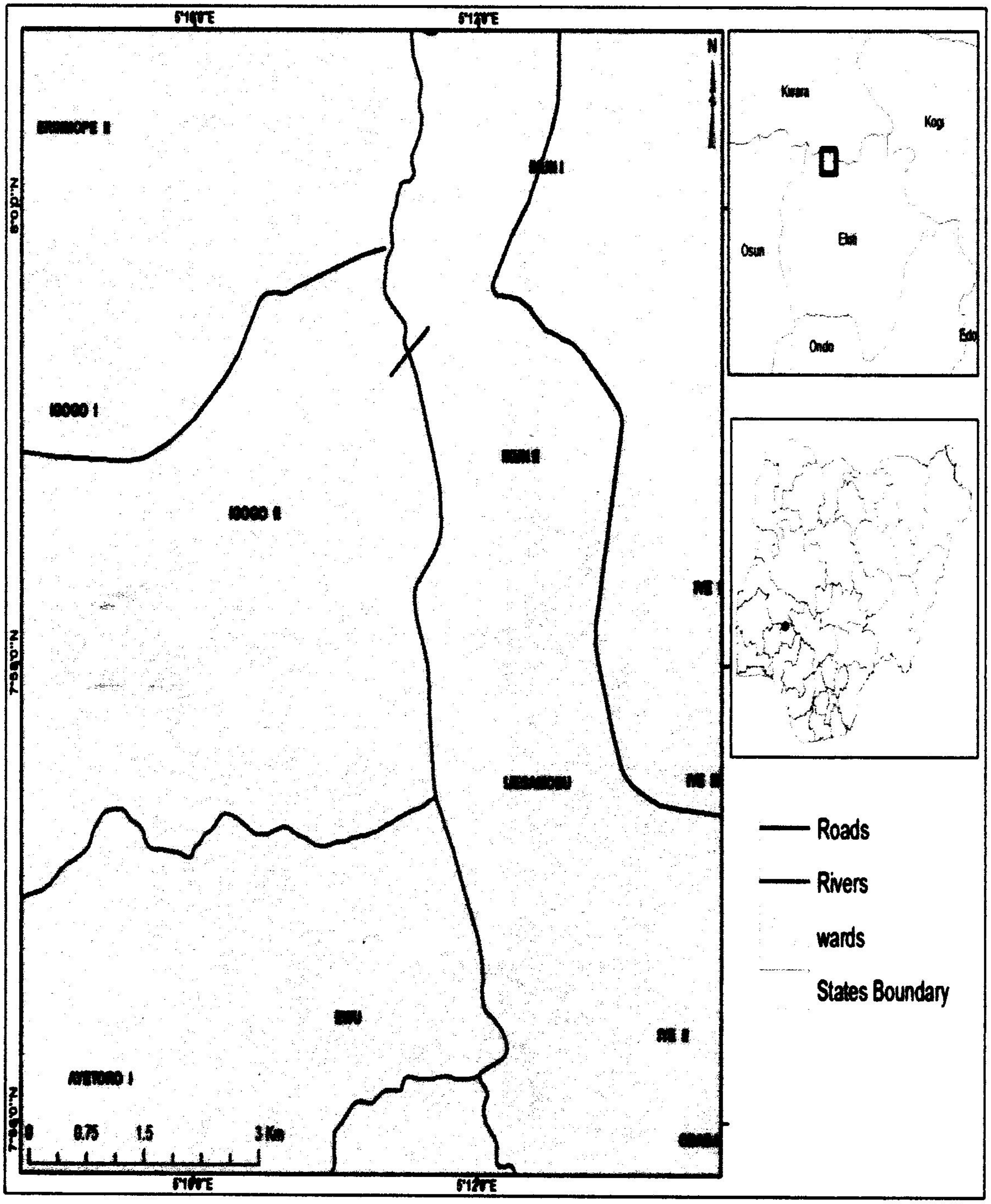


Figure 1: Study Area

3.2. Preliminary and Reconnaissance Survey

Preliminary was done to get familiarized with the study areas, identify routes for ground routing and source support services from the Dams' Staffs as well as to identify sources of additional information to be included in the research. Reconnaissance survey was done to identify accessible points for soil sample collection, the types and state of infrastructures available in the study area.

3.3. Soil Analysis

Soil samples from the top soil, subsoil, parent material and the bed were collected from a 1.5m soil profile dugged at three locations of the study area. 1kg of soil samples was taken from each of the profile and kept inside labelled polythene nylon. Soil was taken from three sampling points: point (N07°59.411and E 005°11.517) point two (N 07°59.346 and E 005°11.396) and point three (N 07°59.438 and E 005°11.666). Four (4) soil samples were taken from each depth of the soil profile. The depths were 0 – 37.5cm, 38 – 75.5cm, 76 – 112.5cm and 113 – 150cm; twelve soil samples were collected from the study area. The soil were bulked, air dried and sieved using 2mm sieve and analysed for organic matter, organic carbon, total nitrogen, phosphorus, potassium, calcium, magnesium, pH, percentage sand, clay, silt, cations exchange and water absorption index were determined at the Soil Physics Laboratory of the Federal University of Technology Akure, Ondo State, Nigeria.

3.4. Mapping

Geographic coordinate of the reservoir and soil sampling points were traced and captured using handheld Geographic Positioning System (GPS) (Garmin eTrex) receiver and recorded appropriately.

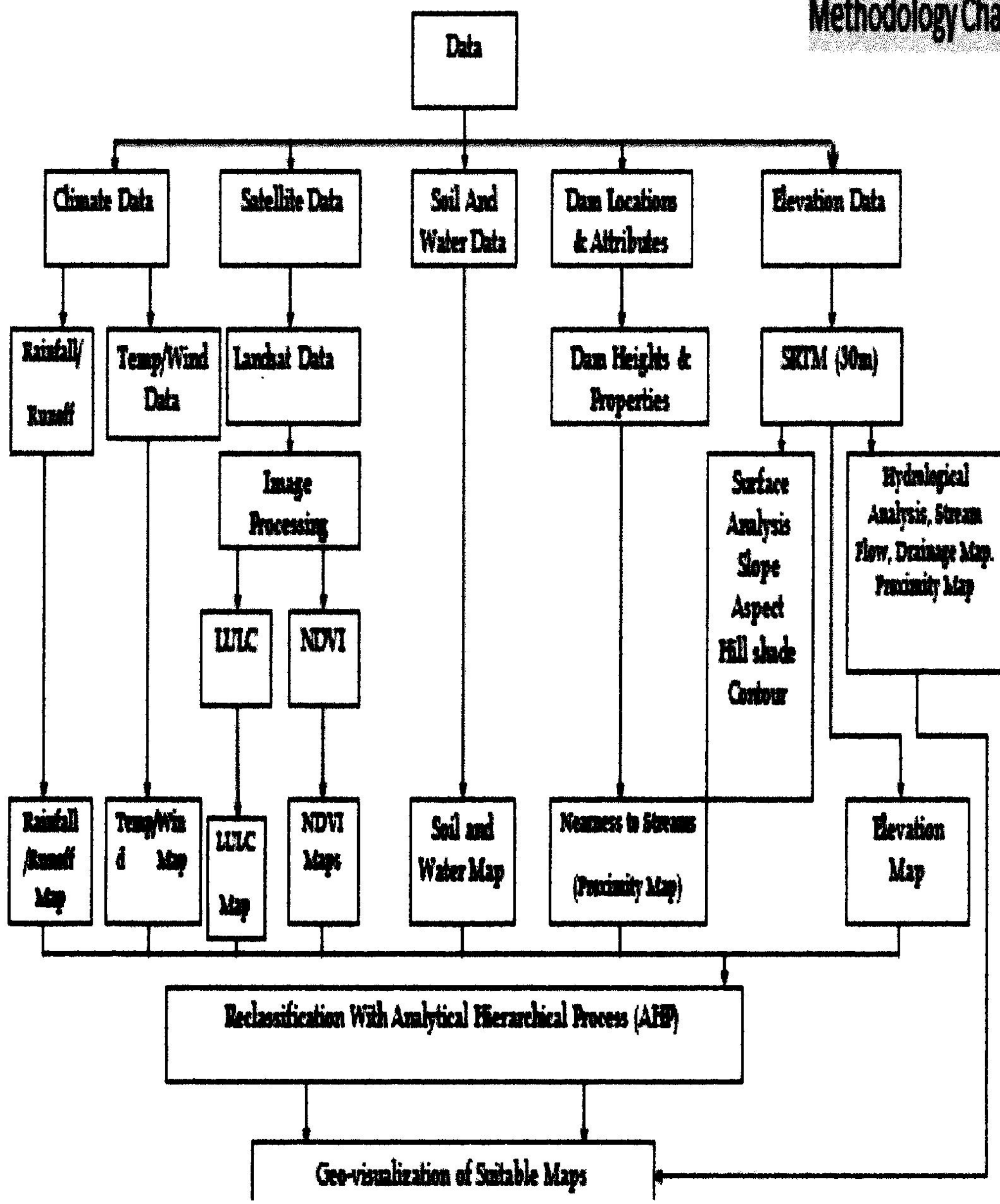
3.5. Suitability Analysis

Land use land cover, vegetation, water index, hydrological and suitability maps were developed at the Centre for Space Research and Applications (CESRA), Federal University of Technology Akure, Ondo State, Nigeria. Landsat 8 OLI satellite datasets and Shuttle Radar Topography Mission (SRTM) were acquired from the Global Land Cover Facility to determine the land use/land cover and the digital elevation model (DEM) respectively. 500m buffer was created around the reservoir covering a total area of 1,478 hectares for the purpose of this study. Hydrological maps (rainfall, runoff, water index and moisture stress) soil map, land use land cover map, vegetation map, elevation map were then reclassified with analytical hierarchical process (AHP) to develop a suitability map that would show areas that are highly suitable, moderately suitable, lowly suitable and not suitable for aquaculture around the reservoirs.

3.6. Data Analysis

Soil parameters across sampling points and depth were analysed using One Way Analysis of Variance using the Statistical Package for Social Science (SPSS) Version 20.0. Means were separated where significant difference occurs at $p \leq 0.05$ using the Duncan's New Multiple Range Test (DNMRT).

Methodology Chart



Chapter Four

4.0. Results and Discussion

4.1 Land Use, Land Cover of Ero Reservoir and its Environs in Ekiti State, Nigeria.

The attributes of land use. land cover of Ero Reservoir, Ekiti State, Nigeria and its environment is presented on Table 1 while the land use land cover map is presented in Figure 3. 20.99% of the study is comprised of water body, 47.74% of the area had light vegetation, 12.29% were dense forested areas, and 12.96% represents areas of wetlands while built up areas was 6.03% of the study area.

Table 1: Attributes of land use and land cover in and around the reservoir

Land cover/land use classes	Area cover (Hectares)	Proportion (%)
Water body	310.29	20.99
Light vegetation	705.52	47.74
Dense forest	181.60	12.29
Wetlands	191.50	12.96
Built-up	89.09	6.03
Total	**1,478.00**	**100.00**

Source: United State Geological Survey, 2017

Results from attributes of land use, land cover of Ero Reservoir and its environs indicates that 20.99% of the study area is comprised of water body. This shows that there would be enough water to meet the water requirement for practising aquaculture in and the reservoir. Cages could equally be sited on the water body for fish culture; this would limit land acquisition of land. Karnatak and Kumar(2014) documented that cages use limited space in existing water bodies and thus eliminate the need to buy land. Compared to pond culture, the investment or capital needed to construct cage facilities is relatively low with high production capacity; production in cages can be as much as 20 times greater than in pond culture (Das *et al.* 2009).

There would be ease of clearing the reservoir environs for aquaculture purpose and it would also lead to reduced cost of construction as 47.74% of the area had light vegetation, 12.29% were dense forested areas. Adisukresno(2008) stated that the vegetation with thick vegetation entails large expense on clearing as a result of the use of machines for clearing. The presence of wetlands representing 12.96% of the study area is equally a positive attribute for aquaculture development. Built up areas was 6.03% of the study area consisting of buildings or non- building structures such as rocky hills.

4.2. Attributes of Normalized Differential Vegetation Index (NDVI) of the reservoir

Site attributes and map of normalized differential vegetation index of the reservoir is presented on Table 2 and Figure 4 respectively. The result indicated that 72.63% of the areas were vegetated while non-vegetated parts represent 27.37% of the study area.

Table 2: Attributes of Normalized Differential Vegetation Index (NDVI) of the reservoir

NDVI	Area cover (Hectares)	Proportion (%)
Non-vegetated areas	1,073.49	72.63
Vegetated areas	404.51	27.37
Total	**1,478.00**	**100.00**

Source: United State Geological Survey, 2017

The result of the normalized digital vegetation index indicated that 72.63% of the study area was vegetated. This could have both positive and negative impact on the use of the environs for aquaculture practice while non-vegetated parts represented 27.37% of the study area; this area covers all non-vegetated or sparsely vegetated habitats which include the bare lands, water bodies, rock. This could be as a result of presence of rocks, depleted soils, which could occur due to agricultural practice, runoffs, and erosion (Natural Resources Management and Environment Department, 2008).

Vegetation is defined as an assemblage of plant species and the ground cover they provide. It is a general term, without specific reference to particular taxa, life forms, structure, spatial extent, or any other specific botanical or geographic characteristics

(Wikipedia 2017). Dense vegetation entails large expense for clearing (the removal or clearing of the existing terrestrial vegetation within a given tract of land). This may be achieved through the manual or mechanized removal of vegetation using industrial equipment, herbicides which kill or inhibit the growth of certain plants, or any other method (i.e. manual) that results in the alteration of terrestrial vegetation (Fisheries and Oceans Canada, 2010) .The clearing work in thickly vegetated areas usually involves cutting trees, digging up roots, removing rocks, etc., this should be minimal in order to reduce costs while there would be decrease in the cost of clearing in light non/lightly vegetated area. Dense vegetated areas in the study area could be hideout for predators. To utilize, such environment, ponds should be protected by netting pond surface area.

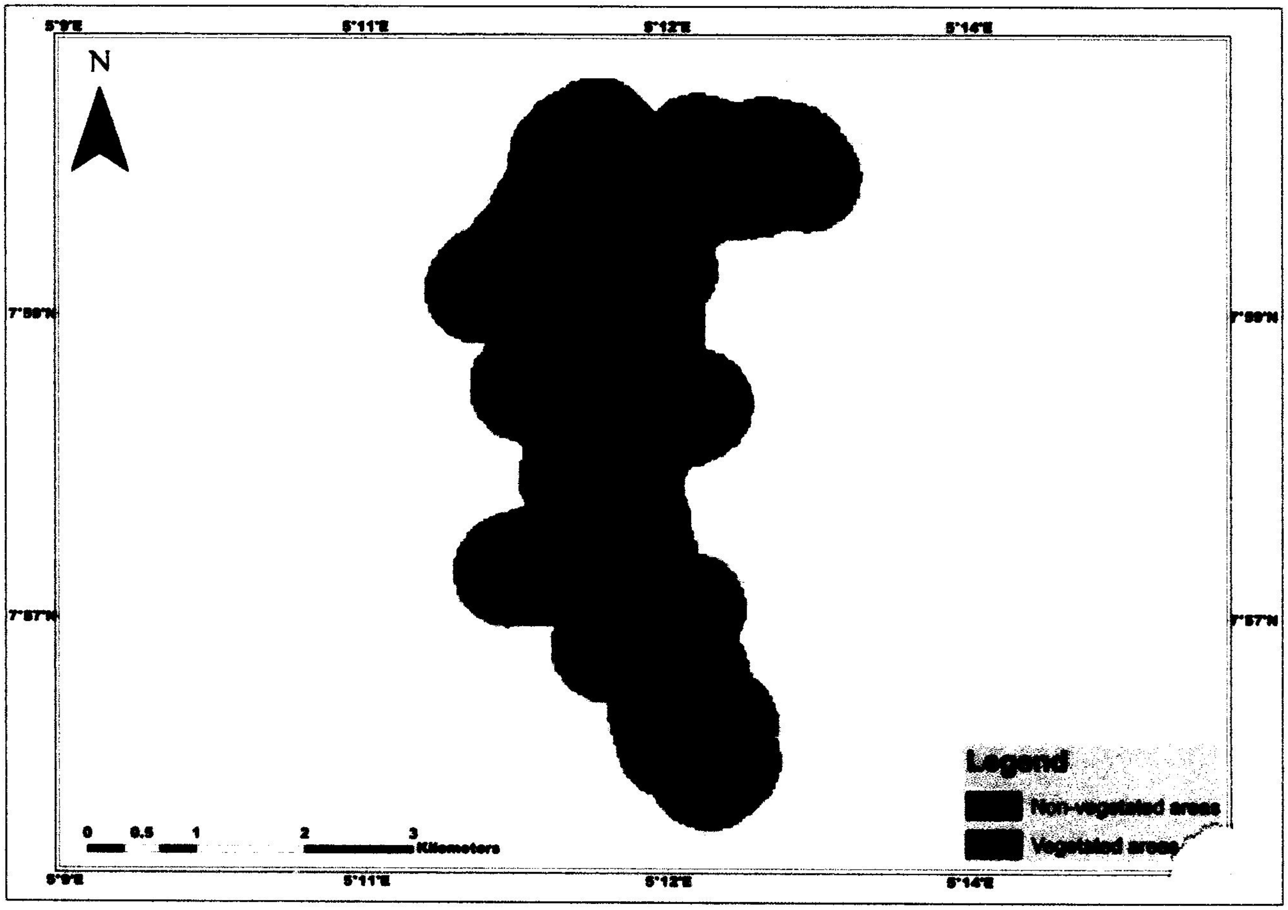


Figure 4: Normalized Differential Vegetation Index (NDVI) of the reservoir

Source: United State Geological Society, 2017

4.3. Soil Composition of the Study Area

Soil composition attributes in and around the reservoir on Table 3 and Figure 5. The result indicated that 88.37% of soil in the study area was classified as nitisols (light clay and loam) while 11.63% contained lixisols (sandy clay loam).

Table 3: Attributes of soil composition in and around the reservoir

Soil classes	Area cover (Hectares)	Proportion (%)
Lixisols (Sandy clay loam)	171.83	11.63
Nitisols (Clay (light),loam)	1,306.17	88.37
Total	**1,478.00**	**100.00**

Source: United State Geological Survey, 2017

Result of soil texture acquired from the satellite imagery was similar to the soil samples classified in the study area. Satellite imagery classified 88.37% of soils in the study area as nitisols (light clay and loam). This suggests that the soil was high in clay contend and loan. This makes a large area of land around Ero reservoir potentially good for fish farming. Wurts(2010) reported that nitisols have clay content ranging between 27% and 40% clay content; which makes them suitable for aquaculture. The other soil texture classified was lixisols (sandy clay loam); clay-loam, or sandy-clay soils are good for water retention and suitability for diking (Boyd and Bowman, 2007)

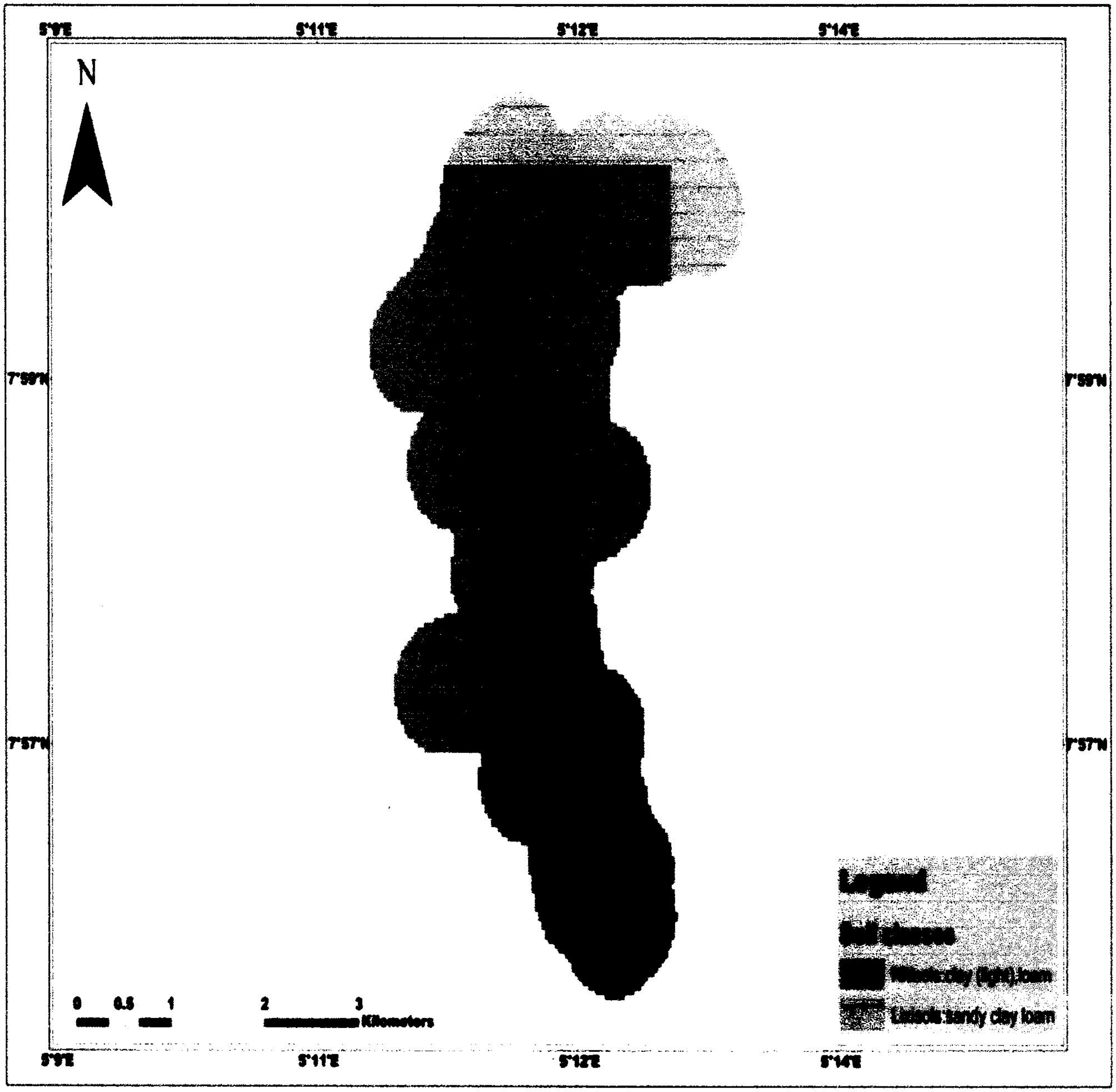


Figure 5: Soil composition in and around the reservoir

Source: United State Geological Survey, 2017

4.3.2. Physiochemical Properties of Some Soil Samples Collected from three Sampling Points around Ero Reservoir, Ekiti State, Nigeria

Physiochemical parameters of soil collected from three sampling point around Ero reservoir is represented on table 4. It reveals that there were no significant differences ($p > .0.05$) in the pH of the soil collected from the sampling points. However, soil in sampling point three had the highest pH (7.08 ± 0.06), while the lowest (6.94 ± 0.10) was recorded in point two. Organic carbon in the soil samples ranged between 1.58 ± 0.11 and 1.70 ± 0.13 with no significant differences ($p > 0.05$). Results further indicated that organic matter ranged between 1.56 ± 0.20 and 1.82 ± 0.20 with no significant difference ($p > 0.03$) with the highest level (1.82 ± 0.20) of organic matter recorded at sampling point three while the lowest (1.56 ± 0.20) organic content was recorded in point two.

The nitrogen content in soils collected at the sampling points showed no significant difference ($p > 0.05$) with sampling point two having the highest (0.08 ± 0.03ppm) nitrogen, while point one and two had the same amount of nitrogen (0.05 ± 0.02ppm) respectively. The phosphorus content of the soil samples ranged from 0.08 ± 0.03ppm to 4.62 ± 1.42ppm. Point two had the lowest level of nitrogen while point three had the highest nitrogen content. Potassium in soil samples across the three sampling points showed no significant differences. Sampling point two had the highest P value of 0.37 ± 0.07ppmwhile point one had the lowest potassium (0.25 ± 0.03). However, the sodium of the soil samples collected at the various locations had no significant difference ($p > 0.05$). Samples collected at point three had the lowest (0.23 ± 0.01ppm) Na^+ while the highest (0.24 ± 0.02ppm) was recorded in point two

There were significant differences in the calcium content of the soil sample collected from the three points around Ero, Reservoir, Ekiti State, Nigeria. Soil collected from location two had the lowest Ca^{2+} (1.38 ± 0.06ppm) while soil taking from point three had the highest calcium content (2.08 ± 0.17ppm. Magnesium ion in the soil samples were not different ($p > 0.05$). Mg^{2+} ranged between 0.65 ± 0.03ppm in soil samples collected from sampling point two and 0.85 ± 0.12ppm in sampling point three. Exchangeable acidity of the soils showed no significant difference ($p > 0.05$). Soil samples collected from point one had the highest (2.04± 1.06) while soil collected at point two had the lowest (1.34 ± 0.23) exchangeable acidity.

There was no significant difference in the amount of sand of the soil taken from the three different points. Soil collected from point three had the lowest sand (22.8 ± 3.76%) while the highest (48.80 ± 1.63%) was recorded in soil samples collected at point one around the reservoir.

Silt content of the soils taken from the different locations in the study area showed no significant differences ($p > 0.05$) Location one had the lowest (17.00 ± 1.00) level of silt of while location three has the highest (21.00 ± 2.52). Furthermore, the clay content of the different locations indicated that location one had the lowest (34.20 ± 2.52%) clay while location three had the highest (56.20 ± 5.76%) clay content. There was no significant difference in in the clay content of the three locations. CEC in soils across the location showed no significant differences with highest (5.00 ± 1.32) in soil sampled at location one while the lowest (4.00 ± 0.27) was recorded in location two. Water holding capacity of the soil collected from the three different location in the study area showed no significant difference with location one having the highest water holding capacity of (40.54 ± 3.90%)

while location two had the lowest (34.24 ± 5.40%)water holding capacity. Classification of soil texture collected from point one was sandy-clay-loam while soils from point two and point three were classified clay soil respectively.

Table 4: Physiochemical Properties of Some Soil Samples Collected from three Sampling Points around Ero Reservoir, Ekiti State

	Sampling Points		
Parameters	Point 1	Point 2	Point 3
pH	6.95 ± 0.11^{a}	6.94 ± 0.10^{a}	7.08 ± 0.06^{a}
Organic Carbon (%)	1.70 ± 0.13^{a}	1.61 ± 0.12^{a}	1.58 ± 0.11^{a}
Organic Matter (%)	1.62 ± 0.17^{a}	1.56 ± 0.20^{a}	1.82 ± 0.20^{a}
Nitrogen (ppm)	0.05 ± 0.02^{a}	0.08 ± 0.03^{a}	0.05 ± 0.02^{a}
Phosphorus (mg/kg)	4.34 ± 0.32^{a}	0.08 ± 0.03^{a}	4.62 ± 1.43^{a}
Potassium (mg/kg)	0.24 ± 0.04^{a}	0.37 ± 0.07^{a}	0.25 ± 0.03^{a}
Sodium (mg/kg)	0.24 ± 0.01^{a}	0.24 ± 0.02^{a}	0.23 ± 0.01^{a}
Calcium (mg/kg)	1.73 ± 0.23^{ab}	1.38 ± 0.06^{a}	2.08 ± 0.17^{b}
Magnesium (mg/kg)	0.75 ± 0.09^{a}	0.65 ± 0.03^{a}	0.85 ± 0.12^{a}
Exchangeable Acidity (mg/kg)	2.04 ± 1.06^{a}	1.34 ± 0.23^{a}	1.25 ± 0.26^{a}
Sand (%)	48.80 ± 1.63^{b}	31.80 ± 3.81^{a}	22.8 ± 3.76^{a}
Clay (%)	34.20 ± 2.52^{a}	49.95 ± 6.00^{ab}	56.20 ± 5.76^{b}
Silt (%)	17.00 ± 1.00^{a}	18.25 ± 2.25^{a}	21.00 ± 2.52^{a}
Cation Exchange Capacity (mg/kg)	5.00 ± 1.32^{a}	4.00 ± 0.27^{a}	4.65 ± 0.36^{a}
Water Holding Capacity (%)	40.54 ± 3.90^{a}	34.24 ± 5.40^{a}	35.44 ± 4.45^{a}
Texture	Sandy-Clay-Loam	Clay	Clay

Mean ± S.E with different superscripts differs significantly at $p \leq 0.05$

The results of physiochemical parameters of soil samples collected from the study area of great importance to pond productivity. The pH of soil samples taken from the three locations was different from each other. However it was observed that the pH of the soil samples increases with increase in depth. Soil pH across sampling points and depth were approximately neutral. This was similar to the findings of Boyd (2008) who recommended that the best pH for pond soils is considered to be about neutral. The organic carbon matter and organic carbon of the soils decreasing with depth; organic matter content of the soil is very important because it relatively affects the water holding capacity of the soil, nutrient holding capacity and soil water evaporation (Boyd, 2008). The levels of organic carbon and matter recorded in some soil samples collected around the reservoir falls with the recommended range of 1.0 to 3.0g/kg for pond culture (Boyd *et al.*, 2007).

Nitrogen and phosphorus are very important element in pond fertility and considered as the second most limiting factors in soils and water. Nitrogen and phosphorus contents of soil across the sampling points decreased with depth. Based on productivity of pond nitrogen content ≤25mg/100g nitrogen content leads to low production, between 25mg -30mg/ 100g soil yields medium pond productivity while nitrogen content of above 50mg/100g soil gives high pond productivity (Ujwala, 2008). The nitrogen of the various soil samples where very low indicating that the soil samples were depleted soils which could be as a result of constant farming practice around the reservoir or due to the excavation of the land during the construction of the reservoir. Hence, applications of inorganic and organic fertilizers such as NPK, poultry and livestock manure could be used to increase primary productivity pond soils with low nitrogen and phosphorus values. Burtle (2015) stated that fertilization increase the production of ponds water by providing nutrient for fish in ponds. Also liming of ponds neutralizes soil acidity and increase total alkalinity and total hardness concentrations in water, this can enhance conditions for productivity of food organisms and increase aquatic animal production (Boyd and Tucker, 2007).

The nutrients present in soil samples across the sampling points and depth were not significant difference from each other except the calcium content; all the nutrients decreased with depth. Generally, relatively small amounts of micronutrients (potassium, sodium, calcium and magnesium) are needed in fish ponds (Adhikari, 2007). This is because fish actively maintain a natural balance of electrolytes in their body fluids by chloride cells located in the gills (Boyd, 2008).Results indicated that the sand, silt and clay content of the soil samples collected around the reservoir were differ significant with increase. Sand and silt decreased with depth while the clay content increased with depth. The general soil texture for the three locations where sandy clay loam, clay and clay for sampling point one, two and three respectively. Ujwala (2008) recommended that clay soil is most suitable for pond construction as it has maximum water holding capacity and can easily be compacted and made leak proof.

4.3.3. Physiochemical Properties of Soil Samples Collected from Different Layers of the three Sampling Points around Ero Reservoir, Ekiti State

Physiochemical parameters of soil samples collected from the different layers of the sampling points around Ero Reservoir are presented on Table 5. The pH of the soil samples increased with increasing depth and significantly different ($p < 0.05$) across depths. Equally, quantities of organic matter, organic carbon, nitrogen, phosphorus, potassium, sodium, calcium and magnesium decreased with increasing depth. Organic carbon in soil collected at 0-37.5cm and 38-75cm were similar ($p > 0.05$) but differ significantly ($p \leq 0.05$) from the organic carbon in soil samples collected at 75.5-112.5cm and 113-150cm respectively. Organic matter in soil along the four depths were significantly different ($p \leq 0.05$) from each other. Nitrogen content at the top layer (0-37.5cm) was significantly higher ($p \leq 0.05$) than the similar values ($p > 0.05$) in soil taken from the other three depths. Phosphorus was similar in soil collected at 38-75cm and 75.5-112.5cm but different ($p \leq 0.05$) from the P content in soil collected at depth of 0-37.5cm and 113-150cm respectively. Potassium in soil collected at 75.5-112.5cm and 113-150cm were similar ($p > 0.05$) but different ($p < 0.05$) from the K^+ in soil collected at 0-37.5cm and 38-75.5cm respectively. Similar ($p > 0.05$) Na^+ was recorded in soil collected at 75.5-112.5cm and 113-150cm but significantly different from the Na^+ in soil collected at 0-37.5cm and 38-75.5cm respectively.

Calcium content of soil at the four layers was similar ($p > 0.05$). Magnesium in soil collected at 75.5-112.5cm and 113-150cm were similar but however different from the Mg^{2+} in soil collected at 0-37.5cm and 37.5-75.5cm. Exchangeable acidity of the soil samples were not different ($p > 0.05$) but increased with increasing depth with the highest recorded in soil samples collected at the last depth (113-150cm). Sand, clay in soils collected from the four layers was not different while the silt in the topmost layer (0-37.5cm) was significantly higher than the values in soils from the other three depths. Results analysis further indicated that the quantity of sand and silt decreased with increasing depth while the clay content, CEC and water absorption index increased with increasing depth. CEC in soil from the first layer was significantly higher than the similar values recorded in soils from the other three layers. Water absorption index in soil at the surface (0-37.5cm) was significantly higher than the similar values recorded in the other three layer.

Table 5: Physiochemical Properties of Soil Samples Collected from Different Layers of the three Sampling Points around Ero Reservoir, Ekiti State

Parameters	Depth			
	0 - 37.50cm	38.00 - 75.00cm	75.50cm - 112.50cm	113.00 - 150.00cm
pH	6.78 ± 0.08^{a}	6.93 ± 0.09^{ab}	7.09 ± 0.03^{bc}	7.15 ± 0.01^{c}
Organic Carbon (%)	1.93 ± 0.05^{a}	1.68 ± 0.06^{a}	1.52 ± 0.03^{b}	1.38 ± 0.03^{c}
Organic Matter (%)	2.09 ± 0.10^{d}	1.82 ± 0.06^{c}	1.51 ± 0.07^{b}	1.23 ± 0.09^{a}
Nitrogen (ppm)	0.13 ± 0.02^{b}	0.06 ± 0.01^{a}	0.03 ± 0.00^{a}	$0.03 \pm 0.01a$
Phosphorus (m/kg)	6.0 ± 1.43^{b}	$4.08 \pm o.21^{ab}$	3.85 ± 0.12^{ab}	3.06 ± 0.46^{a}
Potassium (m/kg)	0.40 ± 0.07^{b}	0.3 ± 0.05^{ab}	0.23 ± 0.03^{a}	0.20 ± 0.02^{a}
Sodium (m/kg)	0.27 ± 0.02^{b}	0.24 ± 0.01^{ab}	0.22 ± 0.01^{a}	0.21 ± 0.01^{a}
Calcium (m/kg)	2.0 ± 0.30^{a}	1.67 ± 0.27^{a}	1.50 ± 0.15^{a}	1.77 ± 0.32^{a}
Magnesium (m/kg)	0.93 ± 0.12^{b}	0.8 ± 0.10^{ab}	0.67 ± 0.03^{ab}	0.60 ± 0.00^{a}
Exchangeable Acidity	1.39 ± 0.31^{a}	1.47 ± 0.27^{a}	1.92 ± 0.66^{a}	2.40 ± 1.40^{a}
Sand (%)	40.47 ± 7.0^{a}	37.8 ± 9.85^{a}	32.13 ± 9.26^{a}	27.47 ± 8.84^{a}
Clay (%)	35.53 ± 4.63^{a}	44.2 ± 4.58^{a}	49.87 ± 8.11^{a}	57.53 ± 9.21^{a}
Silt (%)	24.00 ± 2.31^{b}	18.00 ± 1.15^{a}	18.00 ± 1.15^{a}	15.00 ± 1.00^{a}
CEC (mg/kg)	6.26 ± 1.34^{b}	4.37 ± 0.31^{ab}	4.08 ± 0.39^{ab}	3.44 ± 0.09^{ab}
Water Absorption Index	26.74 ± 3.51^{a}	34.83 ± 1.77^{b}	36.59 ± 1.14^{b}	48.78 ± 1.48^{b}

Mean ± S.E with different superscripts differs significantly at $p \leq 0.05$

4.4 Topography of the Study Area

4.4.1 Elevation Attributes of the Reservoir and its environment

Table 6, Figure 6 and 7 provides information on the topographic attributes of the reservoir and its environment respectively. Majority (68.31%) of the study area had elevation between 501-774m, 25.96% of the area had elevation that ranged between 201and 500 while 5.73% of the study area had elevation between 0-200m. Result of slope attribute of the slowly area is presented on table. The result indicated that 21.03% of the study area had a slope between 0 and 5%, 39.97% of the study area had slope that ranged between 6 and 10, while 44.00% had slope that ranged between 11 and 36%.

Table 6: Elevation and Slope Attributes of the reservoir and its environment

Parameters	Area cover (Hectares)	Proportion (%)
Elevation classes		
0 – 200	84.7	5.73
201 – 500	383.62	25.96
501 – 774	1,009.68	68.31
Total	**1,478.00**	**100**
Slope classes		
0 – 5	310.75	21.03
6 – 10	517	34.97
10 – 36	650.25	44
Total	**1,478.00**	**100**

Source: United State Geological Survey, 2017

The result indicated that 21.03%, representing 310.75 hectares of the study area had a slope between 0 and 5%.Areas with low slope between 1 and 5 percent are suitable for pond construction, but slopes of 2 percent or less are most preferred. This is supported by William, (2008) who said that moderate slopes simplify delivery of water and gravity drainage of ponds. Equally about 39.97% of the study area had slope that ranged between 6 and 10 (517 hectares); this areas could be used for aquaculture development but it would require more cost that would be used for levelling the topography to enable aquaculture practice while 44.00% had slope that ranged between 11 and 36%. This represented areas with very high elevations, indicating areas where there are presence of hills, rocks and high mountains, pond may not be easily constructed in these areas. The high elevation of the study area is a reflection of the high altitude Ekiti State is geographically located

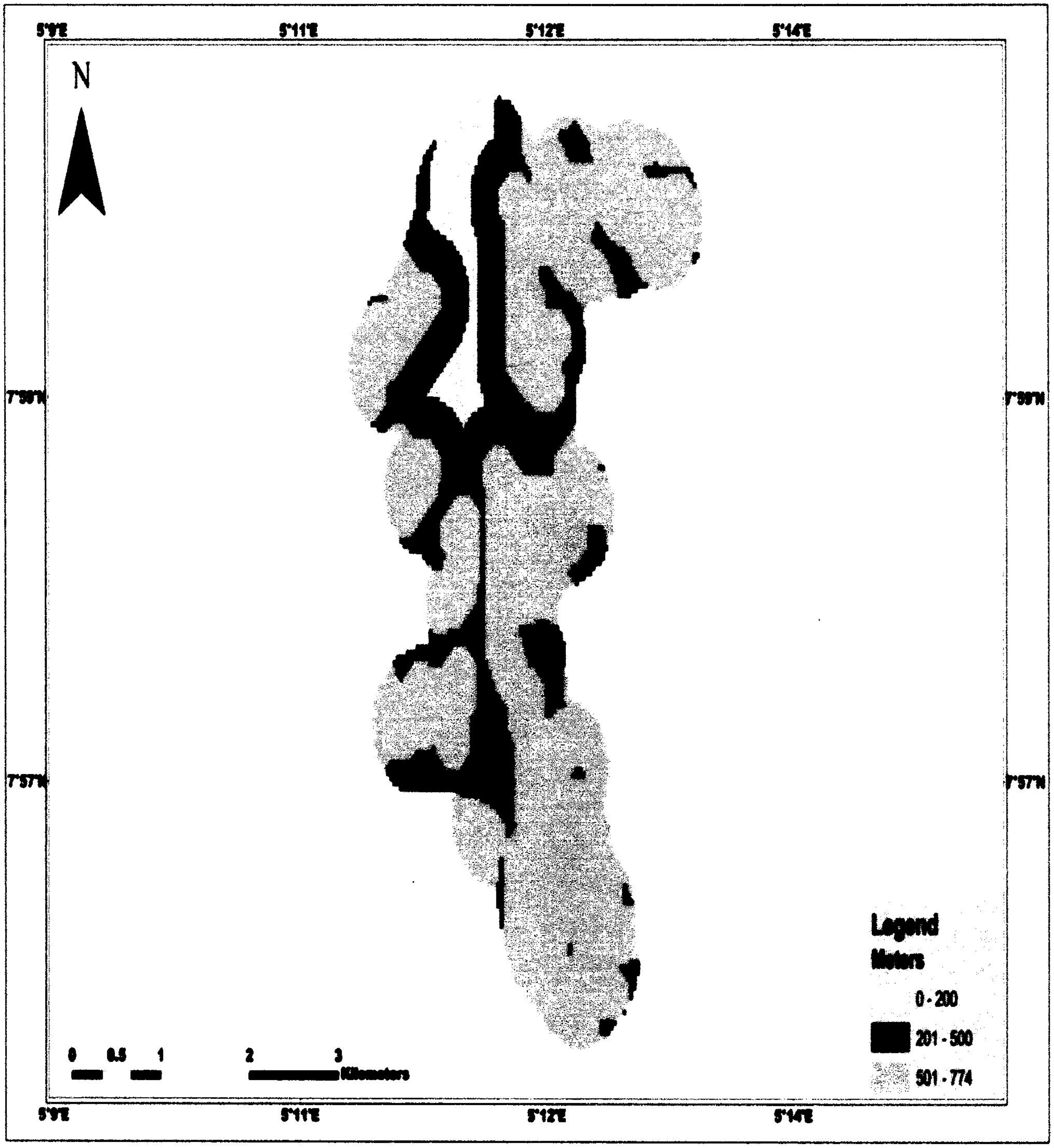


Figure 6: Elevation of the reservoir and its environment

Source: United State Geological Survey, 2017

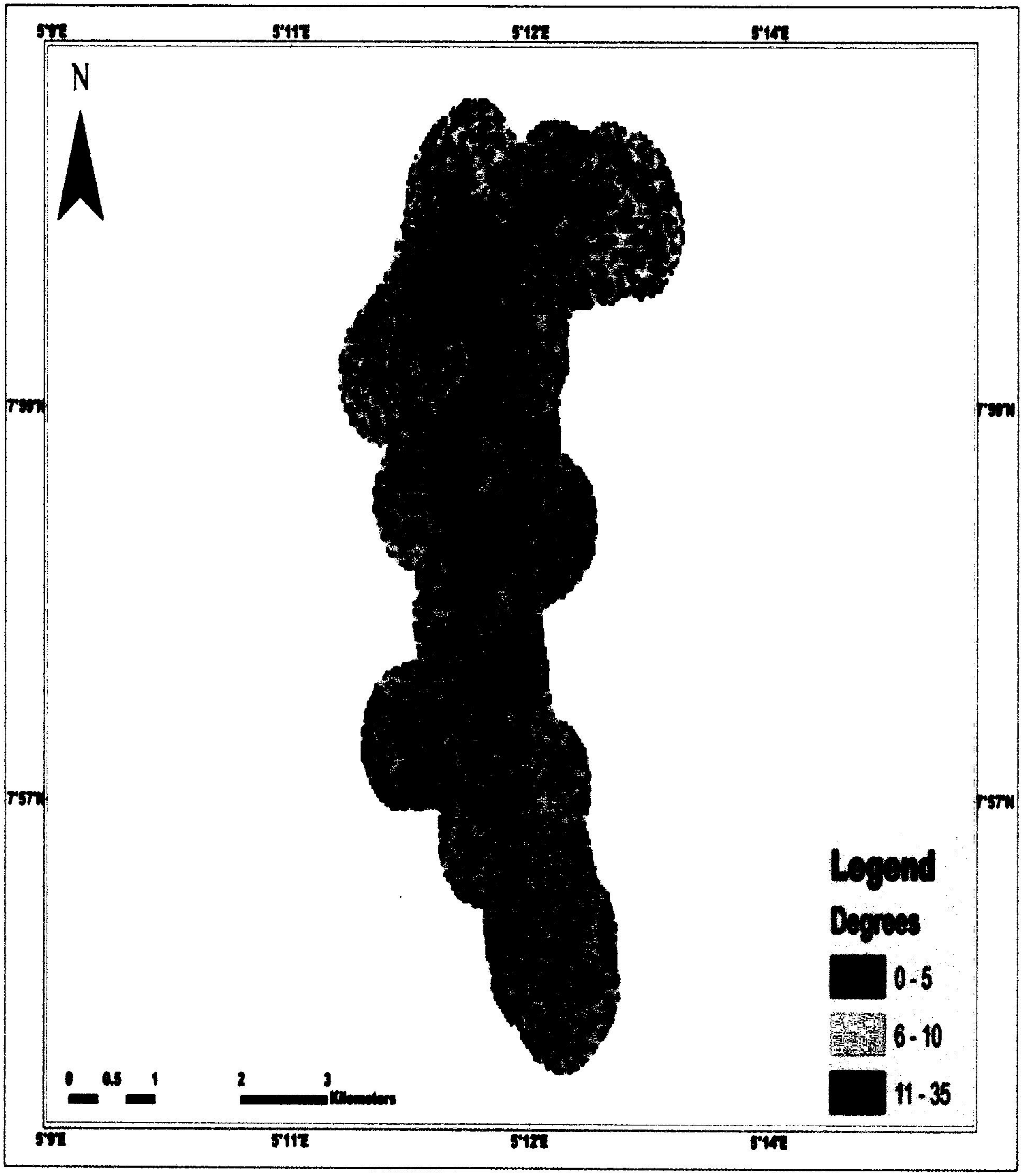


Figure 7: Slope of the reservoir and its environment

Source: United State Geological Survey, 2017

4.5 Hydrological Parameters of the Study Area

Hydrological parameters of the study are presented on Table 7. Maps of rainfall, runoffs, water index and water stress index are presented on Figures 8, 9, 10 and 11 respectively. Rainfall on the study area ranged between 1539 and 1659. Results further indicated that that 70.58% of the study area had runoffs that ranged between 1.86 and 1.90, 24.95% of the study area had run offs between 1.91 and 1.95 while 4.47 % (66 hectares) had run-off between 1.81 and 1.85. Normalized water index indicated that 82.99% (1226.66) of the study area were bare lands while 251.34 hectares representing 17.01 % of the study area were water filled. Moisture stress index ranged between 0.66 and 2.37. 30.32% (454 hectares) of the study area had MSI between 0.66 and 0.83, 561.09 hectares (37.96%) of the study area had MSI that ranged between 0.84 – 0.93 while 31.32% (462.91) had MSI between 0.94 and 2.37.

Table 7: Hydrological Parameters of the Study Area

Parameters	Area cover (Hectares)	Proportion (%)
Rainfall classes		
1539 – 1574	368.81	24.95
1575 – 1613	1043.19	70.58
1613 – 1656	66.00	4.47
Total	**1478.00**	**100.00**
Runoff classes		
1.81 - 1.85	66.00	4.47
1.86 - 1.90	1043.19	70.58
1.91 - 1.95	368.81	24.95
Total	**1478.00**	**100.00**
NDWI classes		
Water-filled areas	251.34	17.01
Bare lands	1226.66	82.99
Total	1478.00	100.00
MSI classes		
0.66 - 0.83	454.00	30.72
0.84 - 0.93	561.09	37.96
0.94 - 2.37	462.91	31.32
Total	1478.00	100.00

Figure 8: Amount of Rainfall in and around the reservoir

Source: United State Geological Survey (2017)

The Ero reservoirs and its environs recorded bi-modal rainy seasons and often experiences heavy rainfall that builds up gradually late April to a maximum in July/August with irregular dry spells occurring around late August. The rainfall increases in mid-August and peak again in September before it finally declined sharply in October drawing to a complete halt, thereby setting-in the dry season. Rainfall in the study area ranged between 1539mm and 1659mm, with 24.95% of the area having a rainfall of between 1539mm to 1574mm, 70.58% of the area measuring a total of 1043.19mmhectares had an average rainfall of 1575mm to 1613mm and the last class of rainfall in the study area had between 1613mm to 1656mm rainfall in about 66 hectares representing 4.47% of the area.

Generally, the hydrological data from the region being considered showed an area having a medium rainfall distribution mostly a rain forest region. The accompanying runoff class and water indexes present a large area that is adequately drained. This scenario shows to a large extent that large volumes of water are easily drained from the catchment into the water bodies which will in turn favour water and aquatic body dependent organisms as well as others consumers of water in the area. It also indicates optimum hydrological conditions which will therefore lead to a more balanced hydro-ecological system.

Yoo and Boyd (2007) reported that the major source of water for filling and maintaining water levels in ponds are surface runoff from springs affected by rainfall. Boyd (2007) stated that the availability of water inland aquaculture is closely related to rainfall and an understanding of local rainfall patterns is of paramount importance in pond management. The neutralization of accumulative effects of waste in fish ponds depends on rain intensity and continuous water flow system. Rains have two distinct effects on water quality in shallow fish-producing systems: a diluting effect by which excess of nutrients, food remains and other materials in the water diminishes; and an increase in turbidity due to excess of particles from sediments in the water. Rainfall causes transport of nutrients and particles, such as agricultural residues, salt particles and materials from rivers and streams, by draining water from margins to the ponds and directly affecting the chemical composition of water (Boyd, 2007).

Rainfall regimen in shallow systems is a main activity which affects the concentration and distribution of inorganic and dissolved nutrients, heat throughout the water column and suspended materials, and, consequently, transparency and depth (Landa, 2009). The excess flow of water as a result of torrent rainfall was shown to have increased the drainage density, runoff, flow discharge, among others. Australian Institute of marine science, states that increased run-off leads to erosion, degradation of water quality and it could result in flooding and this generally affects the success and productivity of ponds in high rainfall/flood prone environments.

Sites attributes of land suitability model for aquaculture development in and around the Reservoir were presented in four different layers representing degree of suitability for it development. The land mass unsuitable for aquaculture development covered 89.73 hectares (6.07%) of the whole area, meaning that aquaculture cannot be practised in these areas. This could be as a result of the presence of hills, rocks, which would make it impossible to practice aquaculture in these areas that has been marked as unsuitable. 359.88 hectares (24.35%) were less suitable; meaning that aquaculture could be practised there, but the presence of some factors such as presence of dense forest, high elevation and slope would increase the cost of clearing and ultimately increase production cost.

Equally site classified as less suitable could also have the presence of less desirable soil parameters, which could affect pond productivity. Less productive soil will increase cost of management as fertilizer and liming would be needed to correct the pH and NPK contents of the soil. Equally, the topography of the location might not be up to/more than recommended slope level r for aquaculture. Majority (950.56 ha) representing 64.33% of the total land mass around Ero reservoir was suitable, i.e, good for aquaculture practice. Choosing the right site ranks second after identifying markets for your product. The fertility of the soil around the sites that were suitable would encourage the development of a benthic community. They may equally contain best soils contained at least 20 or 30% clay. The soils samples in such soils would have right amount of clay content, which will prevent cracking and seepage and thereby reduce maintenance costs.

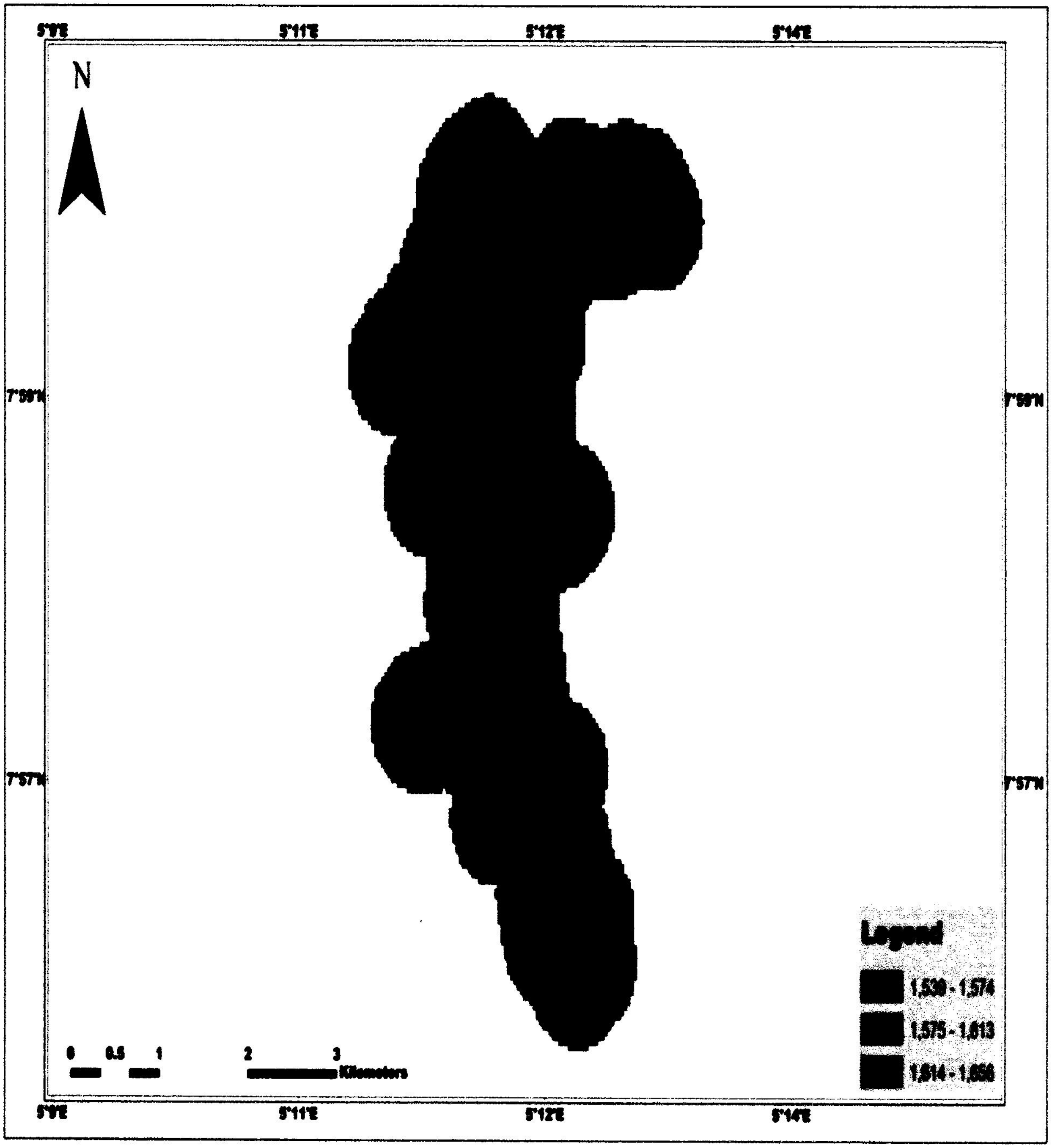


Figure 8: Amount of Rainfall in and around the reservoir

Source: United State Geological Survey (2017)

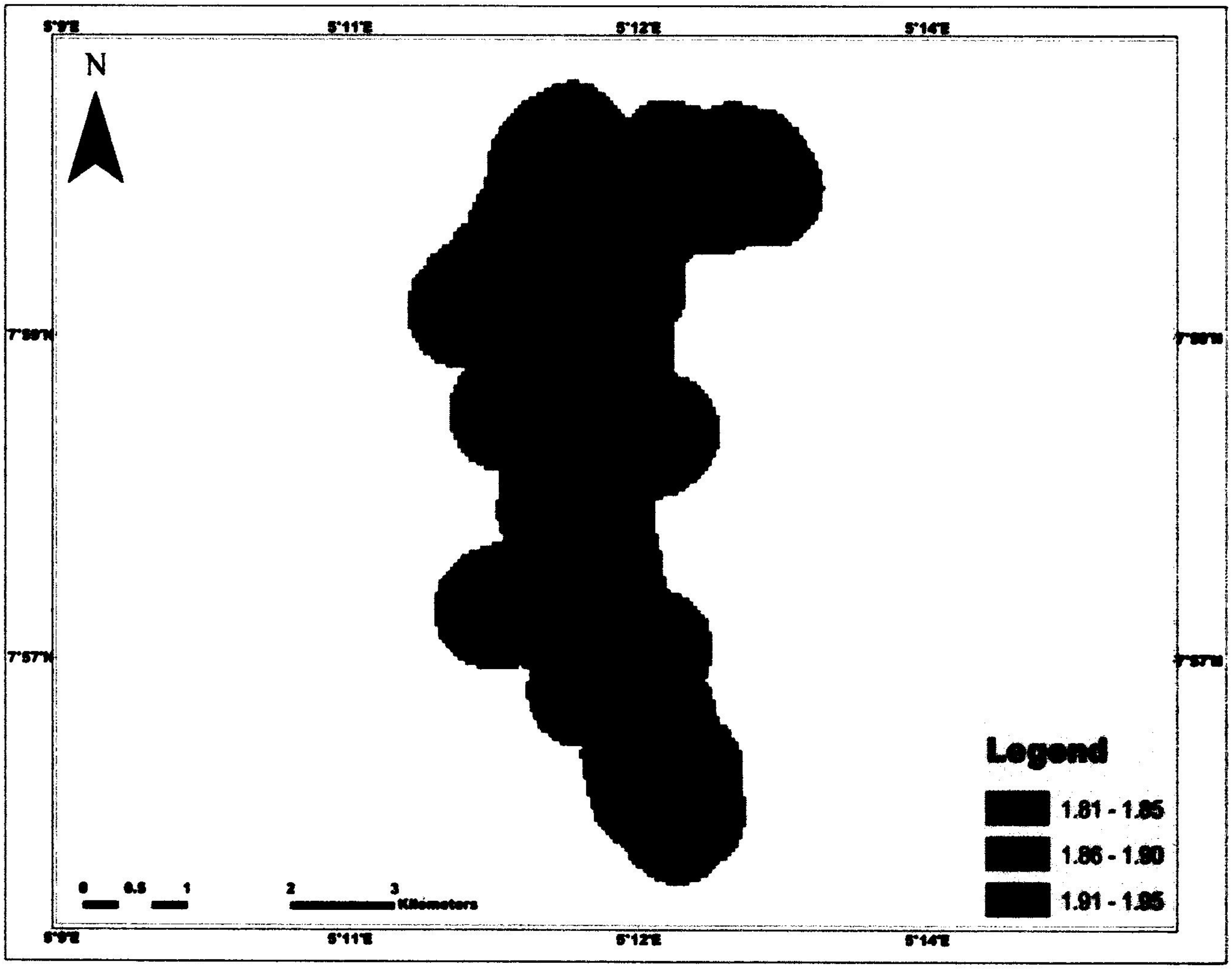


Figure 9: Runoff of the reservoir and its environment

Source: United State Geological Survey, 2017

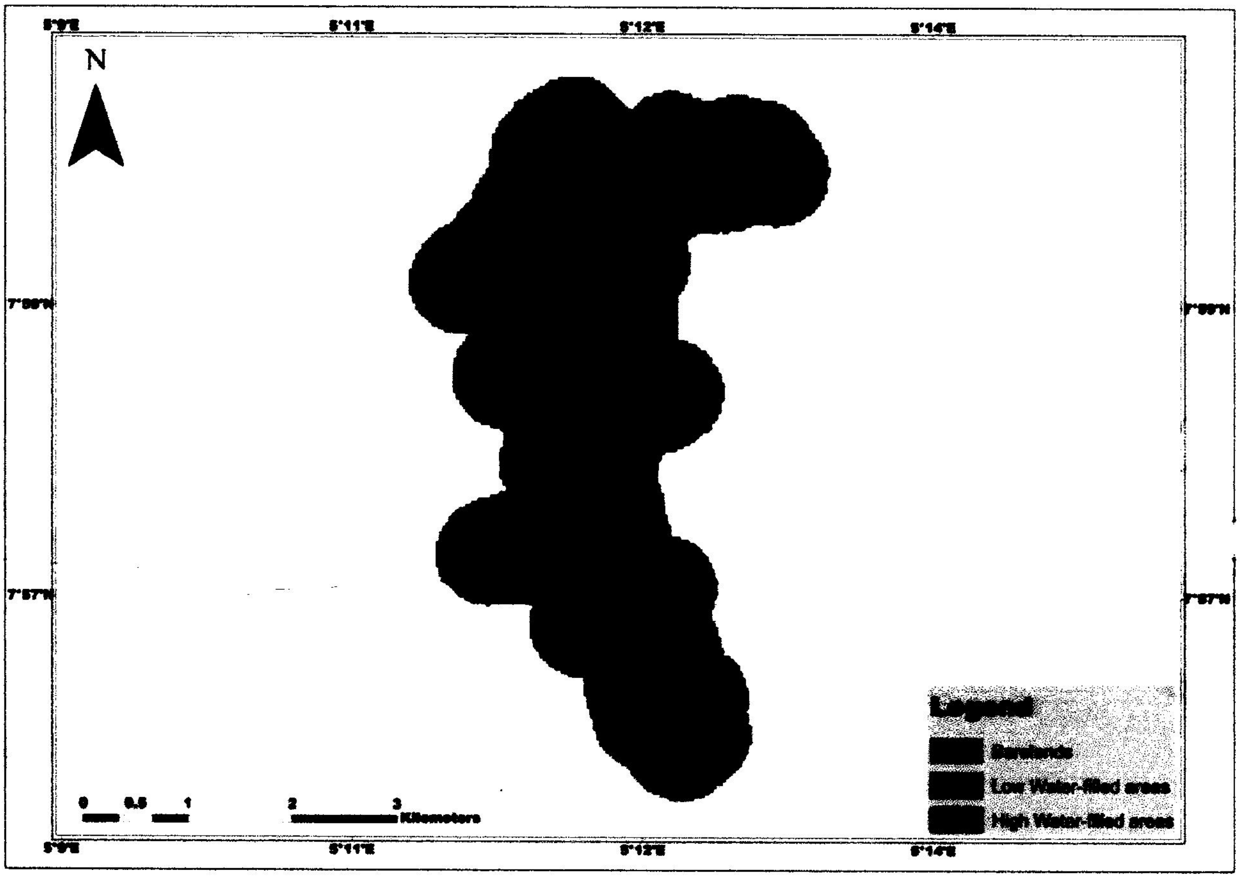


Figure 10: Normalized Difference Water Index of the reservoir and its environment

Source: United State Geological Society, 2017

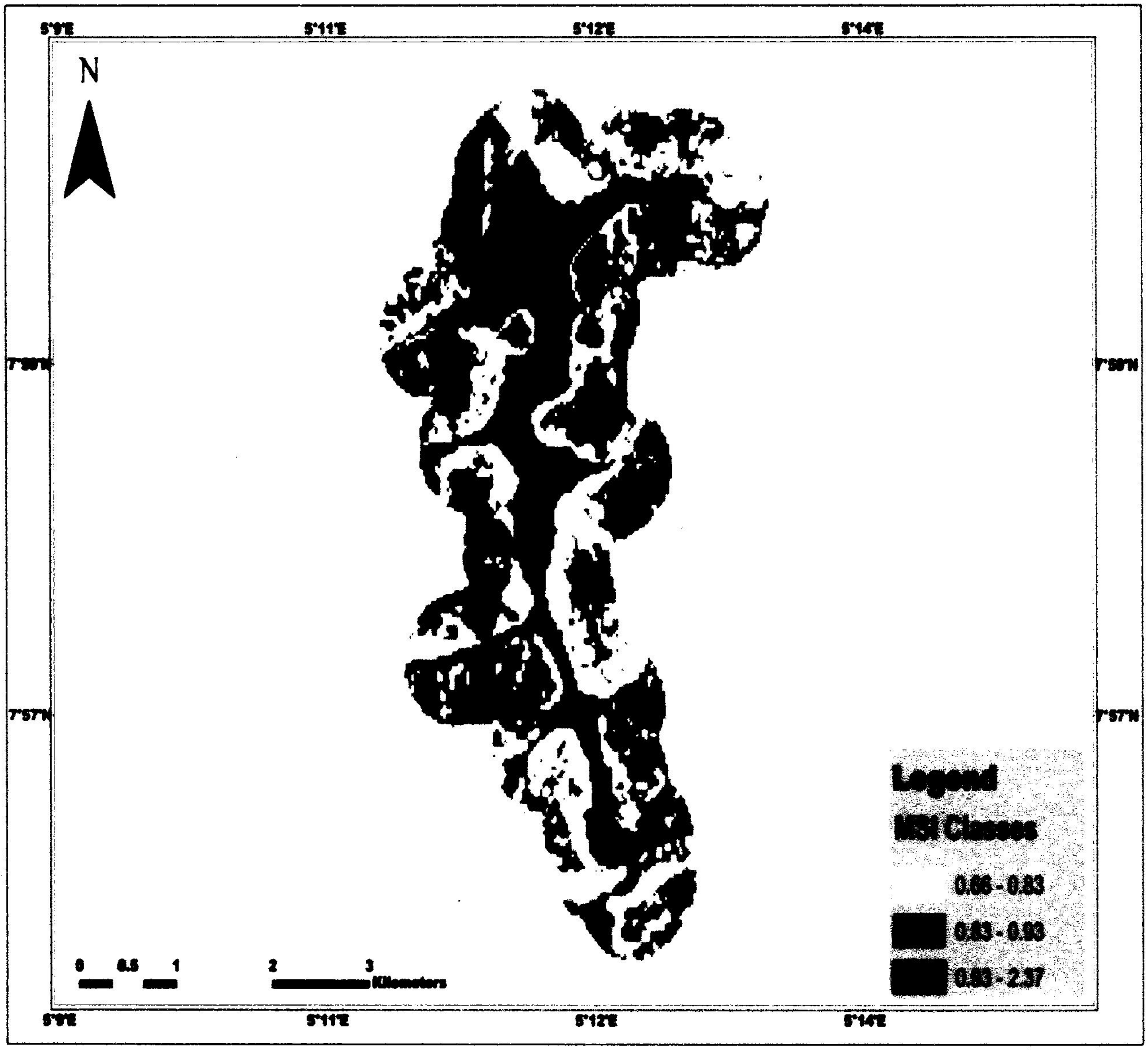


Figure 11: Moisture Stress Index of the reservoir and its environment

Source: United State Geological Survey, 2017

4.6 Suitability Model for Aquaculture Development in Ero Reservoir and Environments

Table 8 and Figure 12 present the land suitability model for aquaculture development with their attributes in and around the reservoir. From the land suitability map, it was observed that the land mass unsuitable for aquaculture development covered 89.73 hectares (6.07%) of the whole area, 359.88 hectares (24.35%) were less suitable, 950.76 hectares (64.33%) were suitable, and 77.63 hectares (5.25%) are highly suitable.

Table 8: Attributes of land suitability model for aquaculture development in and around the Reservoir

Suitability classes	Area cover (Hectares)	Proportion (%)
Not suitable	89.73	6.07
Less suitable	359.88	24.35
Suitable	950.76	64.33
Highly suitable	77.63	5.25
Total	**1,478.00**	**100.00**

Source: United State Geological Survey, 2017

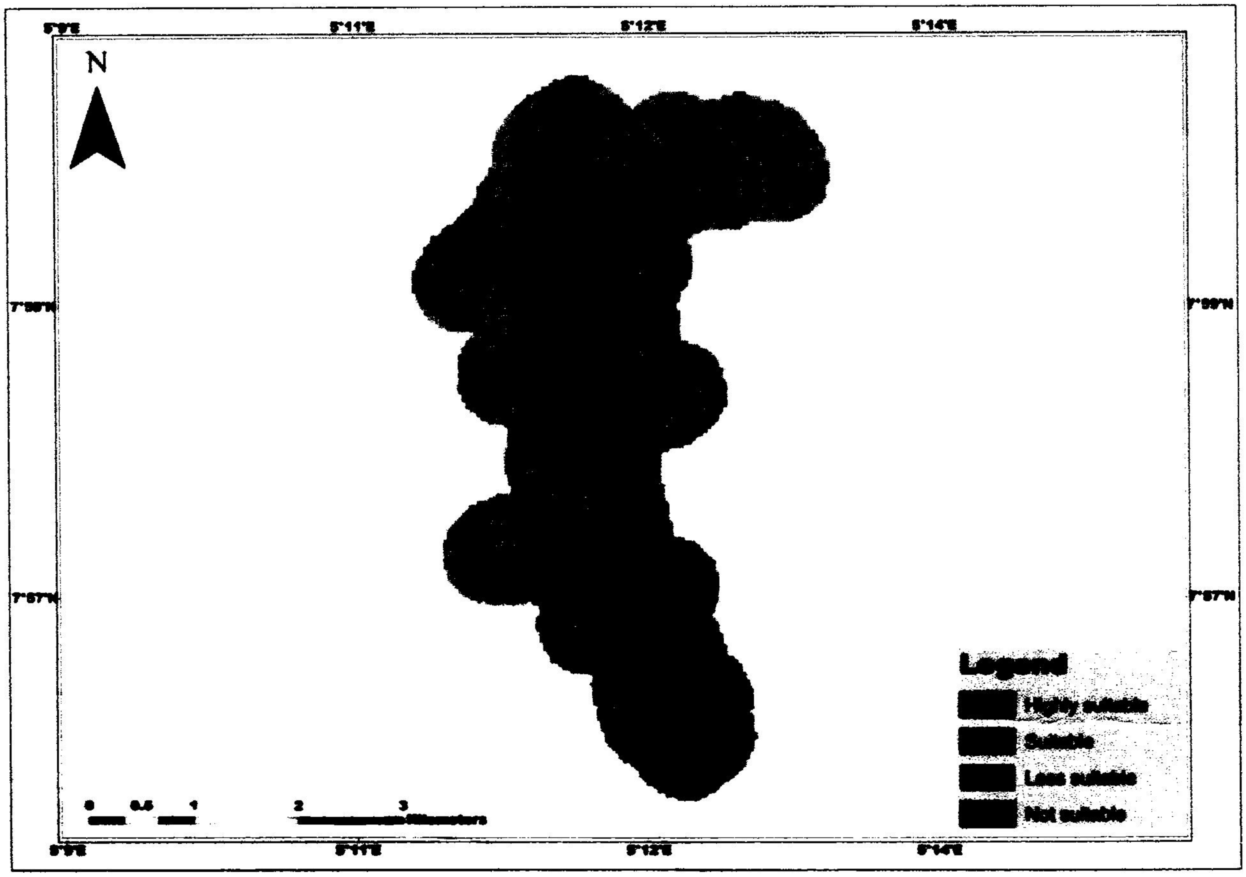


Figure 12: Land Suitability Model for Aquaculture Development in and around Ero Reservoir, Nigeria

Source: United State Geological Society, 2017

Chapter Five

5.0 Conclusion and Recommendation

5.1 Conclusion

The advantage of using remote sensing technique and GIS was not only time and cost effectiveness but it also helped to achieve a more comprehensive and integrated management for aquaculture development criteria, which is difficult through conventional techniques alone. The study established a considerable potential for further exploitation of GIS for optimisation of aquaculture activities in Ekiti State, Nigeria. Furthermore, it demonstrated the effectiveness of using remotely sensed data in providing the necessary spatial information for generating information layers required for aquaculture development. Using this approach, planning of aquaculture could effectively be adapted to local contexts in order to introduce appropriate aquaculture related livelihood options and help alleviate rural poverty in Ekiti state, Nigeria. With this in mind, the expansion of aquaculture in Ekiti State, Nigeria is necessary since the results indicated the possibility of developing aquaculture in the study area is hig h. Hence, individuals, corporate bodies and the Ekiti State Government could invest in the suitable areas for aquaculture development. This will at the long run increase fish availability, create employment, improve livelihood and enhance economic drive of the State.

5.2 Recommendation

The study established the importance of GIS in aquaculture development. Hence, individuals, corporate bodies and the Ekiti State Government could invest in the suitable areas for aquaculture development. This will at the long run increase fish availability, create employment, improve livelihood and enhance economic drive of the State.

The high agricultural potentials of Ekiti State makes the state to standout as major producer of wide varieties of crops, fishes and species of livestock. The abundant human resource in Ekiti State is an added advantage which every interested investor should come to tap for sustainable income and economic development of the state and Nigeria as a whole.

References

Adhikari, S. (2007): Fertilization, Soil and Water quality Management in small-scale ponds: Fertilization requirements and soil properties, 3 pp.

Aguilar-Manjarrez,J., Bensch,A., Carocci, F., Graaf,G., and Taconet, M (2007): use of Geographical Information System (GIS) for Responsible Aquatic Resource Management, *FAO Aquaculture Newsletter*, 7pp.

Alan J. Frans (2009): Depth distribution of soil organic carbon as a signature of soil quality, 11 pp.

Amao J. O, Oluwatayo I. B and Osuntope F. K. (2006): Economics of fish demands in Lagos State, Nigeria. *J. Hum. Ecol.* 19(1):25-30.

Andi G.T, Dahlifa, R. M, and AndiRezki P.A. (2013): Land Suitability Analysis of Tiger Shrimp Aquaculture (*Penaeusmonodon*. Fab) in the Coastal Area of Labakkang District South Sulawesi - Indonesia. *J.ofAquac Res Development* 5: 214 doi:10.4172/2155-9546.1000214.

Araya, Y. H., and Cabral, P. (2010): Analysis and modeling of urban land cover change, Portugal. *Remote Sens.*, 1(*2*): 1549–1563.

Ashok K. Nayak, D. Pant, P. Kumar, Mahanta P. C. and Pandey N. N. (2014): GIS-based aquaculture site suitability study using multi-criteria evaluation approach, *Indian J. Fish., 61(1) : 108-112.*

Atanda, A. N.(2007):Freshwater fish seed resources in Nigeria, Assessment of Freshwater Fish Seed Resources for Sustainable Aquaculture, FAO Fisheries Technical Paper, No. 501, FAO, Rome, 361–380.

Boyd, C.E., (2007): *Soil quality: An introduction,* Kluwer Academic Publishers, London, 330pp.

Boyd C. E, and Julio F Queiroz (2010): The role and Management of bottom soil in Aquaculture ponds, 6 pp.

Boyd C. E, Wood C.W., and Taworn. T. (2010): Aquaculture Pond Bottom Soil quality Management, 48 pp.

Brummett, R., (2007): Fish Seed Supply Study: Africa Synthesis,World Fish Center Technical Paper.

Bhukaswan, T., (2007): The Nam Pong Basin (Thailand). *FAO Fishery Technical Paper*, 265. Food and Agriculture Organization of the United Nations, Rome.

Bureau of Statistics, (2007): *China Statistics Yearbook 2006.* China Statistics Press, Beijing, China.

Cayelan C, Carey Bas W, Ibelings H, Emily P.H, David P.H. (2012): Eco-Physiological Adaptations That Favour Freshwater Cyanobacteria In A Changing Climate. Original Research Article Water Research 46: 1394-1407.

Chen, X., (2006): Practice and discussion on investigation and development of fisheries resources in You Xi JieMian Reservoir in Fujian province. *Journal ofFujian Fisheries*, (1): 84-86.

Coates, D., (2007): Inland capture fishery statistics of Southeast Asia: current status and information needs. FAO RAP Publication 2002/11. Food and Agriculture Organization of the United Nations, Bangkok, 12pp.

Collie, J. S., Vic-Adamowicz, W. L., Beck, M. W., Craig, B., Essington, T. E., Fluharty, D., (2013): Marine spatial planning in practice. *Estuarine, Coastal and Shelf Science,117,* 1–11.

Das, A.K., Vass, K.K, and Shrivastava P.K (2009): Cage Culture in Reservoirs in India. (A Handbook) WorldFishCenter, Technical Manual No. 1948. The WorldFishCenter, Penang, Malaysia, 34pp.

De Silva, S.S. and Funge-Smith, S.(2007): A review of stock enhancement practices in the inland water fisheries of Asia. *FAO RAP Publication 2005/12*. Food and Agriculture Organization of the United Nations, Bangkok.

De Silva, S.S. and Amarasinghe, U.S. (2008): Status of reservoir fisheries in five Asian countries, Monograph No 2, *Network of Aquaculture Centre in Asian-Pacific*, Bangkok, Thailand, 113pp

Douvere, F. (2008): The importance of marine spatial planning in advancing ecosystem-based sea use management. *Marine Policy,32,* 762–771.

Douvere, F. and Ehler, C. N. (2010): The importance of monitoring and evaluation in adaptive maritime spatial planning. *Journal of Coast Conservation*,24pp.

Ekiti State Department of Fisheries Services (2009):*Annual Report*, 5pp.

Ekunwe P.A., and Emokaro C.O(2009): Technical Efficiency of Catfish Farmers in Kaduna, Nigeria Journal of Applied Sciences Research. 5(7):802-805.

Federal Department of Fisheries (2010): Presidential Forum on Fisheries and Aquaculture: Status and Opportunities, 70pp.

Folayan A. (2010):Economic and Investment Opportunities in Agricultural Commodities in Ekiti State, paper presented at the Ekiti State 2010 Agricultural Summit held in Ado-Ekiti,12pp.

Food Agricultural Organization (2007): Geographic information systems, Remote Sensing and Mapping for the Development and Management of marine aquaculture, *FAO Fisheries Technical paper*, 140pp.

Food and Agricultural Organization (2008): Soil quality consideration in the selection of sites for aquaculture, *Fisheries Technical paper*,54pp.

Food Agricultural Organization (2014): *Fisheries and Aquaculture Statistics Report*, Rome, Italy, 105pp.

Food and Agricultural Organization(2016): Fisheries and Aquaculture Development, 2016, 1 -2.

Gunjan Karnatak., and Vikash Kumar, (2014): Potential of cage aquaculture in Indian reservoirs, *International Journal of Fisheries and Aquatic Studies* 1(6): 108-112

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., (2008): A global map of human impact on marine ecosystems. *Science,319,* 948–952.

Hishamunda, N., Bueno, P.B., Ridler, N., and Yap, W.G.(2009):Analysis of aquaculture development in Southeast Asia: a policy perspective. *FAO Fisheries and Aquaculture Technical Paper*. No. 509. Rome, 69pp.

James M. K. and Jose A. M. (2007): Geographic Information Systems, Remote Sensing and Mapping for the Development and Management of Marine Aquaculture, FAO Fisheries Technical Paper 458, pp11 – 100.

Jiashou Liu., Zhongjie Li., and Songguang Xie, (2007):Achievements, Challenges and Strategies for Reservoir Fisheries Development in China, pp13.

José Aguilar-Manjarrez., Alexis Bensch.,Fabio Carocci., Gertjan de Graafand Marc Taconet (2008): Use of Geographic Information Systems (GIS) for Responsible Aquatic Resource Management, Pp7.

Kairo, J. G., Kivyatu, B. and Koedam A, (2007): Application of Remote Sensing and GIS in the Management of Mangrove Forests within and Adjacent ToKiunga Marine Protected Area, *Environ. Dev. Sustain.* 2(5): 12-14.

Kamal-Ahmed S.K., Anamul-Hogue B.M. and Jobaer S.M. (2013): Effect of Export and Import on the GDP of Bangladesh: An Empirical Analysis, International J. of Management, 2(3):28-37.

Katsanevakis, S., Stelzenmüller, V., South, A., Sørensen, T. K., Jones, P. J. S., and Kerr, S.,(2011): Ecosystem-based marine spatial management: Review of concepts, policies, tools, and critical issues. *Ocean and Coastal Management,* 1*(54):* 807–820.

Kaurs. M and Khan A. (2015): Effect of fertilization and Organic Matter on water quality Dynamics, a proximate composition of Cyprinus Carpio, 20pp.

Kutty M.N (2007): Site Selection for Aquaculture: Technical and Non –Technical consideration, pp8.

Masoumi E., Salarzehi H., Arbatani T., and Dezhkam J. (2015): Strategic Analysis of Fishery Industry Development in Iran, Asian *J. of Res. In Business Econ. And Mgt.,* 5(1):180-197.

Micheal Clement(2012): Spatial Planning and Bio-economic Analysis for Offshore Shrimp Aquaculture in Northwest Mexico, pp49.

Miller, J. W and Atanda T. (2011): The rise of peri-urban aquaculture in Nigeria, International *Journal of Agricultural Sustainability*, 9(1): 274-28

Ministry of Agriculture, China (2006):*China Agricultural Yearbook* China Agricultural Press, Beijing, China

Muir, J. F., Gitonga, N., Omar, I., Pouomogne, V., Radwan, I.(,2007): Hidden Harvests: Unlocking the Potential ofAquaculture in Africa, *Technical Review paper*, New Economic Partnership for African Development-Fish for All Summit, 22–25 August, Abuja, Nigeria.

National Bureau of Statistics (2016): Nigerian Gross Domestic Product Report Quarter Two 2016, http://nigerianstat.gov.ng/report/434. accessed on 10th February, 2017.

Nicholas E. Okwodu(2016):Aquaculture for sustainable development in Nigeria, *World scientific news,* 47(2):151-163.

Noelani P, Lisa C, Maria H, James P, Christopher L and Steven G (2014): Development of a GIS-Based Tool for Aquaculture Siting, pp17.

Nobre, A.M., Bricker, S.B., Ferreira, J.G., Yan, X., De Wit M, Nunes, J.P. (2010): Integrated environmental modeling and assessment of coastal ecosystems: Application for aquaculture management. *Coast. Manag.,* 1(*39*): 536–555.

Nguyen H.S., Bui, A.T., Le, L.T., Nguyen, T.T.T., De Silva, S.S.,(2007): The culture-based fisheries in small, farmer-managed reservoirs in two provinces of northern Vietnam: an evaluation based on three production cycles. Aquaculture Research, (32): 975–990.

Nguyen V. H., and Tran H. C. (2012): Freshwater Aquaculture's Contribution To Food Security In Vietnam: A case study of freshwater tilapia aquaculture in Hai Duong province,*J. ISSAAS* 18 (1):6-17 .

Odukwe A (2007): Fish farming in the tropics. A functional approach maxiprints, Awka, Nigeria, Book review, 18pp.

Osawe M (2007): Technical Know-how of catfish grow out for table size in 4-6 months. Proc. Seminar on Modern Fish Farming by DynamoCatfish Production, Lagos, Nigeria. pp. 1-14.

Oyase, A., and Jemerigbe, R, (2016): Contribution of aquaculture to poverty reduction and food security in Nigeria, *International J. of App. Micro. And Biotech Research*, 4 (2016) 26-31.

Ozigbo E, Anyadike C, Adegbite O and Kolawole P(2014): Review of Aquaculture Production and Management in Nigeria, *American Journal of Experimental Agriculture 4(10)*:2-3.

Pérez, O. M. Telfer, T. C, Ross, L. G.(2007): Use of GIS-Based Models for Integrating and Developing Marine Fish Cages within the Tourism Industry in Tenerife (Canary Islands), 12 pp.

Rajchandar P. and Karuppasamy S. (2012): Marine Fishery Information System and Aquaculture Site Selection Using Remote Sensing and GIS, *International Journal of Advanced Remote Sensing and GIS*, 1(1):20-33.

Richard A. (2016): Site selection analysis for suitable Aquaculture fish pond in andonil.g.a. Rivers state, Nigeria, Vol.4 (Iss.3).

Ridge Partners (2010): Overview of the Australian Fishing and Aquaculture Industry: Present and Future, 150pp.

Rita Cestti and. Malik R. P. S (2008): Indirect Economic Impacts of Dams,pp18.

Rossiter , D.G (2007) Classification of Urban and Industrial Soils in the World Reference Base For Soil Resources. J Soils Sediments 7: 96-100.

Ragbirsingh. and De Susan, G.(2007):sites suitability for Aquaculture Development on the Caroni river Basin, Trinad West indice, using GIS, pp13.

Shi, W.,(2007): Fish Enhancement and Aquaculture in Inland Open Waters, China Agricultural Press, Beijing, China.

TDRI,(2009): Thailand natural resource profile: Is the resource base for Thailand's development sustainable ?Thailand Development and Research Institute (TDRI), Bangkok.

Tortajada C.(2012): *Impacts of Large Dams*: *A Global Assessment*, Water Resources Development and Management, DOI 10.1007/978-3-642-23571-9_2

Ujjwala Jadhav(2009): Aquaculture Technology and Environment: pp367.

Vass, K.K. (2007):*Comparative limnology of lakes in Indus, Gangetic and Brahamaputra basins in India*. Abstr. SIL Congress, Canada.

Vass, K.K. (2007):Indian Reservoir Fisheries Development – Constraints and Solutions. *Fishing Chimes*, 27(1): 76-81.

Virapat, C., and Mattson, N.S., (2008): Inventory of reservoir fishery resources in thailand In: De Silva S.S. *Reservoir and Culture-based Fisheries: Biologyand Management*. ACIAR Proceeding No. 98. Australian Centre for International Agricultural Research, Canberra.

Virapat, C., Phimonbutra, U.,andChantarawaratid, C., (2007): *Fishery and Fisheries Management in Thai Reservoirs*. Review and Assessment. Management ofReservoir Fisheries in the Mekong Basin. Mekong River Commission, Vientiane.

Water resources department, pune (2009): laboratory testing procedure for soil & water sample analysis, 134 pp.

White, K., O'Neill, B., and Tzankova. Z (2008): At a Crossroads: Will Aquaculture Fulfill the Promise of the Blue Revolution, pp17.

Wikipedia (2017): Definition of Geographic information systems, ttps://www.google.com/search?q=defination+of+gis&ie=utf-8&oe=utf-8&rls=org.mozilla:en-US:official&client=firefoxbeta&channel=sb&gfe_rd=cr&ei=BzusWJS-ONPG8Ae575zoDQ, accessed on 21st February, 2017.

Wikipedia (2017): Definition of Reservoir,https://en.wikipedia.org/wiki/Special:Search?search=DEFINATION+OF+RESERVOIR&sourceid=Mozillasearch&searchToken=9954w0gaf77dav4tfa15zkbhd, accessed on 15th September, 2017.

Wikipedia (2017): List of Nigerian states by GDP, https://en.wikipedia.org/wiki/List_of_Nigerian_states_by_GDP, accessed on 12th January, 2017.

Wurts A. (2008): Aquaculture Site Selection, 2 Pp.

Xing, Y., Lin, Z. (2007):Investigation to plankton in Kunlong Reservoir and analysis on the fish productivity. *Reservoir Fisheries*, 1(27): 61-62.

Yoo, R.H. and Boyd, C.E. (2007): *Hydrology and water supply for pond aquaculture*. Chapman & Hall Publisher, New York, 483pp.

Zafar M. A., Haque, M. M. Aziz M. S. B. andAlam M. M. (2015): Study on water and soil quality parameters of shrimp and prawn farming in the southwest region of Bangladesh, *J. Bangladesh Agril. Univ.* 13(1): 153–160.

Zhou, H.D, Jiang, C., Zhu, L., Wang, X., Hu, X., Cheng, J. and Xie, J. (2011): Impact of pond and fence aquaculture on reservoir environment, *Water Science and Engineering*, 4(1): 92

Appendices

Appendix 1: Physiochemical Properties of Soil Collected from Different Locations

Descriptive

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pH	Location 1	4	6.9450	.21174	.10587	6.6081	7.2819	6.65	7.13
	Location 2	4	6.9400	.19916	.09958	6.6231	7.2569	6.76	7.15
	Location 3	4	7.0775	.11087	.05543	6.9011	7.2539	6.92	7.16
	Total	12	6.9875	.17556	.05068	6.8760	7.0990	6.65	7.16
Organic C	Location 1	4	1.6950	.26640	.13320	1.2711	2.1189	1.40	2.01
	Location 2	4	1.6125	.23056	.11528	1.2456	1.9794	1.42	1.94
	Location 3	4	1.5775	.22396	.11198	1.2211	1.9339	1.32	1.85
	Total	12	1.6283	.22401	.06467	1.4860	1.7707	1.32	2.01
Organic Matter	Location 1	4	1.6175	.33490	.16745	1.0846	2.1504	1.20	1.96
	Location 2	4	1.5600	.39766	.19883	.9272	2.1928	1.10	2.02
	Location 3	4	1.8175	.39042	.19521	1.1963	2.4387	1.40	2.30
	Total	12	1.6650	.35857	.10351	1.4372	1.8928	1.10	2.30
Nitrogen	Location 1	4	.0525	.03594	.01797	-.0047	.1097	.02	.10
	Location 2	4	.0800	.05657	.02828	-.0100	.1700	.04	.16
	Location 3	4	.0500	.04690	.02345	-.0246	.1246	.02	.12
	Total	12	.0608	.04502	.01300	.0322	.0894	.02	.16
Phosphorus	Location 1	4	4.3400	.64410	.32205	3.3151	5.3649	3.71	5.18
	Location 2	4	3.7625	.33019	.16509	3.2371	4.2879	3.29	3.99
	Location 3	4	4.6200	2.85602	1.42801	.0754	9.1646	2.17	8.75
	Total	12	4.2408	1.58320	.45703	3.2349	5.2468	2.17	8.75

Potassium	Location 1	4	.2350	.08583	.04291	.0984	.3716	.16	.34
	Location 2	4	.3650	.13229	.06614	.1545	.5755	.24	.54
	Location 3	4	.2475	.05737	.02869	.1562	.3388	.20	.33
	Total	12	.2825	.10687	.03085	.2146	.3504	.16	.54
Sodium	Location 1	4	.2425	.01500	.00750	.2186	.2664	.23	.26
	Location 2	4	.2350	.04509	.02255	.1632	.3068	.20	.30
	Location 3	4	.2300	.01414	.00707	.2075	.2525	.21	.24
	Total	12	.2358	.02644	.00763	.2190	.2526	.20	.30
Calcium	Location 1	4	1.7250	.46458	.23229	.9858	2.4642	1.30	2.30
	Location 2	4	1.3750	.12583	.06292	1.1748	1.5752	1.20	1.50
	Location 3	4	2.0750	.34034	.17017	1.5334	2.6166	1.80	2.50
	Total	12	1.7250	.42879	.12378	1.4526	1.9974	1.20	2.50
Magnesium	Location 1	4	.7500	.17321	.08660	.4744	1.0256	.60	1.00
	Location 2	4	.6500	.05774	.02887	.5581	.7419	.60	.70
	Location 3	4	.8500	.23805	.11902	.4712	1.2288	.60	1.10
	Total	12	.7500	.17838	.05149	.6367	.8633	.60	1.10
EA	Location 1	4	2.0400	2.11307	1.05654	-1.3224	5.4024	.80	5.20
	Location 2	4	1.3400	.45431	.22716	.6171	2.0629	.96	2.00
	Location 3	4	1.2500	.52599	.26300	.4130	2.0870	.80	2.00
	Total	12	1.5433	1.21882	.35184	.7689	2.3177	.80	5.20
Sand	Location 1	4	48.8000	3.26599	1.63299	43.6031	53.9969	44.80	52.80
	Location 2	4	31.8000	7.61577	3.80789	19.6816	43.9184	21.80	39.80
	Location 3	4	22.8000	7.52773	3.76386	10.8217	34.7783	15.80	29.80
	Total	12	34.4667	12.68738	3.66253	26.4055	42.5278	15.80	52.80
Clay	Location 1	4	34.2000	5.03322	2.51661	26.1910	42.2090	27.20	39.20
	location 2	4	49.9500	11.98263	5.99131	30.8830	69.0170	36.20	65.20
	Location 3	4	56.2000	11.51810	5.75905	37.8721	74.5279	43.20	68.20
	Total	12	46.7833	13.25593	3.82666	38.3609	55.2057	27.20	68.20
Silt	Location 1	4	17.0000	2.00000	1.00000	13.8176	20.1824	16.00	20.00
	Location 2	4	18.2500	4.50000	2.25000	11.0895	25.4105	13.00	24.00
	Location 3	4	21.0000	5.03322	2.51661	12.9910	29.0090	16.00	28.00
	Total	12	18.7500	4.07040	1.17502	16.1638	21.3362	13.00	28.00

CEC	Location 1	4	4.9925	2.64055	1.32027	.7908	9.1942	3.30	8.92
	Location 2	4	3.9650	.53923	.26961	3.1070	4.8230	3.41	4.69
	Location 3	4	4.6500	.71077	.35539	3.5190	5.7810	3.60	5.16
	Total	12	4.5358	1.52241	.43948	3.5685	5.5031	3.30	8.92
WHC	Location 1	4	40.5350	7.79284	3.89642	28.1349	52.9351	33.45	51.66
	Location 2	4	34.2350	10.79971	5.39985	17.0503	51.4197	21.58	47.91
	Location 3	4	35.4375	8.90439	4.45219	21.2686	49.6064	25.20	46.77
	Total	12	36.7358	8.83919	2.55165	31.1197	42.3520	21.58	51.66

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	.049	2	.024	.754	.498
	Within Groups	.290	9	.032		
	Total	.339	11			
Organic C	Between Groups	.029	2	.015	.251	.784
	Within Groups	.523	9	.058		
	Total	.552	11			
Organic Matter	Between Groups	.146	2	.073	.519	.612
	Within Groups	1.268	9	.141		
	Total	1.414	11			
Nitrogen	Between Groups	.002	2	.001	.497	.624
	Within Groups	.020	9	.002		
	Total	.022	11			
Phosphorus	Between Groups	1.530	2	.765	.264	.773
	Within Groups	26.042	9	2.894		
	Total	27.572	11			
Potassium	Between Groups	.041	2	.021	2.192	.168
	Within Groups	.084	9	.009		
	Total	.126	11			
Sodium	Between Groups	.000	2	.000	.193	.828
	Within Groups	.007	9	.001		
	Total	.008	11			
Calcium	Between Groups	.980	2	.490	4.230	.051
	Within Groups	1.042	9	.116		
	Total	2.023	11			
Magnesium	Between Groups	.080	2	.040	1.333	.311
	Within Groups	.270	9	.030		
	Total	.350	11			
EA	Between Groups	1.496	2	.748	.454	.649
	Within Groups	14.844	9	1.649		
	Total	16.341	11			
Sand	Between Groups	1394.667	2	697.333	16.691	.001
	Within Groups	376.000	9	41.778		
	Total	1770.667	11			
Clay	Between Groups	1028.167	2	514.083	5.114	.033
	Within Groups	904.750	9	100.528		
	Total	1932.917	11			
Silt	Between Groups	33.500	2	16.750	1.013	.401
	Within Groups	148.750	9	16.528		
	Total	182.250	11			
CEC	Between Groups	2.190	2	1.095	.423	.668
	Within Groups	23.305	9	2.589		
	Total	25.495	11			

WHC	Between Groups	89.494	2	44.747	.523	.610
	Within Groups	769.950	9	85.550		
	Total	859.444	11			

Post Hoc Tests

Homogeneous Subsets

pH

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 2	4	6.9400
Location 1	4	6.9450
Location 3	4	7.0775
Sig.		.327

Means for groups in homogeneous subsets are displayed.

Organic Carbon

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 3	4	1.5775
Location 2	4	1.6125
Location 1	4	1.6950
Sig.		.526

Means for groups in homogeneous subsets are displayed.

Organic Matter

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 2	4	1.5600
Location 1	4	1.6175
Location 3	4	1.8175
Sig.		.378

Means for groups in homogeneous subsets are displayed.

Nitrogen

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 3	4	.0500
Location 1	4	.0525
Location 2	4	.0800
Sig.		.412

Means for groups in homogeneous subsets are displayed.

Phosphorus

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 2	4	3.7625
Location 1	4	4.3400
Location 3	4	4.6200
Sig.		.512

Means for groups in homogeneous subsets are displayed.

Potassium

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 1	4	.2350
Location 3	4	.2475
Location 2	4	.3650
Sig.		.103

Means for groups in homogeneous subsets are displayed.

Sodium

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 3	4	.2300
Location 2	4	.2350
Location 1	4	.2425
Sig.		.569

Means for groups in homogeneous subsets are displayed.

Calcium

Duncan

Location	N	Subset for alpha = 0.05	
		1	2
Location 2	4	1.3750	
Location 1	4	1.7250	1.7250
Location 3	4		2.0750
Sig.		.180	.180

Means for groups in homogeneous subsets are displayed.

Magnesium

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 2	4	.6500
Location 1	4	.7500
Location 3	4	.8500
Sig.		.153

Means for groups in homogeneous subsets are displayed.

EA

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 3	4	1.2500
Location 2	4	1.3400
Location 1	4	2.0400
Sig.		.427

Means for groups in homogeneous subsets are displayed.

Sand

Duncan

Location	N	Subset for alpha = 0.05	
		1	2
Location 3	4	22.8000	
Location 2	4	31.8000	
Location 1	4		48.8000

Sig.		.080	1.000

Means for groups in homogeneous subsets are displayed.

Clay

Duncan

Location	N	Subset for alpha = 0.05	
		1	2
Location 1	4	34.2000	
Location 2	4	49.9500	49.9500
Location 3	4		56.2000
Sig.		.053	.401

Means for groups in homogeneous subsets are displayed.

Silt

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 1	4	17.0000
Location 2	4	18.2500
Location 3	4	21.0000
Sig.		.216

Means for groups in homogeneous subsets are displayed.

CEC

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 2	4	3.9650
Location 3	4	4.6500
Location 1	4	4.9925

Sig.		.410

Means for groups in homogeneous subsets are displayed.

WHC

Duncan

Location	N	Subset for alpha = 0.05
		1
Location 2	4	34.2350
Location 3	4	35.4375
Location 1	4	40.5350
Sig.		.381

Means for groups in homogeneous subsets are displayed.