SPATIAL DISTRIBUTION, CONTROL AND ECONOMIC IMPACT OF AQUATIC PLANTS IN AJIWA DAM, KATSINA STATE, NIGERIA

BY

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(SPS/11/MGE/00075)

BEING A PARTIAL FULLFILMENT FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN LAND RESOURCES DEVELOPMENT
(M.Sc. LAND RESOURCES DEVELOPMENT)

DEPARTMENT OF GEOGRAPHY
BAYERO UNIVERSITY KANO

JANUARY, 2016

DECLARATION

I, Waheeda Mukhtar Ibrahim do hereby wish to declare that this work was sincerely done to the best of my knowledge and ability.

_____________________________ ____________________

Signature Date

CERTIFICATION

This is to certify that this work has been thoroughly examined and approved by:

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APPROVAL PAGE

ACKNOWLEDGEMENT

I do hereby wish to express my sincere gratitude to Almighty Allah for giving me the courage, capability and endurance to put this work through, alhamdulilLah.

My next appreciation goes to my dear supervisor Dr Ibrahim Baba Yakubu for guiding me tirelessly and patiently right from scratch through the completion of the work. May Allah, The Almighty reward him abundantly.

I would also like to thank my parents; my mother Dr Zulai Sule Ingawa, my father Alhaji Mukhtar Ibrahim and Honourable Kabir Barau Dankanjiba who contributed in one way or the other for the success of this work.

The next set of gratitude goes to my husband Alhaji Abubakar M. T. Bello, my twin sisters Hassana and Husaina Mukhtar Ibrahim, my brothers Sadeeq, Mukhtar, Hassan and Husain Mukhtar Ibrahim, my baby sisters Hameeda and Sumayya Mukhtar Ibrahim and finally my daughters Baby Zulaiha and Baby Khadija Abubakar Muhammad. Thank you all and may Allah Bless you abundantly.

DEDICATION

This work is dedicated to my beloved parents; Dr Zulai Sule Ingawa and Alhaji Mukhtar Ibrahim may Allah continue to bless and guide them abundantly.

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ABSTRACT

The central aim of this work was to assess the spatial distribution, classification, control and economic impact of aquatic plants dominant in the Ajiwa Dam. The key methodology used to achieve this aim was field survey which adopted the purposive sampling technique whereby samples were collected through wading, using boats or walking along the bank. All macrophytes present were recorded together with the estimated percentage cover of overall macrophytes growth. The principal findings of the work indicated that about 80% of the emergent macrophytes are new and developing and that the distribution of the aquatic plants was highly influenced by the water depth and the rate of fishing and grazing at the area. The most abundant plant is *Typha australis* at 50% closely followed by *Salvinia molesta* at 30% and *Nymphae lotus* was the scarcest at 5%. The aquatic plants could cause serious threat to the activities of irrigation, domestic water supply etcetera by acting as weeds infesting water ways and this work researched how to control them by adopting the economic impacts to be derived from them. It was concluded that aquatic plants pose serious threat to the ecosystem but they could be used in many ways especially for food and medicine to make them environmental friendly and it was recommended that regional workshops be held to better access the wealth of additional information that could not be accessed through this research.

CHAPTER ONE

1.0 INTRODUCTION

Every day of our lives we benefit from what nature provides. The food we eat, the water we drink, the clothes we wear, even our mobile phones and computers have been manufactured with natural resources extracted from species and ecosystems that have played a major role in our success as a civilization. In technologically advanced societies this link to nature may seem distant and probably irrelevant, but it is there through complex supply chains, and we still depend on it. In many parts of the world people rely on the resources nature provides by using them directly, selling them or working in activities that exploit them. Even so, despite the innumerable services that nature provides, for centuries we have consumed these resources as if they were infinite, destroying habitats, putting thousands of species at risk and causing the extinction of many others.

In Katsina State, very little work has been done on the socioeconomic impact of aquatic plants. Anka (2004) did his work on Ajiwa Dam but did not study the socioeconomic impacts of the dam. The work was done at smaller scope and did not cover the whole state; just some enclaves. However, it must be stated that policy issues and environmental consequences to the immediate neighbourhood or surroundings were omitted from the researches.

Lancar and Krake (2002) attributed macrophytes as weeds that often reduce the effectiveness of dams for fish production, irrigation, domestic water supply and flood control. They went further to state that many aquatic plants are desirable since they play temporarily, a beneficial role in reducing agricultural, domestic and industrial pollution and that they play a useful role of providing continuous supply of phytoplankton and help fish production. This shows that there is indeed some spatial distribution in the socioeconomic benefits to be derived from these macrophytes.

Additionally, the rapid rate of urbanization in Nigeria results in the proliferation of more dams and/or upgrade of existing ones. Kumar (1999) stated that after several decades of evolving dam construction activity, even today's needs are far from satisfied in many developing regions. This shows that developing countries are still in need of constructing more and more dams which provides more room for developing such management studies that could help to ameliorate the challenges faced by such dams; the excessive growth of aquatic plants to be precise.

Worldwide, over 45,000 large dams have been built, and nearly half the world's rivers are obstructed by a large dam. The belief that large dams, by increasing irrigation and hydroelectricity production, can cause development and reduce poverty has led developing countries and international agencies such as the World Bank to undertake major investments in dam construction. By the year 2000, dams generated 19% of the world's electricity supply and irrigated over 30% of the 271 million hectares irrigated worldwide (Wetzel, 2001). However, these dams also displaced over 40 million people, altered cropping patterns, and significantly increased salination and water logging of arable land (Dreeze et al; 1997). The distribution of the costs and benefits of large dams across population groups, and, in particular, the extent to which the rural poor have benefited, are issues that remain widely debated. In the context of this research however, such benefits are restricted to the impact of aquatic macrophytes that are situated at the Ajiwa Dam.

Dams provide a particularly good opportunity to study the potential disjunction between the distributional and productivity implications of a public policy. The technology of dam construction implies that those who live downstream from a dam stand to benefit, while those in the vicinity of and upstream from a dam stand to lose. From an econometric viewpoint, this implies that we can isolate the impact of dams on the two populations, and from a policy perspective, this suggests compensating losers is relatively easy. The inadequacy of compensation in such a comparatively simple case would suggest that the distributional consequences of public policies are, perhaps, harder to remedy than is typically assumed.

Generally, aquatic ecosystem is comprised of a wide diversity of flora and fauna genetic resources and other minor products that increasingly serve human needs through their contributions to agriculture, industry, medicine and energy. The composition of the flora species of the Nigerian aquatic environment has not been fully studied and documented (lmevbore and Bakare 1974). Many individuals such as Gallagher (2007) and Anwar (1990) regardaquatic macrophytes as "weeds" which infest waterways and interfere with navigation, irrigation, fisheries production and water quality, while they inadvertently tend to overlook the benefits and services rendered by aquatic macrophytes.

The aquatic environment is vastly different from the terrestrial environment with which we are more familiar. Compared to air, water is a more viscous medium, a better solvent, and more stable thermally, but it also transposes more force and reduces diffusion rates. These properties of the aqueous environment have direct and indirect effects on aquatic macrophytes. Conversely, aquatic macrophytes modify the aquatic environment through their development and metabolic activity (Brewer and Parker, 1990).

Aquatic vegetation is an essential component of the aquatic ecosystem with both positive and negative implications on the water body. Efforts are always made to curtail the excessive growth of aquatic plants in order to prevent them from becoming a nuisance in the ecosystem. One of the ways of solving such problem is the positive economic use of such plants as well as their social uses. In line with the context of this research, instead of just affirming that the aquatic vegetation impact negatively, why not search for those positive effects of such plants and provide some awareness to the populace so as not to destroy them but use them sustainably for some socioeconomic purposes.

1.1 STATEMENT OF RESEARCH PROBLEM

Dams have one of the most important roles in utilizing water resources. The major role is of course supplying water for such purposes as domestic uses, irrigation, generation of hydroelectric power, recreational activities and flood control (Lancar and Krake, 2002). They were constructed long years before gaining present information about hydrology and hydromechanics. They are not ordinary engineering buildings. Biswas and Cecilia (2001) stated that dam projects, which are useful in meeting the demand for water in desired times and in regulating stream regimes, have undertaken an important function in the development of civilization. They went further to state that nearly 700 dams were built every ten years up to 1950s. This number grew rapidly after 1950s. While the dams were built and completed it was observed that there was something missing and detrimental, they impact in one way or the other on the downstream areas and even upstream and this impact could pose great threats to the environment. Although the effects of water on human life and the development of civilizations are well-known all over the world, it is claimed that the economic benefits expected from the projects designed to utilize water resources could not be gained and also necessary precautions to decrease the environmental, economic and social losses were not taken.The gap this research hopes to fill is to assess the spatial distribution of aquatic plants dominant at the Ajiwa Dam and the economic benefits to be derived from the identified species. Aquatic plants are generally believed to be weeds and are always destroyed. This is regarded to be a great waste of land resources and as such the research will assess some of these aquatic plants hopefully to make an awareness of their positive and/or negative impacts so that such resources are not wasted but utilized optimally and sustainably especially at this critical period of Economic Crisis in our dear country Nigeria. Upon completion of the research, it is hoped that people could locate these plants and use them for a variety of purpose instead of regarding them as weeds and just wasting them away.

1.2 RESEARCH QUESTIONS

This research work upon completion intends to answer such questions as:

1. What are the different kinds of aquatic macrophytes dominant in Ajiwa Dam?
2. What is the spatial distribution of the identified species within the Ajiwa Dam?
3. What are the socioeconomic impacts of the identified species to the immediate environment?
4. How may the local people manage these aquatic macrophytes for their socioeconomic activities?

1.3 AIM AND OBJECTIVES

The aim of this research is to assess the spatial distribution, classification, control and economic impact of aquatic macrophytes dominant in the Ajiwa Dam.

This is achieved through the following objectives:

1. To identify the different kinds of aquatic macrophytes at the Ajiwa Dam.
2. To determine the spatial distribution of the identified species within the dam.
3. To describe the socioeconomic impact of each of the identified species.
4. To explore how the local people may manage these identified species in terms of their socioeconomic activities.

1.4 SIGNIFICANCE OF THE RESEARCH

The relevance of this research is to elaborate and improve the manner in which people manage aquatic plants. As stated earlier, people destroy a wide diversity of these species, regarding them as weeds infesting waterways for their irrigation and other purposes, thus destroying them. Utilization as a method of weed control within the aquatic ecosystem is considered to be one of the safest methods of weed control as this provides the riparian communities double advantages in terms of saving the environment and many economic impacts of the species. The flora diversity of Dams possess a great potential to both man and higher animals so rather than just destroying the species, the resources should be used optimally. This may help boost social and economic aspects of the local community and the country at large.

1.5 SCOPE AND LIMITATIONS

The study will cover the Ajiwa Dam that is located at the Ajiwa village which is an enclave of Batagarawa Local Government Area of Katsina State. The scope of the study will take an in-depth assessment of aquatic macrophytes at the particular territory of Ajiwa Dam as well as the geographies of surrounding districts of Batagarawa and Katsina. The ability to comprehensively address the project's objectives and scope is limited by some factors the greatest of which is budget. A research like this involves inputs of many resources such as access to the Dam, collection of samples, production of maps, and transportation among others. All these inputs cannot be accessed without adequate money.

Another factor is lack of cooperation from my place of work as the research requires subsequent visits to the study area. This really made a great limitation to my work because I am not always allowed to embark on my journeys to the study area until after work has closed.

Some of the respondents in the study area also are not ready to help with information about the dam and other features thus limiting the research's work.

1.6 JUSTIFICATION OF THE RESEARCH

The extent to which people get rid and dump off aquatic macrophytes in different locations of aquatic environments in the country as a whole is relatively high. As reported by Lancar and Krake (2002), macrophytes are unabated plants which grow and complete their life cycle in water and cause harm to aquatic environment directly and to related eco-environment relatively. They went further to state that macrophytes cause great losses to the aquatic environment and that their management is of utmost importance to improve the availability of water from the source to its end users and as such, they should be controlled through manual cleaning, chaining, cutting, dredging, mowing and a host of other techniques.

Gallagher (2007) stated that aquatic plants are on-going problems for several aquatic environments and that they should be prevented and controlled through chemical, physical/mechanical, biological and operational controls.

This is regarded to be a grave waste of resources because they are believed to have some positive as well as negative impacts on the environment. Such positive impacts are expected to be used and managed sustainably by the locals, the populace of Katsina State and Nigeria as a whole.

Because it is believed that aquatic plants are very important land resources that should not be destroyed but rather, utilized in one way or the other optimally and sustainably, this make them to be important and hence should not be destroyed but utilized.

1.7 DESCRIPTION OF THE SUBJECT MATTER OF THE WORK

The subject matters of this research work are Ajiwa Dam, aquatic plants and the surrounding community. In a descriptive form, aquatic plants are plants that have adapted to living in aquatic environments (saltwater or freshwater). They are also referred to as hydrophytes or macrophytes. These plants require special adaptations for living submerged in water, or at the water's surface. The most common adaptation is aerenchyma, but floating leaves and finely dissected leaves are also common (Sculthorpe, 1967).

Aquatic plants can only grow in water or soil that is permanently saturated with water. They are therefore a common component of wetlands (Keddy, 2010). The principal factor controlling the distribution of aquatic plants is the depth and duration of flooding. However, other factors may also control their distribution, abundance and growth form, including nutrients, disturbance from waves, grazing and salinity.

One of the largest aquatic plants in the world is the Amazon water lily; one of the smallest is the minute duckweed. Many small aquatic animals use plants like duckweed for a home or for protection from predators. But areas with more vegetation are likely to have more predators. Some other familiar examples of aquatic plants might include floating heart, water lily, lotus and water hyacinth (Keddy, 2010).

Having dams to provide raw water for treatment and supply of portable water to urban communities like Katsina town for human consumption and domestic utilization is necessary, because, by the nature of the soil of the area, water is extremely low making borehole drilling and maintenance very difficult, expensive and uneconomical (Muhammad, 2010).

Ajiwa waterworks was constructed and commissioned by His Excellency Brigadier General Musa Usman; a military Governor of the North-Eastern State on 12th April, 1975. The waterworks was constructed within two phases. The first phase was of course completed first and had a stored water capacity of 25 million litres. As a result of population increase, more demand on portable water for domestic and other purposes and also population increase in the Katsina city ignited the completion of the second phase. The second phase was constructed in 1985 with additional stored water capacity of 25 million litres (Parkman, 1994). The designed purpose of Ajiwa waterworks is to treat the raw water from Ajiwa Dam and pump the treated water to Urban Katsina and near villages for drinking, domestic use and other purposes. The common chemicals used for treating raw water from Ajiwa Dam are Aluminium Sulphate (Alums), Calcium Hydroxide (hydrated lime), Polyelectrolyte, Poly-quaternary amine, Chlorine gas and Chlorine powder (KTSWB, 2006). After treatment of the raw water with the above chemicals, the water is further treated using the processes of sedimentation, filtration and disinfection. A wastewater is discharged from the Dam and this is the water being used by farmers for irrigation in the area.

Ajiwa Dam is Katsina State's major supplier of portable water for various purposes such as domestic and agricultural uses. However it must be stated that the infrastructures at the station are all but damaged and as such the magnitude of operation of the dam is relatively low. A lot of machineries and equipment need to be replaced for better performance.

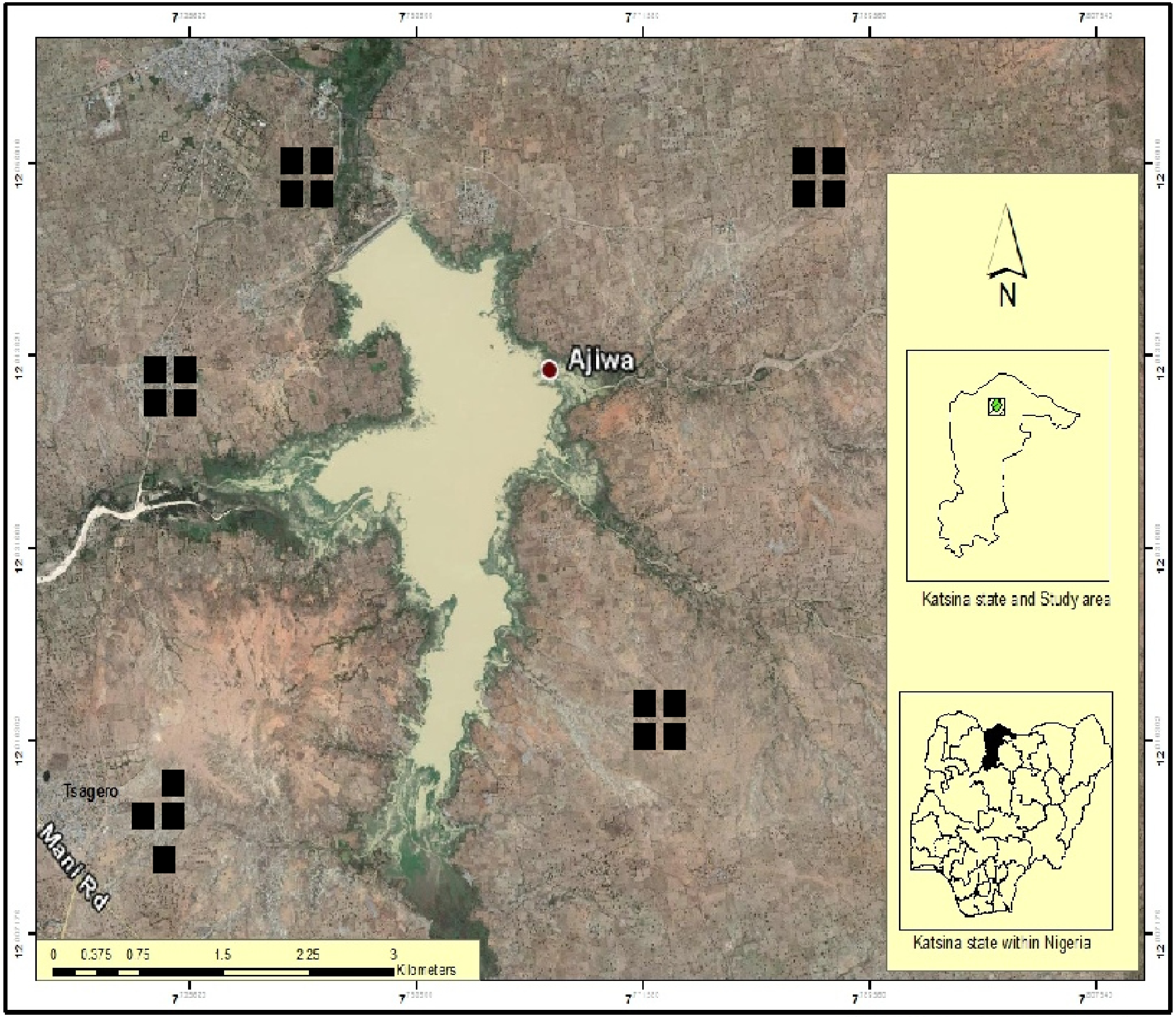
The people of Ajiwa village are mainly farmers. They take advantage of the Ajiwa Dam for the execution of various agricultural activities such as irrigation and fishing, tourism (entertaining visitors with a tour of the dam using their boats) and some of them are migrant labourers to the immediate environs of Batagarawa and Katsina. However, all these activities are influenced by the relative distance of the Dam to the village and Urban Katsina. For example, the distance between Ajiwa Dam and Ajiwa Village is about 8km. Accessibility is fair but with better roads and transport facilities (better cars or even trains), the agricultural and socioeconomic activities of the local people would fetch far enormous prices thereby boosting the livelihood standards and economy of the village and Katsina State at large. Also, the distance of the dam to Batagarawa and Urban Katsina is about 20km in which case transportation of goods and services would be easy with better roads and other transport facilities, thus boosting the economy of the populace.

As mentioned earlier, some of the villagers are migrant labourers to Urban Katsina and Batagarwa. Although, these jobs fetch them some income that they cater for their families, it must be stated that there is a great potential at their village i.e. the Ajiwa Dam with which they can utilize and get better income for themselves, their family and the economy of the State. They could make use of what this research is trying to put through or even other potentials such as agricultural and recreational purposes.

1.8 STUDY AREA

1.8.1 Location

The study area of this research, Ajiwa Dam, is located in Ajiwa village of Batagarawa Local Government Area of Katsina State (Figure 1). The area lies between latitudes $12^0$54'N to $13^0$00'N and longitudes $07^0$43'E to $07^0$47'E it is shown on figure 1 below:



KEY

= Settlements

Figure 1: Ajiwa LGA showing the location of Ajiwa Dam

Source: Extracted from Google Earth (2014)

1.8.2 Climate

The climate of the study area is generally classified as semi-arid according to Koppen's Classification of Climate (Iwena, 2000) with a long dry season of about seven to eight months (November to May), and a warm rainy season lasting for four month (June to September). The weather varies considerably according to months and season. This has been divided into five according to rainfall and temperature parameters:

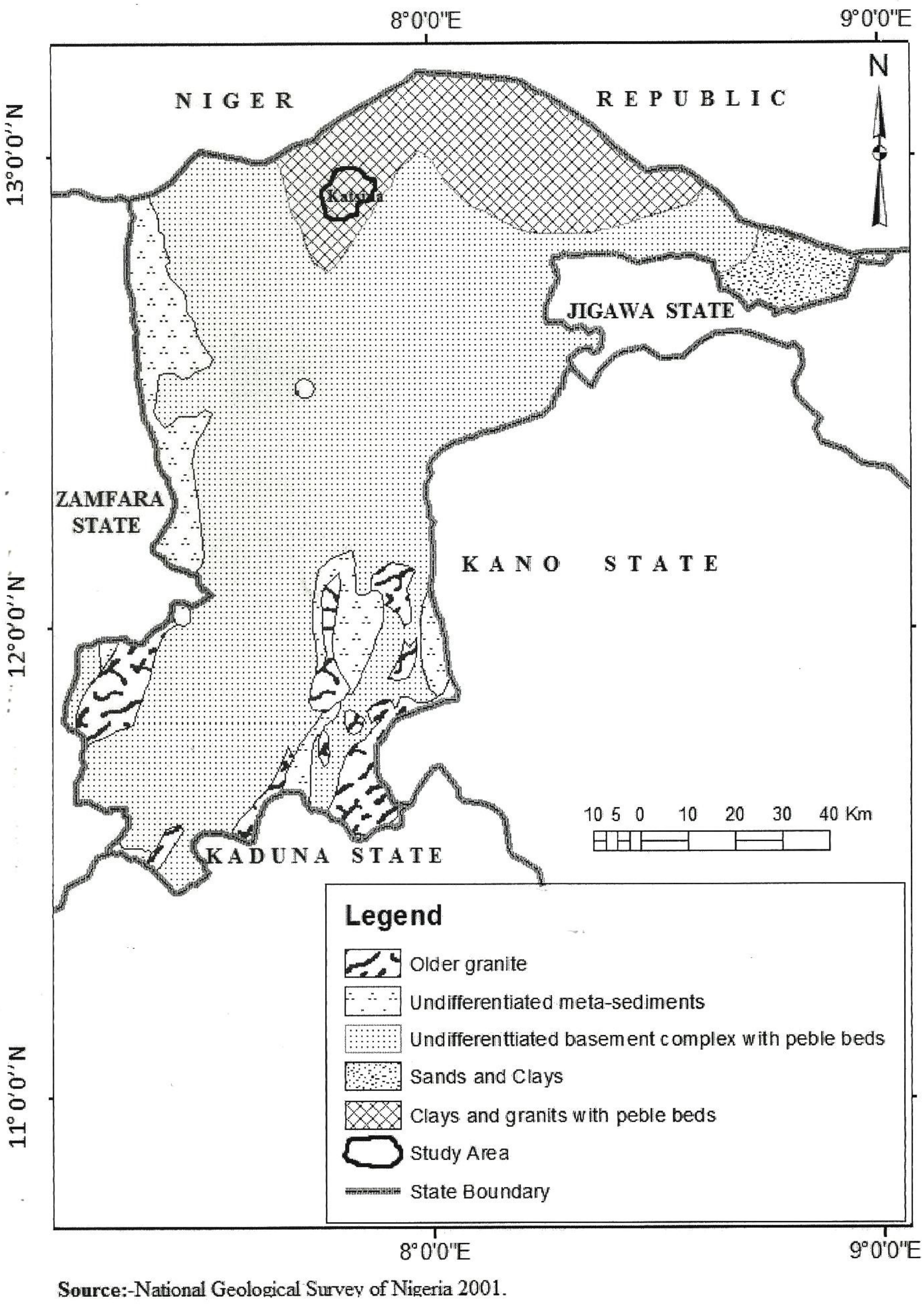
1. A cool dry season from December to February.
2. A hot dry season from March to May.
3. A warm wet season lasting from June to September.
4. A less marked season at the termination of the rains, normally between Octobers to November during which the dry Harmattan dust laden winds blow south from the Sahara. These are the coolest months with lowest temperatures both maximum and minimum dailies and monthlies.
5. The months of March, April and May are the hottest with mean temperature frequently exceeding 37^0C.

Rainfall usually starts in June or July to September. During these rainy months i.e. between Junes to September; the south westerly winds are dominant and heavily ladened with moisture. Single maximum rainfall is recorded normally, in August (Iwena, 2000). Average annual rainfall varies from 1150mm in Funtua to less than 700mm in Daura. Within and around the area, an average rainfall of 270mm was recorded at the Katsina airport meteorological station. The mean annual temperature is 32^0C (80^{0F}) but varies from season to season. In November to February or March when Harmattan is blowing, the temperature during this time drops to 25^0C but rise up to 37^0C in the month of April and even higher to early days of November. The relative humidity is always low between 20% and 40% in January and rising to 60% and 80% in July (Innocent, 1998).

1.8.3 Geology

Katsina State on the basis of geology is divided into two major rock types. The sedimentary or soft rock on which the study area is located (stretching to the north east) and the basement complex (or the hard terrain in the southern part). Generally, the sedimentary rocks are of cretaceous origin comprising the Gundumi formations (Innocent, 1998). The sediments of this formation directly overly uncomfortably the basement complex which provide depressions on which they were laid, and were made of based conglomerates, clayey grits, salty sands, pebbly sands and clays, all inter bedded (Innocent, 1998). Lees of the basement complex rocks can be seen consisting of counselling crystalline, prophytic granite and granite gneiss. Persistent intercalation of bluish and purplish clays is occasionally present in the grits wile bands or horizons of quarter pebbles are common at certain levels (Iwena, 2000).

The Precambrian basement complex rocks are generally noted to dip down at low angle to the northwest, in this geological system, the unconsolidated and partially consolidated deposits consist more or less of loose sediments. Such layers of sands and gravel transmit, store and release water effectively because of the inter-connecting pore spaces (Innocent, 1998). Their hydraulic conductivity is enhanced and they make profitable aquifers. The clay and sandy /clay stones provide the seal. Confining aquifers and the sedimentary fills of the study area have been eroded away by streams; particularly River Tagwai leaving only or mainly isolated patches in place and re-exposing the basement complex. The Gundumi formations of this area are believed to be much more permeable than the basement complex resulting in the occurrence of overflow of ground water in some areas and in others resulting in drainage overlying alluvial sediments (KTARDA, 1990). The geology of Katsina State is illustrated on the map below:



Source:-National Geological Survey of Nigeria 2001.

Figure 2: Geological map of Katsina State

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1.8.4 Drainage, Hydrology and Water Resources

The Tagwai River and its tributaries such is the dense hydrological network in the study area. The hydrology of the study area is described as good enough to sustain regional water development. The hydro-meteorological data obtained from Katsina Airport Meteorological Station exhibits good values of precipitation of up to 749.2mm per annum on the average. Infiltration values are also high owing to the gently undulating topography and the absorptive top soil made up to sand and sandy laterites, which discourage excess run-off. Hence the recharge of the subsurface water bearing formation is encouraging (Innocent, 1998).

Water supply and sanitation in Katsina State is characterized by low levels of access to an improved water resources and limited access to sanitation. Responsibility for water supply is shared between the state and its local governments. The State is in charge of water resources management. It has the primary responsibility for urban water supply; and the local governments together with communities are responsible for rural water supply. Water supply service quality and cost recovery are low (WHO/UNICEF, 2010). Water tariffs are low and many water users do not pay their bills. Service providers thus rely mostly on occasional subsidies to cover their operating costs. Investments are mainly financed by foreign donors and fall short of what is needed to achieve a significant increase in access (WHO/UNICEF, 2010).

1.8.5 Soil and Vegetation

The types of soil on the country are related to nature of the rocks. Thus we can distinguish between soils on the basement complex rock and those on the sedimentary formations. So based on the above, the soil type found in the study area is the brown and reddish-brown types of soil, they are coarse light sandy soils which are said to have been formed from wind-sorted desert sand, which accumulated in the resent geological periods when the Sahara desert encroached hundreds of miles south of its present limit, the parent materials of the soils are the basement complex and the sand drift. The soil type supports the cultivation of crops that can do well on less fertile soil. In the upland area, the soil is very fertile hence supports the production of high fertile soil needing crops such as vegetables and sugarcane.

The vegetation of Ajiwa is typical of Sudan Savannah which stretches from the Sokoto plain through the northern part of the high plains of Hausa land to the Chad Basin. The actual vegetation is made up of short grasses of 1.5 to 2 metres high and some stunted trees including Acacia and Baobab.

1.8.6 Population and Economy

The study area is advantageously located in a very good agricultural land hence having the characteristic of greatest population density of the northern Nigeria. This is because the land can support the cultivation of economic crops like groundnut, millet, sugarcane and vegetables.

In terms of economy, agriculture is the most important occupation in Ajiwa whereby over 90% of the population are farmers who practiced farming at subsistence or commercial level.

The economy of Katsina state is a middle income economy and emerging market, with expanding financial, service, communications, and technology and entertainment sectors. Nigerian economy is ranked as the 21stlargest economy in the world in terms of nominal GDP, and the 20th largest in terms of Purchasing Power Parity (Wikipedia, 2016). Katsina State is believed to be among the driving factors of the boost in the Nigerian Economy. Its re-emergent, though currently underperforming, manufacturing sector is the 10th largest in the country (Wikipedia, 2016). It produces a fairly large proportion of goods and services to the Nation especially from the Agriculture, Education, and Youth Empowerment Sectors among others.

Previously hindered by years of mismanagement, economic reforms of the past decade have put Katsina State back on track towards achieving its full economic potential. Although much has been made of its status as a major exporter of cotton and ground-nut, Katsina State produces only about 33% of the Nation's supply of these products (Wikipedia, 2016).

The largely subsistence agricultural sector has not kept up with rapid population growth, and Nigeria at large, once a large net exporter of food, now imports a large quantity of its food products, though there is a resurgence in manufacturing and exporting of food products.

The Population of Katsina State according to the 2006 census is 6,483,429 people (NPC, 2005) with Batagarawa Local Government Area having a total of 189,059 people and a projection of 239,660 by the year 2016 (NPC, 2005).

The population is so large that the available resources are becoming limited and scarce. A research like this upon completion hopes to contribute to the economy of the State and the country at large because the research hopes to assess the utilization of the natural resources available at the study area for a variety of purposes.

1.9 LITERATURE REVIEW

Water supply in Katsina State is sourced through the damming of rivers and digging of wells and bore-holes that reach sub-surface or underground water sources. Existing dams include Ajiwa Dam, Malumfashi Dam, Jibia Dam and Mairuwa Dam, supplying major towns of the state and their environs with water. Under the states multi-purpose regional water scheme, the Zobe, Ajiwa, Jibia and Gwaigwaye Dams will supply water for both consumption and irrigation purposes. Presently, about 24 urban and many other semi-urban and rural locations are supplied with pipe-borne water, such that over 50% of the state's population enjoy this facility. There are also over 1000 bore-holes and 27 rehabilitated wind- mills spread over the various rural locations in the state (Adamu, 2000).

1.9.1 Nature of Dams

A Dam according to Charley (1969) is a barrier constructed across a stream or river to impound water and raise its level. McGraw-Hill Encyclopaedia of Science and Technology (1960) defines a dam as a structure that bars or detains the flow of water in an open channel or watercourse. In the same manner, Encyclopaedia International (1980) describes dam as an artificial barrier across an open channel of water to create a reservoir or raise water level. It is a barrier built across a river to create a lake (Hornby, 2000). However, Iwena, (2000) sees a dam as an extensive area occupied by water trapped on a river course. From the foregoing, therefore, a dam can generally be defined as barrier built across a water course to hold back or control the flow of water for storage, diversion or detention.

The construction of dams have been going on from early man's period of civilization as evidence are available in the region of Bacelonia around Euphrates and Tigris in present-day Iraq. The construction of barrier across streams channels for the purpose of impounding water goes back to about 5,000 years from now. In most cases, the ideas for which these dams have been constructed have to a great extent been accomplished at both individual and societal levels. According to Adams (1975), large projects in historical development have been undertaken in Africa not for power but as multipurpose schemes. The first modern dam scheme was the Gezira project developed from 1913 to 1950. It consists of a system of irrigation canals and Sehar dam, which direct water from the Blue Nile into the main canal. WCED (1987) observed that in the Republic of Cameroon, in addition to Lagolo Dam, other dams including Song-Loulon and Edea Dams on the Sanaga River are respectively the third and fourth largest dams in West Africa after Kainji Dam on the River Niger in Nigeria, and the Akosombo Dam on the Volta River in Ghana. NEST (1991) documented that, dams have been built in Nigeria since about 1918 notably for domestic water supply. Hamadou (1997) reported that in Nigeria, right from 1920, hydroelectric power was generated on the Jos Plateau. In 1964, the first major hydro-electric power project in Nigeria started with the building of a dam across the Niger River at Kainji. In 1967, the first phase of the project was completed. At present, the Federal Government of Nigeria has spent billions of Naira to construct many dams for portable water supply and hydro-electric power generation. The Bakolori Dam built in mid 70s on River Sokoto in the North Western part of the country floods 30,000 hectares of arable land with irrigation water. In a village Bagauda, South of Kano, the Tiga Dam in Kano State was built. Also, the Shiroro Dam and Kanji Dam in Niger State were constructed in 1993 and 1964 respectively with the purpose to serve industries with electricity. The number of dams and irrigation projects according to NEST (1991) has been increasing rapidly and feasibility studies are being carried out for most of larger rivers in Nigeria. Hamadou (1997), however, observed that besides the Hydro-Electric Power (H.E.P) these dams serve in the development of water supply, irrigation agriculture, control of floods etc.

Iwena (2000) classifies dam on the basis of structural form and material used. Dams are also often classified according to their mode of impoundment and the use for which they are built. To this end, dams are classified into four major types: gravity dams, arch dams, buttress dam and earth-filled dams.

The Gravity dams are solid concrete structures with triangular cross sections. The dam is thick at its base and thinner towards its tops. When viewed from the top, it is either straight or only curved and the upper stream is nearly vertical. It is described by Encyclopaedia International (1980) and Babalola (2003) as roughly triangular dams in cross section. The broad based gravity dam holds water by the brute force of its weight. An example of this type is found on Columbia River in Washington.

Arch Dams are those that employ the same structural principles as the arch bridge. Arch dam is a type whereby the upper stream curve of the slender dam directs water pressure through the abetment to the retaining canyon walls. It is normally built in the form of upended arch with bases on the walls of canyon. Arch dams are thinner and therefore require less material than any other type of dam. Arch dams are good for sites that are narrow and have strong abutments. They are usually made of concrete and more often in the shape of a V than U–shape. The gorge is often in the shape of a V, less often it is a U-shape. They use much less of concrete than gravity dams. The best design is a double-curved arch. Arch dams are generally classified as thin, medium and thick, depending on the ratio of the width of the base (b) to the height (h). Examples of this type of dam are the Kariba Dam in Rhodesia; the Glen Canyon Dam on the Colorado River in Arizona, which is 216m high, and 475m long; the Vallon de Baume in France which is 12m high and 18m long and curved with a radius of about 14m; and the Monte Novo dam in Portugal which is about 5.7m high and 52m long, including the wing walls at both ends.

Buttress Dams are watertight upstream face and a series of buttresses that support the face and the water pressure and the weight of the structure to the foundation. An example is the Pidima Dam built in 1953 in Greece.

Encyclopaedia International (1980) describes Earth-filled Dams as those that utilize natural materials with minimum of processing and may be built with primitive equipment under addition where any other construction materials would be impracticable. They are the earliest known dams and seem to be the easiest to construct. However, numerous failures of many earth-filled dams that are poorly designed make it an apparent threat. Earth-filled Dams require much more engineering skill in their conception and construction that any other types of Dam. The highest earth-filled embankment dam in the world is the Oroville Dam in California. Embankment Dam is the type of dam with earth materials, rock and dirt. It is the oldest form of Dam. It generally costs less than those concrete dams. It is interesting to note that Ero Dam in Mobal Local Government Area of Ekiti State falls into this category.

Around half of Africa's total wetland area consists of floodplains, and they include famous, large-scale examples that cover several thousand square kilometres such as the Inner Niger Delta in Mali, the Okavango Delta in Botswana, the Sudd of the Upper Nile in Sudan and the Kafue Flats in Zambia (Lemley et al. 2000; Thompson and Polet 2000). There are also many smaller and less well-known floodplain systems that are locally important. Africa's floodplains typically serve as critical habitat for birds, including wintering grounds for migratory species, and the availability of water in many floodplains during the dry season is an important resource for grazing wildlife. Millions of people across the continent are also dependent on the floodplains for their economic livelihoods. Production activities dependent directly on the floodplains include agriculture, fishing, grazing and wood and non-wood harvesting of riparian forest resources (Adams 1992; Scudder 1991). In many instances, the uses of these wetlands are integrated with those of surrounding semi-arid, or "dry lands", and thus floodplains have an economic importance beyond the initial areas inundated (Scoones, 1991). Hydrologists also maintain that floodplains in some semi-arid regions may also recharge groundwater resources in surrounding areas (DIYAM 1987; Thompson and Hollis 1995). By influencing transfer of water and sediment downstream, economic activities and developments in upstream areas can drastically affect both the inundation area of a floodplain and its crucial ecological functions. This will in turn impact on the various economic activities that may be dependent on the floodplain. For example, diversion of upstream water supplies for irrigation, water supply, and flood control and hydroelectricity generation will interrupt the continuous downstream transfer of water and sediment which would otherwise take place. The result is a change in channel flow regime and morphology, sediment transport rates, water quality and water temperatures, which will have dramatic consequences to the ecology of lowland river ecosystems and floodplains (Wilcock, 1993). If the latter disruptions have a negative impact on downstream economic activities, such as irrigated agriculture, fishing and recreational activities, then there could be significant costs involved. Thus, in the presence of significant environmental impacts, the net benefits of a development project or program cannot be appraised in terms of its direct benefits and costs alone. The forgone net benefits of disruption to the natural environment and degradation must also be included as part of the opportunity costs of the development investment.

1.9.2 The Role of a Dam

The main role of a Dam to a certain community is to supply water for such purposes as irrigation, generation of electricity, domestic water supply, and recreation among others. Jackson (2009) stated that dams are built to capture water to irrigate crops in areas where rainfall does not provide enough ground moisture for plant growth. Simple irrigation systems often depend on small diversion dams that raise the height of a stream. Flowing water backs up against the dam until it overflows into a canal, ditch, or pipe that carries the water to fields. People build dams to divert water out of rivers for use in other locations or to capture water and store it for later use. The volume of water flowing in any given river varies seasonally. In the spring and early summer, rivers typically swell with water from rainstorms and mountain snowmelt. In the drier months of late summer and autumn, many rivers slow to a trickle. Storage dams impound seasonal floodwater so it can be used during periods of little or no rainfall. The water that backs up against a storage dam forms an artificial lake, called a reservoir. Release of water from the reservoir can be controlled through systems of pipes or gates called outlet works.

1.9.3 The Meaning and Distribution of Aquatic Plants

Aquatic plants are central members of wetland communities that provide food and shelter, directly or indirectly for many organisms, erosion control, oxygen enrichment of water through photosynthesis, nutrient cycling, absorption of pollutants (Halls, 1997), reduction of sediment suspension, refuges for zooplankton from fish grazing and suppression of algal growth by competing for nutrients and light and the release of allelopathic substances (Takamura et al. 2003).

Aquatic plants make particularly good weeds because they reproduce vegetatively from fragments. They constitute the primary producers of aquatic ecosystems. They convert incident radiant energy of the sun to chemical energy in the presence of nutrients like phosphorous, nitrogen, iron, manganese, molybdenum and zinc. In the aquatic ecosystem, the phytoplankton are the foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell fish and finfish (Emmanuel and Onyema, 2007). The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers (Davies et al., 2009). Townsend et al. (2000) and Conde et al. (2007) reported that plankton communities serve as bases for food chain that supports the commercial fisheries. Davies et al. (2009) have also reported that phytoplankton communities are major producers of organic carbon in large rivers, a food source for planktonic consumers and may represent the primary oxygen source in low-gradient Rivers. Phytoplankton is of great importance in bio-monitoring of pollution (Davies et al., 2009). The distributions, abundance, species diversity, species composition of the phytoplankton are used to assess the biological integrity of the water body (Townsend et al., 2000). Phytoplankton also reflects the nutrient status of the environment. They do not have control over their movements thus they cannot escape pollution in the environment. Barnes (1980) reported that pollution affects the distribution, standing crop and chlorophyll concentration of phytoplankton. The abundance of pheriphyton also increases with increase in nutrient content. Periphyton can be an important source of food for herbivores.

Aquatic plant distribution, abundance, and vigour are influenced by abiotic factors including water, temperature, pH, dissolved oxygen, nutrient levels, turbidity (Squires et al. 2002), sediment type, water and wind currents, depth, and changes in water levels. Biotic components of a given water body, such as the presence and density of herbivorous fish (Hanson and Butler 1994), insects, molluscs, diseases (fungi, nematodes), plant-to-plant interactions, and movement of vegetative portions of aquatic plants by man (e.g., plant parts entangled in fish nets) also influence the distribution and abundance of aquatic plants.

1.9.4 Classification of Aquatic Plants

Aquatic plants grow in shallow to deep water zones. The three main types of aquatic plants according to Anene (2003) are:

1. Single-celled phytoplankton
2. Periphyton (algae growing attached to substrates)
3. Multicellular macrophytes

Phytoplankton:phytoplankton are microscopic plants, drifting at the mercy of water current (Anene, 2003). They constitute the primary producers of aquatic ecosystems. They convert incident radiant energy of the sun to chemical energy in the presence of nutrients like phosphorous, nitrogen, iron, manganese, molybdenum and zinc. They are restricted to the aphetic zone where there is enough light for photosynthesis. The distribution, abundance and diversity reflect the physio-chemical conditions of aquatic ecosystem in general and its nutrient statue in particular, Anene (2003). Phytoplankton includes several groups of algae (e.g., green algae, golden brown algae, euglenophytes, dinoflagelates and diatoms) and one group of photosynthetic bacteria (Cyanobacteria). Planktonic algae may be either benthic (attached to a substrate) or planktonic (floating in the water column). There are large numbers of phytoplankton (greater than 400 species) in many bodies of freshwater; phytoplankton are most common in habitats with high nutrient levels. In the aquatic ecosystem, the phytoplankton are the foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell fish and finfish (Emmanuel and Onyema, 2007). The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers (Davies et al., 2009). Townsend et al. (2000) and Conde et al. (2007) reported that plankton communities serve as bases for food chain that supports the commercial fisheries. Davies et al. (2009) have also reported that phytoplankton communities are major producers of organic carbon in large rivers, a food source for planktonic consumers and may represent the primary oxygen source in low-gradient Rivers. Phytoplankton are of great importance in bio-monitoring of pollution (Davies et al., 2009). The distributions, abundance, species diversity, species composition of the phytoplankton are used to assess the biological integrity of the water body (Townsend et al., 2000). Phytoplankton also reflects the nutrient status of the environment. They do not have control over their movements thus they cannot escape pollution in the environment. Barnes (1980) reported that pollution affects the distribution, standing crop and chlorophyll concentration of phytoplankton.

Periphyton: Periphytonmay grow attached to other plants (ephytic periphyton) or on rocks and other substrate (epibenthic periphyton). Typically, periphyton is made up of diatoms, a variety of filamentous algae (including Spirogyra, Anabaena, Oscillatoria, Lyngbya, and Pithophora spp) and cyanobacteria. The abundance of pheriphyton also increases with increase in nutrient content. Periphyton can be an important source of food for herbivores.

1.9.5 The Concept of Macrophytes

From the classification of aquatic plants by Anene (2003), macrophytes are the third category and they are considered to be important component of aquatic ecosystems. They are genuinely aquatic (hydrophytes) and amphibious plants (amphiphytes) and that in most cases species determination needs no microscope (Wetzel, 2001).This covers large algae (e.g. Charophytes), bryophytes and vascular plants.

In running water environments, macrophytes contribute to the oxygen budget and to the autochthonous carbon pool. Roots, stems and leaves of macrophytes provide structural elements in an otherwise unstructured water column, thus enhancing spatial diversity in the aquatic ecosystem. Microbes, invertebrates and vertebrates (Jeppesen et al., 1998) live on the surface of, and in spaces between organs of aquatic plants. Fish prey and fish, use aquatic plant stands as a nursery, feeding ground and seek shelter in dense vegetation (Lillie and Budd, 1992).

The spatial functioning of macrophytes is influenced by the growth form of each species. The most simple scheme follows Sculthorpe (1967): emergent (helophytes), floating-leaved, free-floating (pleustophytes) and submerged species. Submerged plants with small leaves and growing in dense stands, provide ample structure, whereas floating-leaved plants and pleustophytes provide little submerged surface, but support animals such as amphibians and water birds. As a consequence, aquatic macrophytes are one of the essential ecological components wherever they occur in running waters.

Westlake (1967) defines macrophytes as the plants that are rooted in shallow water with vegetative parts emerging above the water surface. These emergent vegetative parts are thought to be most particularly productive of all aquatic macrophytes since they make the best use of all three possible states; with their roots in sediments, beneath water and their photosynthetic parts in the air. Oyedeji and Abowei (2012) stated that aquatic plants are hydrophytes and occupy different ecological niche in the aquatic environment. They further stated that Aquatic vascular plants can be ferns or angiosperms from a variety of families, including the monocots and dicots, single-celled phytoplankton, periphyton and multi cellular macrophytes.

The term aquatic macrophytes excludes filamentous algae and basically a grassland species that grows as a natural biotic component in most shallow depth, still, slow flowing and running water bodies. Fresh water macrophytes include all members of chaeophyta e.g. (stonewort), bryophyte (e.g. mosses and liver warts), Pteridophyta (e.g. Ferns and Ferns allies) and spermatophyta (e.g. Seed bearing plants and the cone bearing plants) which grow in freshwater aquatic environment (Okojie, 1998).

1.9.6 Classification of Macrophytes

Pyne, (1986) and Nather (1990) classified freshwater macrophytes into four categories:

1. Free-floating: These are plants with roots if present; hanging in water or plants that float on the surface of water bodies and their roots are being swimmers. E.g. *Azoita africana, Eichhornia crassipes, Pistia stratiotes, Lemna pausicostata, Lemna gibba. Lemna perpusilla,Salvinia sp* etcetera.
2. Submerged species: These are usually rooted in substrate with vegetative parts permanently submerged. E.g. *Myriophyllum sp, Ceratophyllum dermersum, Potomogeton crispus, p. pectinatus, Najas marina* etcetera.
3. Emergent species: These are rooted in shallow water with the vegetative parts emerging above the water surface. E.g. *Nymphaea lotus, Typha australis, Phragmites sp, Echinochloa stagnina, E. pyramidalis, E obtusiflora, Cyperus sp* and *Sesbarnia dalzelii.*

4. Marginal Species: These are macrophytes that can survive on land or water most of which belong to the Families Araceae, Cyperaceae and Poaceae.

Wetzel (2001) stated that macrophytes colonize many different types of aquatic ecosystems, such as lakes, reservoirs, wetlands, streams, rivers, marine environments and even rapids and falls (e.g., family Podostomaceae). This variety of colonized environments results from a set of adaptive strategies achieved over evolutionary time and that primary production of macrophytes can surpass that of other aquatic primary producers.

Macrophytes generally colonize shallow ecosystems where they become important components, influencing ecological processes (e.g., nutrient cycling) and attributes of other aquatic attached assemblages (e.g., species diversity).

Macrophytes affect nutrient cycling, for example through transference of chemical elements from sediment to water, by both active and passive processes e.g., decomposition (Dibble and Thomas, 2009). Limiting nutrients released by macrophytes, like phosphorus and nitrogen, are rapidly used by micro-algae and bacteria (which also use organic carbon released by macrophytes); these microorganisms may be free-living or attached to macrophytes surfaces and their detritus. In addition, several species of macrophytes produce an elevated percentage of refractory matter (basically fibrous material) that is relatively slow to decompose; thus, they also contribute to a return of carbon to sediment. Macrophytes may also influence nutrient cycling in two other ways: retention of solids and nutrients by their submersed roots and leaves and reduction of nutrients released from sediment by protection against wind (and wave) action (Madsen et al., 2001). Moreover, this protection against waves also promotes the stabilization of shores and a reduction in erosion. In addition, macrophytes may influence several other physicochemical properties of the water column. For example, conspicuous changes in oxygen, inorganic carbon, pH and alkalinity may result from their metabolism (Mack et al., 2000).

Owing to their high rate of biomass production, macrophytes have primarily been characterized as an important food resource for aquatic organisms, providing both living (grazing food webs) and dead organic matter (detritivorous food webs). It is true that macrophytes may represent an important source of organic matter for aquatic herbivores and detritivores in some ecosystems. However, this idea has been systematically rejected in most ecosystems after stable isotope studies, which have shown that algae, both free-living and attached, are often more important than macrophytes in food webs (Okojie, 1998).

Independent of this controversy, from a purely biological point of view, macrophytes affect the structure of populations in addition to the diversity and composition of other aquatic assemblages. The effect of macrophytes on populations and communities has been widely demonstrated for a variety of organisms, such as micro- and macro-invertebrates (e.g., Bergström et al., 2000).

CHAPTER TWO

CONCEPTUAL AND THEORETICAL FRAMEWORKS

2.1 CONCEPTUALIZING THE STUDY OF AQUATIC PLANTS

2.1.1 Aquatic plants: Patterns and Modes of Invasion, Attributes of Invading Species and Assessment of Control Programmes

The natural human inclination to concentrate attention on the strange and the unusual is reflected vividly in the voluminous literature devoted to those aquatic plants that possess anomalously disjunctive or cosmopolitan geographical distributions (Sculthorpe, 1967). Since rivers, lakes and other water bodies are separated by tracts of land, it could be expected that aquatic plants would tend to be locally distributed within a particular land mass and that the seas and oceans would provide insurmountable barriers to dispersion between continents. Indeed, approximately 25 to 30% of the known aquatic plants are considered to be true endemics with distributions limited to a single river or portion of a river system (Cook, 1985). In contrast however, several families and species of aquatic plants are so widely distributed over several continents, some even reaching remote oceanic islands, that they can be described justifiably as cosmopolitan. In addition, some temperate and tropic aquatic plants exhibit curious discontinuities in their ranges, over and above that due to the configuration of seas and land masses (Sculthorpe, 1967). While these continue to attract speculation and discussion, in most cases it is difficult, if not impossible, to show that the discontinuity is genuine and that the plant has not in fact been introduced in historical times to certain parts of its present day range (Sculthorpe, 1967).

As a result of the mechanisms of dispersal, invasion, colonization and competition on one hand, and changing climatic, physical and edaphic factors of the environment on the other, migration of species continue to occur now as they occurred during geological and historical time. Aquatic floral everywhere are thus in a continual state of flux. The situation has been confounded further by man's relentless expansion of his agriculture, communications, industry and domestic life wherein he has modified existing habitats and created new, artificial habitats. Additional complications have been introduced by man's propensity for employing aquatic systems for the disposal of his waste products. Human activities that have led to the alteration, disturbance and degradation of aquatic systems have thus served to extend the range of habitats available for colonization by aquatic plants and to accelerate the natural flux of species between habitats.

2.1.2 The Concept of Invasion

The processes of plant invasion have attracted considerable attention worldwide (e.g. Grubb, 1985; Moony and Drake, 1986) and are often used to explain features of the diversity and succession of plant assemblages. However, remarkably few theoretical considerations of the invasion process seem to be generally applicable (Johnstone, 1986). Part of this problem stems from imprecise definition of the relationship between invasion and succession. Here we follow the view expressed by Johnstone (1986) that the prime cause of invasion can be seen as the removal or overcoming of a barrier that has previously excluded a plant species from an area. Whilst these features can be classified on the basis of time, time is not the cause of biological change; rather biological phenomena are described by their dispersion in time and space. In this context therefore, plant succession is seen to be caused by sequential, but interlinked, episodes of invasion, establishment, maintenance and decline. Progressive, retrogressive and cyclical succession patterns thus reflect different modes of system instability (Johnstone, 1986).

Invasions may occur naturally in the absence of anthropogenic influences. Natural invasions occur when an intervening barrier is removed or through the development of biotic or abiotic transporting mechanisms able to overcome the barrier in question. This leads to the suggestion that barriers and transporting mechanisms oppose one another and provide powerful forces in the direction and timing of succession episodes (Breen, 1987).

2.1.3 The Invasion Stages

Extensions to the geographic range of plant species can only be brought about by the dispersal of breeding populations. When introduced to an area previously unoccupied by its own kind, individuals of a particular species have no chance of becoming established unless the initial immigrants form part of a propagule i.e. the minimum number of individuals able to find a reproducing population under favourable conditions (MacArthur and Wilson, 1967). Despite the fact that several aquatic plants possess some form of dormant stage in their life cycles, adapting them for dispersal, we have seen that few aquatic plants are dispersed between distant unconnected water bodies by natural mechanisms. Indeed, most initial introductions of aquatic plants to new continents have been deliberate in that the introduced species were perceived to have some special attraction and/or intended use for humans (Cook, 1985).

As is the case with terrestrial plants, we can recognize three main stages in a successful aquatic plant invasion, namely: the arrival of an individual or propagule, establishment of the population through reproduction and dispersal to new localities. Subsequent adaptation of the invader to the new environment may also favour the selection of new genetic strains.

Each stage involves a series of interactions between the physical, chemical and biological features of the environment and the biological characteristics of the invader. These interactions can promote, delay or prevent successful completion of the stage (Arthington and Mitchell, 1986). The whole invasion process is then repeated when a propagule is successfully dispersed to a new locality. Clearly, the rate at which invasion occurs will depend on the number of individuals or propagules present in the initial inoculum and in the dispersal stage. An exponential increase in this will ensure an exponential acceleration in the apparent rate at which invasion takes place until environmental factors become limiting (Arthington and Mitchell, 1986).

2.1.4 Attributes of Invading Species

In contrast to the terrestrial environment, aquatic environments are often held to be relatively constant thus encouraging species with perennial life cycles and a predominance of asexual reproduction (Sculthorpe, 1967). While this assertion may hold true for the wet temperate and tropical latitudes, many aquatic habitats in semi-arid, sub-tropical and temperate latitudes experience alternate periods of wetting and drying over both short term (seasonal) and long term (unseasonal) cycles (Mitchell and Rodgers, 1985). Free floating invasive aquatic plants have been responsible for some of the most widespread and serious problems and are considered to be noxious weeds in most countries of the world (Sculthorpe, 1967).

In contrast, submerged and emergent aquatic plants that are rooted in the sediments are dependent on a more stable hydrological regime for survival (Sculthorpe, 1967). These plants can tolerate short term changes in water level, though they are unlikely to present problems in situations where rapid or extensive fluctuations occur. Indeed, water level manipulation is often used to control population of these plants. In this group, Phragmites, Typha, Myriophyllum aquaticum and Alternanthera possess an emergent growth form while Myriophyllum spicatum, Egeria, Elodea and Hydrilla are all submerged plants (Sculthorpe, 1967).

The translocation of nutrients to or from underground storage organs and the reproductive events of flowering, setting seeds and the formation of dormant propagules seem to occur largely in response to environmental signals, particularly seasonal changes in photo-period, light intensity and temperature (Mitchell and Rodgers, 1985). In contrast to rooted plants, free-floating aquatic plants respond to both seasonal changes in the environment and to changes in population density.

2.1.5 Management of Invasive Aquatic Plants

Excessive populations of invasive aquatic plants not only cause marked changes in the natural vegetation of aquatic ecosystem but also inhibit or prevent the management and utilization of water resources (Mitchell and Rodgers, 1985). Despite the fact that the biologic and economic consequences of theses impacts are often difficult to evaluate objectively they are invariably regarded as being undesirable and therefore regarding some form of remedial action (Arthington and Mitchell, 1986).

Manipulation of the environment to achieve certain objectives is a well-known characteristic of modern man and forms, for example the basis of his (largely successful) agricultural practice. However, agricultural systems are highly simplified with a greatly reduced diversity of species. The management of natural or semi-natural aquatic ecosystems that contain large numbers of species is considerably more difficult because of the complex inter-relationships that exist between the various components. It is essential that these relationships be understood before management options are formulated and implemented. This situation therefore requires that research aimed at understanding the complexities and inter-relationships of the aquatic environment should enjoy a high priority (Arthington and Mitchell, 1986). However progress and the betterment of the human race cannot always wait for the result of these investigations.

Management procedures therefore often have to be designed and instituted on the basis of available knowledge, however inadequate it might be. Thus it is essential that continual environmental monitoring forms part of a management programme which, in turn, must be sufficiently flexible to enable incorporation of viable alternatives if unforeseen developments occur (Mitchell, 1974). However, it must be emphasized from the outset it is absolutely necessary to clearly define the aims and objectives of any management policy before procedures of its implementation are designed or carried out.

Management strategies employed against invasive aquatic plants can conveniently be divided into two basic groups namely the protectionist and interventionist. The former attempt to retain particular ecosystems in a hypothetical natural or pristine state by preventing invasions and usually contains a strong legislative element. Typically, these strategies involve some form of environmental or ecological management that is designed to reduce habitat disturbance. The most important invasive aquatic plants, the primary colonizers of disturbed systems are thereby excluded.

In contrast, interventionist strategies seek to suppress or remove existing invaders from a particular habitat, thereby reducing their population size to a more acceptable level and minimizing their impact on ecosystem functioning. Typical strategies include various forms and combination of manual, mechanical, chemical and biological control techniques that confine the invader to a low level. These actions almost invariably return the habitat to an earlier succession stage and increase the probability that the first invader may be replaced by a second, more problematic, invasive species (Cook, 1985).

2.2 THEORIES ADDRESSING THE STUDY OF AQUATIC PLANTS

A rose by any other name is still a rose. But for plants residing under water or along the fringes of streams, ponds, and lakes, a name implies much more. For frightened young fish, it means shelter from predator peril. For frogs and backswimmers, it means floats for life and leisure. And for minnows, moose, and molluscs, it means food, from the smallest alga to the soggiest lily. For a frustrated lake resident, aquatic plants may all be called seaweeds, while a scientist may call them macrophytes (rooted aquatic plants) and extol their virtues. Still others hold each name in shrouded reverence, marvelling at the gentle swell of the purple bladderwort or the primitive majesty of the horsetail. Yet although each person may view the plant kingdom with unequal parts idolatry and contempt, all those who spend time around lakes share a core set of reasons for understanding aquatic plants (Creed, 1998).

2.2.1 Species Richness Theories

There are numerous theories and hypotheses relating to spatial patterns of richness. A fairly typical short list modified from Fraser and Currie (1996) is provided in Table 1.In essence, our case is that at the macro-scale they collapse to dynamic hypotheses (based on climate) and historical contingency, and that as distinct ecological hypotheses the relevance of the other hypotheses (4-7 in Table 1) is largely to local-to-landscape scales of analysis. The use of the phrase distinct ecological hypotheses is stressed, as we are not arguing that these mechanisms and processes have no role in macro-scale patterns, but that in so far as they do, it is a role largely dictated by, and thus not independent of climate. The distinction between historical and dynamic hypotheses is based on

Table 1: Commonly cited general hypotheses of diversity

General hypothesis	Argument
Area	richness reflects sampling effects and environmental heterogeneity.
Historical factors	glaciations effect, dispersal, higher speciation rates.
Available energy	partitioning of energy among species limits richness.
Environmental stress	fewer species are physiologically equipped to tolerate harsh environments.
Environmental stability	fewer species are physiologically equipped to tolerate varying environments
Disturbance	this prevents competitive exclusion.
Biological/ecological Interactions	competition and predation affect niche partitioning.

Source: Fraser and Currie (1996).

the repeatability or probability of recurrence of a particular state or form. Thus: (1) historical, or time-bound knowledge, refers to the analysis of complex states having very small probabilities of being repeated, i.e. states of low recoverability; whilst, (2) physical, or dynamic, or timeless knowledge, refers to the analysis of states having a high degree of probability of being repeated, such analysis leading to the formulation of laws of general validity (Schumm, 1991). The search for dynamic hypotheses of species richness can thus be likened to the search for the general laws of ecology (Brown, 1999), from which historical contingency supplies the deviations. Whereas the historical focus of the entry in Table 1 is at the macro-scale, historical signals may in fact be evident on a range of scales, from continental glaciations to the creation of forest gaps in relation to an ENSO (EL Nino Southern Oscillation) cycle.

2.2.2 Climate and Energetic

Dynamic models may take different forms. The equilibrium theory of island biogeography (ETIB) (MacArthur and Wilson, 1967) is one form of dynamic hypothesis. It invokes a general relationship between extinction and immigration (plus speciation), controlled by a few obvious environmental parameters, to regulate patterns in species-area regressions. Although it is not a climatic model, it is based on the premise that the resource base of an island dictates richness in a predictable fashion. An increasingly popular model, which was built upon the ETIB, is Wright's (1983) species-energy hypothesis. Wright took the apparently simple step of replacing area as the independent variable predicting richness with available energy, where this refers to the rate at which resources available to the species of interest are produced on the island as a whole. In effect, for plants, he multiplied the annual rate of actual evapotranspiration (AET) averaged over each island (taken from a global map of AET) by the area of the island. The islands in Wright's analysis ranged over two orders of magnitude in both area (1200 km2 for Jamaica to 770,500 km2 for Australia) and species number (137 species on Spitzbergen to 12,000 for Australia), and both variables were logged prior to analysis. Despite the usual improvement that this transformation brings, only 70% variance was accounted for in the regression. Wright's paper has nonetheless proven influential, perhaps in part because it coined the species-energy theory or hypothesis, since adopted by others engaged in macro-scale studies of species richness (e.g. Lennon et al., 2000). The basic idea in the species-energy hypothesis is that the amount of available energy sets limits to the richness of the system (Wright, 1983).

Studies under this rubric have used a variety of measures of energy, including: temperature, AET, primary productivity and potential evapotranspiration (PET), where each of these measures may be annual or seasonal values, and where a variety of alternative formulations of each is available (Lennon et al., 2000). It needs to be understood that these indices of energy differ in kind and may exhibit strongly contrasting patterns at the macro-scale. For instance, AET can be crudely characterized as an estimate of the amount of water used to meet the environmental energy demand. It thus estimates water balance and is recognized as a good correlate of plant productivity, i.e. it measures use of energy by plants (thus in turn available to animals) rather than climatic energy per se. Temperature is the simplest measure of environmental or climatic energy, and may provide good correlates with, e.g. birds; but may be anticipated to be less powerful in models of the richness of solar ectotherms such as butterflies (Lennon et al., 2000). The point here is a simple one and an ecological truism that it isn't just a question of the amount of energy, but of its availability to the trophic level or taxonomic group in question that matters.

Heat and light are both necessary for photosynthesis. Thus, a good measure of climatic energy regime for plants should incorporate both. In contrast, net primary production (NPP) does not measure the inputs for plants, but is an indicator of the availability of energy (in chemical form) for heterotrophs. O'Brien (1998) has developed a theoretical model of plant species richness at the macro-scale that is consistent with the ideas of species-energy theory, but which is more satisfactory and we believe more general than previous formulations (Whittaker & Field, 2000). Her insight is that it is the interaction between water and energy that is foundational to an understanding of spatial variation in photosynthesis, and thus biological activity, and through this activity, spatial patterning in the capacity for plant species richness to be supported. In general, richness should be anticipated to increase as a linear function of rainfall and a parabolic function of energy (heat and light); the latter as photosynthesis is dependent on a narrow range of temperature conditions below which water freezes and above which it vaporizes. The emphasis on considering the water balance as well as the energy regime in modelling vegetation has of course been noted by other authors (Currie, 1991).

O'Brien's water-energy dynamics theory is more fundamental because it generates clear expectations as to the form of the relationship between climate and richness. In her studies of southern African woody plants, the most powerful simple model of richness was found to be a two-variable model based on a linear relationship with annual rainfall and a parabolic ($x-x^2$) relationship with minimum monthly PET (Thornthwaite's formula). Subsequent analyses demonstrate that this holds for species, genus and family richness (O'Brien et al., 1998) and that it can be developed into an interim general model capable of reproducing known patterns of richness elsewhere on the planet (i.e. for regions of other climates and bio-geographic histories), irrespective of whether they are latitudinal or longitudinal in form (O'Brien, 1998).A simple capacity rule (Brown, 1981) encapsulates these ideas, as follows: whatever the geographical pattern of variation in water-energy dynamics, it will tend to be matched by the geographical pattern of variation in the amount and duration of chemical energy production, in biological dynamics and thus (over geological time) in the capacity for taxonomic richness (O'Brien et al., 1998). Given this rule, climate can be conceptualized as setting the general form of the predictable macro-scale pattern in richness, i.e. the climatic potential for richness (O'Brien, 1998).

The model is capable of improvement, most simply by the inclusion of a measure of topographic relief (O'Brien et al., 2000), but appears to be capable in its original two-variable form, of capturing the first order macro-scale pattern of variation in woody plant richness globally. It is not to be anticipated, for good ecological reasons that the spatial patterns in all other taxa will follow this relationship, but it may nonetheless provide a foundation for building a more general understanding of richness variations in other taxa (e.g. for mammals). Notwithstanding the substantial body of work on climatic relationships to richness, the debate persists as to the underlying mechanisms (Loehle, 2000), with several authors pointing to inconsistency of diversity-productivity relationships. In practice, this inconsistency is the result of comparisons being made at vastly different spatial scales and whereas the relationships being revealed by work at the macro-scale are generally consistent, at local scales of analysis, climatic controls are less evident as other factors that exhibit greater heterogeneity at these scales kick in with their signal (Purvis and Hector, 2000).

2.2.3 Stress, Stability and Disturbance

The ideas that fewer species are physiologically equipped to tolerate harsh or varying environments and that disturbance prevents competitive exclusion, are similar in at least one respect: they are founded on the implications of environmental variability for the persistence of species in an area. As Colinvaux (1993) notes, the basic answer as to why stressful habitats such as hot springs, salt flats and mountaintops tend to support few species is that they are rare, scattered and sometimes ephemeral. The problems of species' adaptation to such environments, their small size (or, in cases, extreme unproductively), and the difficult of migrating between such sites provides elaboration of the case. Considering harshness and variability of environments in respect to their nature and causes, most sites that are unfavourable and have a low richness for these reasons are either localized and relate to plate tectonics, e.g. hot springs, mountaintops, serpentines outcrops, or are regionally distributed as a function of climate, e.g. extreme desert environments.

Mangroves may be considered as occupying harsh or stressful environments and as a further illustration of this class of systems. Mangroves are the woody plants that occupy estuaries and intertidal zones throughout the tropics and subtropics. These ecotonal systems between the marine and terrestrial worlds support a relatively low diversity of the dominant higher plants, with thirty to forty species in the most diverse areas and only one or a few in many places (Field et al., 1998).

These environments are subject to pronounced environmental fluctuations dictated by tidal conditions, involving extreme edaphic conditions of high and varying salinity. Whilst the pattern of variation in gross richness between the Indo-West Pacific and the Atlantic, Caribbean and Eastern Pacific region appears best explained by historical scenarios associated with the origins of mangrove taxa (Ellison et al., 1999), patterns of richness at the local scale within large land masses or groups of islands do appear to correlate with a variety of measurable environmental variables, often including precipitation in a leading role (Duke et al., 1998).

Despite the importance assigned to climatic factors in some studies, the fact remains that mangrove ecosystems are unusual environments, linearly distributed as narrow, discontinuous ribbons around coastal margins. Area-controlled analyses restricted to mangroves are possible only at a local scale of analysis, and they are at best only a small part of the signal (or noise?) within macro-scale, area-controlled analyses of richness. Considering the role of disturbance, relatively few aspects of environmental variability on the macro-scale would appear to be independent of climatic controls. For instance, the distribution of high-energy storms (hurricanes, cyclones, typhoons), and of large fires are both functions of the general circulation, and of inter-annual variations in circulation such as ENSO (Kitzberger et al., 2001). On a longer time-scale of variation, glaciations of temperate latitudes could be considered under this rubric, as large-scale disturbances through which climate-richness relationships may have been modified to varying degrees in different parts of the globe. One category that is independent of climate and which can impact powerfully on ecosystem functions is large volcanic eruptions. However, given the ability of plant species to persist as dormant propagules and to bounce back from intensive volcanic activity (Whittaker et al., 1999), it is unlikely that volcanic eruption impacts will be detectable in macro-scale plant richness; although they may well be detectable locally (e.g. in species numbers). The impact of disturbance on richness may not be simply negative of course.

The Intermediate Disturbance Hypothesis (IDH) (Connell, 1978) is essentially a patch-dynamics or succession model, invoking conditions for maximal diversity whereby repeated local disturbances occur that are frequent enough to prevent competitive exclusion over an entire area, but not so frequent as to eliminate most species. As Wilson (1994) notes, both actual physical scale and frequency must be commensurate with the physical size and generation times of the organisms concerned for this model to operate. In his assessment of the relevance of the IDH to New Zealand plant communities, Wilson (1994) argues that the processes involved, such as fires, floods, tectonic processes, landslips etc., operate at spatial scales too large for there to be mosaics within areas of $1000m^2$, the upper limit he uses for alpha or within-community diversity, except in the context of forest gaps. He therefore places the IDH as essentially a landscape-scale model. In practice, it is hard to see how the IDH can be tested at the macro-scale, as this requires a simultaneous measurement for each grid cell of all important disturbance phenomena, their area of impact, intensity of impact and frequency, including, e.g. fires, severe storms, landslips, volcanic eruptions, etc., and it is not at all clear how a meaningful quantification can be obtained by this means (Peterson and Parker, 1998). Most grid cells will contain patches that are little disturbed and patches that are very disturbed, hence it seems unlikely that disturbance regime will in fact vary measurably at the macro-scale. Examination of recent papers citing the IDH in the ISI Web of Science data base confirms that evaluations of the IDH tend to be landscape (or local to landscape) in scale and that even at this scale it has mixed success (Townsend et al., 1997).

The closest to a test at a regional or geographical scale encountered is the study by Hiura (1995), although in fact the data used are from small patches of forest and are thus based on local inventories rather than species range data. Similarly, Loehle's (2000) interesting attempt to develop a model accounting for richness variations, which incorporates biological traits in respect of disturbance regime, is essentially operational at the landscape scale, requiring climatic inputs to enable regional calibration.

2.3 METHODOLOGICAL FRAMEWORKS ADDRESSING THE STUDY OF AQUATIC PLANTS

Despite the evidence that macrophytes increase habitat heterogeneity and positively affect richness and composition of animal assemblages, most investigations ignore the measurement of heterogeneity or use non-systematic and difficult methods to compare measurements. These same shortcomings were also recognized for terrestrial studies trying to determine the effects of habitat heterogeneity on animal diversity, where the measurement of habitat heterogeneity was inconsistent, making comparisons among different studies very difficult (Tews et al., 2004).

A wide range of sampling and survey methodologies have been developed by different countries for specific applications including conservation, ecological status, drainage impact, management, ecological habitat and river restoration or enhancement. For example, Dawson (2002) developed guidance for the field assessment of macrophytes of rivers within the Star project. The Star Project was carried out by Hugh Dawson of Dorset- United Kingdom to establish a good ecological status and the general monitoring of ecological status in the

United Kingdom. It is adopted in this research to serve as a guide for the assessment of macrophytes at the Ajiwa Dam. It is quoted in details below:

The methodology required as part of the Star programme was developed specifically for the surveying of macrophytes in natural and anthropogenic-altered running freshwaters for the purpose of monitoring ecological status.

2.3.1 A summary of the Star method

What is the Star Field Survey Methodology?

1. Purpose: to facilitate the establishment of good ecological status and the general monitoring of ecological status.
2. Biota sampled macrophytes (plants identifiable with the naked eye).
3. Water courses sampled: rivers and streams, the method is not suitable for standing waters, canals (unless water flow is constant in one direction) or tidal rivers.
4. Underlying principles: within the aquatic macrophytes flora, there is a spectrum of tolerances to environmental perturbation, for example, nutrient enrichment will probably be expressed by assigning scores to species e.g. for STAR on a scale of 1-10; the higher the score the lower the tolerance to nutrient enrichment.
5. Basis of operation: the macrophytes flora and physical character of defined lengths (100m) of water course are surveyed using a standard checklist. The presence, absence and percentage area covered by each macrophyte are recorded and used to calculate a score. Physical parameters are recorded to aid interpretation.

For what purposes can the Star Field Survey Methodology be used?

6. Uses: the method can be used to give qualitative assessment of whether a site is impacted by anthropogenic effects and (for physically similar sites) and downstream

changes in status. A model structure or typology is devised to compare the status of physically dissimilar sites.

7. Applications: the principal application for which the method has been developed and to be tested is to produce a standard methodology and data set to allow pan-European comparisons for the Water Framework Directive (WFD), to facilitate the establishment of good ecological status and the general monitoring of the ecological status.

Survey Planning

8. Alternative methods: a Star diatom survey should be undertaken at the same time as the aquatic plant survey if possible.
9. Sampling strategy: the location of survey sites varies according to the purpose of the survey. Less impacted control or semi-natural sites may help determine impact.
10. Logistics of sampling: a minimum of one survey per year for three years is recommended, each being undertaken at the same time within the hydrological cycle or survey season (mid June to mid September in central and northern Europe) and after several days of low or low-normal flow. Operator safety, shade, river flow and water clarity need to be considered when selecting a survey length. Survey materials include sampling aid, camera and protective clothing/equipment. Surveyors should be familiar with the provisions of national access and conservation laws and should follow appropriate health and safety guidance. Survey can be undertaken by one operator, although, multiple-staffing is recommended; surveyors should allow one person-day per survey although this may vary considerably.
11. Ancillary data collection: background information on site geomorphology, pollution incidents and river management can be useful when planning and interpreting surveys.

How to carry out a Star Macrophytes Field Survey

12. Pre-survey preparation: consult equipment checklist and take appropriate equipment. Surveyors should be familiar with the necessary health and safety guidance.
13. Field survey: the stretch to be surveyed (the survey length, 100m) is selected or located and if possible for survey it is measured out and marked. Standard field sheets are used to record site and survey details. The macrophytes flora and physical character of the survey length are then surveyed by wading, boat or walking along the bank. Sampling aids are used where necessary. All macrophytes present are recorded, together with the estimated percentage cover of overall macrophytes growth. Representative samples (algae, *Ranunculus, Callitriche* and *Potamegeton* species) and species which are uncertain are taken for laboratory identification and preparation of herbarium specimens. Physical parameters of the survey length are estimated, a sketch map drawn and a photograph taken.

Quality Assurance

14. Error and variability: variability between surveyors in data recorded in the field can be reduced correct application of the method and adoption of quality assurance. The impact of natural background variation within the survey season and between physically dissimilar sites can be reduced by careful timing of surveys and selection of survey lengths. Measures of confidence should be assigned to relate to the survey and the comparability of sites.
15. Quality assurance procedures: quality assurance comprises measures integral to the survey method itself (e.g. on-site checks and multiple-staffing), training requirements and audit surveys. Two alternative audit protocols are provided.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN

The way in which researchers develop research designs is fundamentally affected by whether the research question is descriptive or exploratory. It affects what information is collected. In the context of this research, the research question is exploratory because we are trying to answer the "why is it going on" question. This is so because the impact of aquatic plants is there for all to see- that they prevent water from performing its role at the dam to various units of irrigation, domestic, hydroelectric power generation to mention but a few. But why do people not explore the positive values of such aquatic plants? Instead they just go about destroying them and thus, losing the economic benefits to be derived from them.

3.2 PROCEDURES FOR SAMPLING

The sampling procedure adopted for this research is the Purposive Sampling. The purposive sampling is a type of non-probability sampling that enables the researcher to get all possible cases that fit particular criteria using various methods. This work adopted the purposive sampling technique because it is amenable to selecting a sample on the basis of knowledge of the population, its elements and the purpose of the research. In other words, selection of units is made on the basis of our judgement about which of the elements would be most useful or representative.

The elements considered for selection at some stages in the selection process involve a target population that is spread across the Ajiwa Dam, hence involved sampling at various stages; basically two stages. In the first stage, aquatic plants species were selected with respect to their characteristics whether they are submerged or marginal species. Floating aquatic plant species at the second stage were selected and were accessible through a boat using hands and rakes as applicable.

3.3 PROCEDURES FOR DATA COLLECTION

Because of the adoption of purposive sampling procedure, the collection of data included gathering various species of aquatic plants at the study area and the recording of abiotic habitat parameters- crucial factors influencing the presence or absence of macrophytes which include land use type, bank structure and sediment type. The habitat parameters were assessed thoroughly regardless of the absence or presence of aquatic plants. These different sets of habitat parameters were considered in order to allow relations between macrophytes appearance and abiotic features. Additionally, each data collected was documented (by using digital photography) including the plant species for further analysis. A motorboat was used to access the individual stretches so as to provide an adequate coverage of the species. Plant materials were collected by hand or by using a rake as done by Danjuma (2007). Although his work was on irrigation agriculture, he collected plant materials for experimentation using hand rake.

3.4 PROCEDURES FOR DATA HANDLING AND ANALYSIS

All data collected from the field was digitally photographed as stated earlier. The print-outs of which were used for identification and further analysis. The analysis involved identification, classification, distribution and economic importance of each of the collected species. This was achieved with the help of a comprehensive research from various literature sources whereby each result was analysed and documented.

3.5 PROCEDURES FOR DATA PRESENTATION

The data obtained was then presented pictorially and also using descriptive sources from different literatures consulted. This was so because this research is the descriptive type otherwise called observational because the subjects were observed without intervening and later referred to related literatures for further description and finally explorations of potentials to be achieved from that subject matter that is Aquatic Plants. And also because the kind of data for the research is basically the purposive type and thus the analysis and presentation was in a pictorial as well as a descriptive form.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 SPATIAL DISTRIBUTION OF AQUATIC PLANTS

The species collected include *Typha australis, Phragmites karka, Salvinia molesta, Pistia stratiotes, Lemna pausicostata, Azolla caroliniana,* Water hyacinth, *Echinochloa colona, Oryza sativa, Nymphae lotus and Eulophia caricifolia.*The distribution, abundance, and vigour of these species are influenced by abiotic factors including water, temperature, pH, dissolved oxygen, nutrient levels, turbidity, sediment type, water and wind currents, depth and changes in water levels. Biotic components of the water body, such as the presence and density of herbivorous fish, insects, molluscs, diseases (fungi, nematodes), plant-to-plant interactions, and movement of vegetative portions of aquatic plants by man (e.g., plant parts entangled in fish nets) also influence the distribution and abundance of the aquatic plants. However, the aquatic plants at the study area are spatially distributed at different degrees based on the factors cited above but fishing, grazing and other activities have made the distribution very low.

The water level at the study area is at its peak during the rainy season and thus influencing the spatial distribution of aquatic plants. In other words, the change in water level at the study area greatly influences the abundance and spatial distribution of aquatic plants. This is evident because during the first reconnaissance survey, the plants were not in abundance but with the subsequent visits to the study area when rainfall was at its peak, the plants were distributed everywhere.

NORTHERN PARTS OF AJIWA DAM

At the Northern part of Ajiwa dam, the dominant species present include *Typha australis, Lemna pausicostata* and *Oryza sativa. Typha australis*is the most dominant specie with an estimated percentage cover of 60% followed by *Oryza sativa* with 34%. *Lemna pausicostata* was the scarcest at this part of the dam with an estimate of 6%.

SOUTHERN PARTS OF AJIWA DAM

The Southern part of Ajiwa Dam has species like *Pistia stratiotes* at an estimated percentage of 30% closely followed by *Echinochloa colona* at 28%. *Typha australis* was also present at this part with an estimated percentage of 24%.*Eulophia caricifolia* was estimated at about 15%.*Nymphae lotus* was the scarcest at this part with 3%.

WESTERN PARTS OF AJIWA DAM

At the Western parts of Ajiwa Dam, *Typha australis* was the only specie dominating the region at 100% estimate.

EASTERN PARTS OF AJIWA DAM

The species dominant at the Eastern parts of Ajiwa Dam include *Phragmite karka* at an estimated percentage of 22%. Salvinia molesta was estimated to be 55% at this area.*Typha australis* was dominant at 10%. *Azolla caroliniana* was dominant at 8% whereas Water hyacinth was the scarcest at 5%.

Most aquatic plants are depth sensitive and require a specific water depth in order to thrive. From the classification of the four types of aquatic plants stated earlier, their depths can be determined which are explained below:

Emergent aquatic plants: This category of plants from the study area grows rooted in saturated soils around the shoreline or in water up to about 2 feet deep. Mature emergent stems, leaves and flowers extend well above the water surface. Most of them look like terrestrial plants.

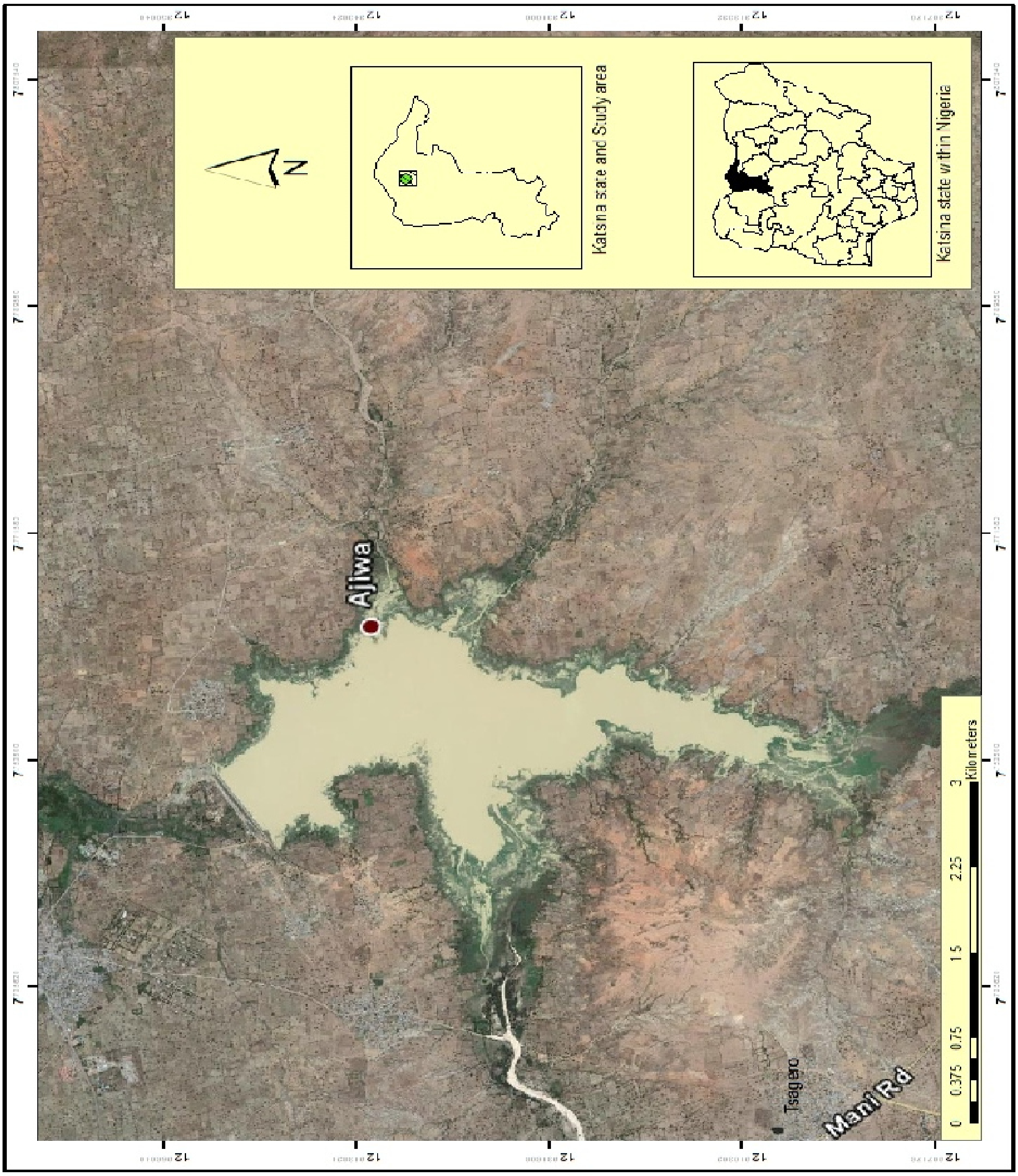
Free-floating aquatic plants: This category floats on or under the water surface. Their root systems, if present, generally hang beneath the plant and are not attached to the bottom. They are usually found in protected areas or where water currents are very slow. Since they absorb nutrients entirely from the water column, these aquatic plants are frequently found where nutrient content is high. Examples are the water hyacinth and the duckweed.

Rooted floating-leaved aquatic plants: These plants grow attached to the sediments in water depths from 1.5 to 10 feet. They are recognized by oval or circular leaves that float on or project just above the water surface. The floating leaves are connected to the bottom by long, flexible and fairly rigid stems. An example is the water lily.

Rooted submersed aquatic plants: These plants grow at water depths where light is sufficient. Submersed plants grow with stems and leaves under water. Submersed species usually have long, thin and flexible stems that are supported by the water and also produce flowers above the water surface.

However, the density of herbivorous fish is low at the study area which shows that there is abundance of ordinary fish but due to high level of fishing activities by settlers at the study area, the abundance of aquatic plants has been hindered (plant species being entangled with fishing hooks and nets).

Temperature impacts both chemical and biological characteristics of surface water. It affects the dissolved oxygen level in the water, photosynthesis of aquatic plants, metabolic rates of aquatic organisms and the sensitivity of these organisms to pollution, parasites and disease. The problem of low dissolved oxygen levels is magnified by the fact that the metabolic rates of aquatic plants increase as water temperature rises, thus increasing their biochemical oxygen demand. Low dissolved oxygen levels leave aquatic plants in a weakened physical state and more susceptible to disease and other pollutants.



Source: Extracted from Google Earth (2014)

KEY

1. *Typha australis*
2. *Phragmites molesta,*
3. *Salvinia molesta,*
4. *Pista stratiotes*
5. *Lemna pausicostata,*
6. *Azolla Caroliniana,*
7. *Water hyacinta*
8. *Echinocha colona,*
9. *Oryza sativa,*
10. *Nymphae lotus,*
11. *Eulophia carici-folia*

4.2 CLASSIFICATION OF AQUATIC PLANTS

Aquatic plants occupy diverse ecological niches in the aquatic environment. There are many possible classifications of aquatic plants which could be based on habitat, morphology or biological group. Westlake (1998) gave an example of aquatic plants classification that has six groups as follows:

1. Amphiphytes: plants that are adapted to live either submerged or on land.
2. Elodeids: stem plants that complete their entire life cycle submerged, or with only their flowers above the waterline.
3. Isoetids: rosette plants that complete their entire lifecycle submerged.
4. Helophytes: plants rooted in the bottom, but with leaves above the waterline.
5. Nymphaeids: plants rooted in the bottom, but with leaves floating on the water surface.
6. Plueston: vascular plants that float freely in the water.

The emergent plants at the Ajiwa Dam are new and developing and are mainly present on the water surface. Immediate examples are *Typha australis* and *Pharagmiteskarka* as shown on Plates 1 and 2 respectively. Floating leaves macrophytes are relatively, large plants visible with the unaided eye, floating on the water surface. Examples are *Salvinia molesta, Pistia stratiotes*and *Lemna pausicostata* as in the Plates 3, 4 and 5 respectively. The submerged macrophytes are also relatively large plants visible to the unaided eye but submerged in the water.

Plate 1: *Typha australis*- dominant at the Northern, Southern, Western and Eastern parts of Ajiwa Dam

Plate2: *Phragmites karka*- dominant at 3m away from the eastern bank of Ajiwa Dam


Plate 3: Salviniamolesta floating at the eastern parts of Ajiwa Dam


Plate 4: *Pistia stratiotes*: dominant at 2m away from the southern fringes of Ajiwa Dam

Plate 5: *Lemna pausicostata* dominant at some irrigation canals at the northern fringes of Ajiwa dam

4.3 CONTROL OF AQUATIC PLANTS

The control of aquatic plants can be effective when certain pre-requisites are known. Mere existence of one or few plants in the water does not mean that they are weeds. It must be established that they are weeds and that they can cause losses or reduce some immediate and future gain. However, some aquatic plants must remain to replenish dissolved oxygen, prevent erosion and enhance aesthetic values. The balance can be based on local conditions (Loeb, 1994).

However, some plant and algal covers retard fish growth. The covers prevent light penetration into the water and causes underneath darkness thereby reducing the amount of light for photosynthesis, which is the primary source of food in the water. Plant and alga covers, affect the whole ecological system. Their presence can cause diurnal fluctuation of dissolved oxygen. When decomposed; aquatic plants exert high Biochemical Oxygen Demand in water. *Salvinia molesta* cover can reduce temperature by 12ºC and dissolved oxygen by one-sixth of 1m below the surface (Eyo, 2000).

Eyo (2000) further stated that aquatic plants and algae interfere with useful and efficient netting of fish in the water. Excess plant growth causes impediment of water flow rate. Algal blooms and emergent weeds can cause water pollution and impair the aesthetic value of the pond. This is because when decomposed, alga and emergent weeds produce toxins and bad odour. The toxins can be toxic to fish.

Aquatic plants can cause increased water loss from the water through evapotranspiration. They also destroy lowland and water crops. Water canes, water chestnuts, water lotus and rice farms are choked by aquatic plants resulting in heavy losses. Disease can be spread through aquatic plants, since these plants are good breeding grounds for mosquitoes and other insects.

The control of aquatic plants depends on their kind, extent and age of infestation, water depth and its regularity, accessibility to the methods available, impact of the technique on the entire ecosystem and costs. An integration of various techniques, including manipulation of several environmental factors, need be instituted.

In the context of this research, the control of the above is duly considered to be the economic use of the plants and it is discussed on the next item below.

4.4 ECONOMIC IMPORTANCE OF AQUATIC PLANTS

Pyne (1986) and Okojie (1998) reported a variety of products and services of considerable benefits offered by aquatic macrophytes, which include:

1. FEED FOR FISH AND OTHER AQUATIC VERTEBRATES

It has been reported that aquatic plants play an important role in the life cycle of fish. A free-floating aquatic macrophytes *Lemna pausicostata* is eaten directly by Tilapia species (Mbagwu and Adeniji, 1988). While other fish species feed on periphytic algae growing on the surfaces of aquatic plants.

Mbagwu and Adeniji (1988) also report that there are 24 fish families in the freshwater ecosystem which some are herbivorous species. He asserted that 37 fish species are feeding onmacrophytes, and 20 of the macrophytes-feeding species belong to the family Cypriniciae, 8 to the family Cichlidae. Among these, grass carp is reported to be the only fish used on a large scale for aquatic weed control.

2. BREEDING GROUNDS FOR AQUATIC LIFES

Aquatic vegetation also provides breeding substrate for a large number of insects and other invertebrates, which serve as fish food. Under non-explosive, non-invasion conditions, for example, fishery managers consider floating aquatic plants as beneficial except where they interfere with methods of harvesting fish. Imevbore and Bakare (1974) reported that fish fry used aquatic vegetation for shelter purpose as well as their spawning grounds.

3. AQUATIC PLANTS AS BIO-FERTILIZERS

Aquatic plants accumulate large quantities of nitrogen and phosphorus in their tissues. They will therefore improve soil if applied as soil additives. The concept of bio-fertilizers, the growing of a minor crop that provides nutrients to a major crop, though relatively new to aquatic science, is already becoming popular. Azolla specie, a free-floating fern that fixes nitrogen in a symbiotic relationship with the Cyanobacterium Anabaena azollae, is widely used as a


Plate 6: *Azolla caroliniana* dominant at 1m away from the eastern reaches of Ajiwa Dam


Plate 7: Water hyacinth dominant at 4m away from the eastern bank of Ajiwa Dam

bio-fertilizer for rice crops. Rice-fish polyculture, with *Azolla* specieas a bio-fertilizer, has become popular in Asian flooded rice field. Maltby, (1986) reported that *AzoIla* specie has been used to a lager extent to fuel rice production in waterlogged areas in china. In a report from the Philippines, dried water hyacinth has been successfully used as a bedding material that enhances the formation of mushrooms [*Eichhorniacrassipes*] (Loeb, 1994).

4. AQUATIC PLANTS AS SOURCE OF ENERGY

The value of aquatic plants as energy source centres mainly on its use as fuel for fish smoking and for domestic energy. Meanwhile, by subjecting aquatic plants to bio-chemical reaction, they can be converted to energy source (fuels) whether in liquid, gaseous or solid forms. For example, it has been reported that the stems of *Aeschynomene crassicaulis, Echinochloa spp*. and *Cyperus papyrus* among others are used as fuel especially for cooking and fish smoking (Kio and Ola-Adams 1987). Eyo (2000) highlighted the use of water hyacinth in the production of biogas, and proposed the construction of dome type biogas digester to utilize water hyacinth for biogas production that will provide energy for the local community and the slurry that will be ready source of fertilizer for the farmland.

Plate 8: *Echinochloa colona* dominant at 2m away from the southern bank of Ajiwa Dam

5. INDUSTRIAL USES OF MACROPHYTES

Aquatic plants offer a wide range of materials that could serve the needs of innovative industry. The materials could be used for construction, matting, bedding and pulp/paper. Obot (1984) reported that the mature silky inflorescences of the spike of *Typha australis*are used in stuffing pillows and mattresses and the fragrant dry tuber of *Cyperus maculatus* is also sold in Northern Nigeria as perfume. He asserted that perfume is also produced from underground stems of *Cyperus articulatus*, when the leaves are burnt over the fire as a mosquito repellent, and that the aerial stems are used in the weaving of colourful mats commonly sold in northern part of Nigeria. *Vossia cuspidate, Cyperus papyrus* and *Eichhornia crassipes* (water hyacinth) has also been identified to possess economic potentials for pulp, paper and fibre. The potential for aquatic plants in water treatment has also been investigated. Some aquatic plants are very sensitive to pollutants and could be used as bio-monitoring agents.

Kio and Ola-Adams (1990) have reported the potentials of water hyacínth as a mopping agent and scavenger of heavy and toxic element in industrial domestic effluents.

The inflorescence of the Nypa palm (*Nypa fruticans*) has been reported to yield palm wine and sugar while the foliage has been extensively used for thatching, and *Raphia vinifera* has been identified as raw material used in making brushes, brooms and mats (Obot 1984). It is also identified to be used locally in making roofing poles and bed sheets, cards, fishing tackle and snares for game. According to Kio and Ola-Adams (1990) strips of the young, unopened fronds and mid ribs of *Phoenix rectinata* are used for weaving sleeping mats, sieves and bags. *Laguncularia racemosa* yields timber, tannin and dyeing materials.

6. AQUATIC PLANTS AS SOURCES OF HUMAN OR ANIMAL FOOD

It has been reported that floating rice (*Oryza sativa*) is the most widely known aquatic plant used as food. Other aquatic plants offer various food items. For example, the seeds of burugu (*Echinochloa stagnina*) are collected for food in Monai on the western shore of Lake Kainji. The seed of *Echinochloa stagnina* is also an important food item for fishermen in the Inner Delta of the Niger River and prized sugary syrup is obtained from the stalks of the grass. Kio and Ola-Adams (1990) reported that the rhizome, floral receptacle and fruits of *Nymphaea lotus*(water lily) are either eaten raw or cooked for food and *Ludwigia stolonifera* is used as an ingredient of soup in the Yelwa area of Kebbi State (Obot and Ayeni, 1987).

Plate 9: *Oryza sativa* dominant at some irrigation canals at the northern bank of Ajiwa Dam

Plate 10: *Nymphaea lotus* dominant at 1m away from the southern fringes of Ajiwa Dam

Imevbore (1971) and Obot (1984) in a survey of aquatic environments; identified 52 macrophytes but only 14 -of these were found utilizable for livestock production. Some aquatic plants can be processed as animal feeds. Even water hyacinth can be used in limited quantities in a mixture with other feeds by cattle, sheep, goats and other ruminants. Aquatic macrophytes used as fodder include *Vossia cuspidata, Leersia hexandra, Bracharia mutica, Echinochloa pyramidalis, Sorghum arundinaceum, Paspalum virginatum* and *Echinochloa stagnina*.

7. MEDICINAL VALUES OF AQUATIC PLANTS

A variety of aquatic plants are also used in curative therapy in traditional communities. A good number of these ethno-botanic materials have been reported to yield compounds, which could be of use as modern drugs and pharmaceuticals Okojie (1998). Kio and Ola-Adams (1987) reported that *Polygonum senegalense* is pounded with native hydrated sodium carbonate and rubbed on the limbs for rheumatic and other swellings. This concoction is also applied to syphilitic sores. *Althemanthera hodiflora* on the other hand, is used for simple stomach disorders and *Pistia stratiotes* is used for ulcerative conditions of the mouth and tongue. Obot and Ayeni (1987) also report that *Pistia stratiotes* is used as part of a concoction for the treatment of flu. The emergent nitrogen-fixing legume *Neptunia oleracea* is used in the treatment of yellow fever and guinea worm infection. Bubayero (1986) confirmed that between 75 and 80% of the Nigerian populace patronise the traditional healers that make use of a variety of plants including aquatic macrophytes. Many of these aquatic medicinal plants yield exceptionally promising compounds for use in modern drugs and pharmaceutical industries. *Polygonum senegalense* and *Nymphaea lotus* stems and roots are traditionally used in eruptive fevers and for urethral discharges. The stems and roots are also regarded as emollient and diuretic while the decoction of the flower is narcotic and sedative. In some parts of the country *Heliotropium indicurn* is used for treatment of fever in children and also as a vermifuge and eye-lotion. In Ghana, it is commonly mixed with clay to arrest abortion. The juice of *Ethulia conyzoides* can be squeezed into the eyes for headache; the root when mixed with red pepper treats constipation, and the leaves are given in food to prevent abortion. *Cyperus articulatus* is used to treat cough and when mixed with grains of paradise (*Aframomum melegueta*) would cure headache if applied to the forehead. Dried and pulverised *Cyperus articulatus* is useful as fumigant and can be mixed with scented resins for the clothing, and air-fresheners in rooms. Dalziel (1967) reported that the bark of mangroves is extensively used in many parts of West Africa for diarrhoea or dysentery especially in children, to check haemorrhage, for sore throat and also for urethral infection. Kio and Ola-Adams (1990) also confirmed that, in Cameroon, mangrove bark is used for leprosy and craw-craw, when pulverised and rubbed into the scarified skin and it is also boiled for use as a lotion.

8. AQUATIC PLANTS AS SOURCES OF RECREATION, TOURISM AND AESTHETICS.

Some aquatic plant species of great potentials in horticulture and recreation have been identified. Of greater potential are some members of the Family Orchidaceae such as *Eulophia caricifolia, Eulophia horsfallii* and *Eulophia angolensis,* smaller aquatic plants such as *Najas sp.*may also be used in the aquarium as ornamentals and as agents of aeration (Okojie, 1998). The presence of aquatic plants has favoured the possibilities of most Nigerian water-bodies being developed into recreation centres that will include sport, hunting, fishing, bird watching, nature photography to mention but a few. It has been reported that the annual income from visitors to Kenya's Amboseli National Park was estimated at US $1.3 million in 1979, where the associated aquatic systems are one of its principal attractions (MENR, 1981). United States Department of the interior and Department of Commerce (1982) have shown that in 1980, 5.3 million Americans spent US $638 million on hunting macrophytes-dependent water fowl and migratory birds in the USA. The most developed, and in fact the first National Park in Nigeria, is the Kainji Lake National Park. However, lbeun and Nehir (1989) reported that emphasis is placed on the terrestrial wildlife, theKainji Lake hydroelectric dam complex and historic sites without due attention to the variety of the associated aquatic fauna and flora.

Plate 11: *Eulophia caricifolia* dominant at 5m away from the southern fringes of Ajiwa Dam

4.5 MANAGEMENT OF THE IDENTIFIED SPECIES BY THE LOCAL PEOPLE

From the foregoing, it has been vastly described as to what types of species are dominant at the Ajiwa Dam and the possible benefits that could be derived from them. However, it must be stated that the local people may not have access to the report of this research and that even if they do; it is not likely that they could comprehend the contents. In this respect, a sensitization and enlightenment policy is strongly recommended both at the individual and government levels. The state government is advised to develop some enlightenment programmes that could reach the local people so that they could harness the observations of this research. Also some monetary guides and support should be arranged for proper tackling of the issue. Other possible management practices are explained further at item **5.2** in the next chapter.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Despite the general belief that most aquatic macrophytes pose obnoxious threat to the ecosystem, they could still be used in various ways to make them environmentally friendly particularly if their utilization is integrated with mechanical control which favours consistent but sustainable aquatic macrophytes control by the riparian communities at low cost and for added economic benefits.

The research has shown that theflora at Ajiwa Dam includes a great wealth of aquatic plants of socio-economic value. Thesecould play an important role in local economies where they could be traded in markets as medicinal plants, harvested for making handicrafts and as construction materials, or cultivated for food to mention but a few. Also the uses of aquatic plants are diverse but the most predominant are as medicines and food. Other significant uses explored in the research include use as ornamentals, animal feed, production of handicrafts and construction materials.

5.2 RECOMMENDATIONS

Information on the socio-economic value of species is not easily accessible, as it is often scattered, kept in people's heads, or published in the grey literature. The information presented in this research was collated through a combination of literature survey and field observations. It is therefore highly recommended that regional workshops be held to better access the wealth of additional information that could not be accessed through this research. This research raises important questions, such as what results would be obtained if the same kind of analyses were performed on the vast and renowned freshwater ecosystems of Nigeria and even sub-Saharan Africa (i.e. the Congo basin, Zambezi basin and eastern Great Lakes). I therefore encourage scientists and organizations to carry out similar researches investigating classification, distribution, control and economic value at a species level, in order to reveal the true importance of species to local communities and countries at large. Furthermore, a list of further recommendations is described below:

1. That a comprehensive chemistry of these macrophytes be studied with the objective of ascertaining the potency as regards their utilization in both orthodox and traditional medicine.
2. Need for nutritional investigation be conducted into some of these macrophytes as regards their inorganic minerals contents and their subsequent use as supplements in animal diets
3. Need for training of personnel as regards to the techniques entailed in conversion of aquatic plants to biogas and fuel as the prices of conventional household fuel goes up.
4. Centres for utilization of aquatic macrophytes should be established in order to put more emphasis in research as it bothers on the positive and ecosystem friendly use of the plants.
5. The use of the macrophytes as supplement to conventional fertilizers (inorganic fertilizers) should be adequately studied as organic alternatives capable of eliminating or abating the deleterious impacts of the inorganic fertilizers on the environment.
6. Extra effort should be put in place to make objective comparison between the use of the animal manure and manure that are derivatives of aquatic macrophytes with the aim of establishing their positive effects on phytoplankton /zooplankton production in ponds.

In a nutshell, I vehemently recommend that Environmental Impact Assessments be conducted before any actions that impact on wetlands are approved and that they include a fully balanced cost/benefit analysis based on the inclusion of a total economic valuation of the wetland in question. Subsequent actions should, in appreciation of these values, ensure the adequate conservation and/or sustainable use of these wetland resources. If we continue to destroy and degrade inland wetlands and their associated species at the rate at which we are doing so today we will, often unwittingly, cause the loss of many species to the great detriment of the large numbers of people who depend upon them for many aspects of their daily lives. The conservation value of species has long been recognized by organizations such as the International Union for Conservation of Nature and Natural Resources (IUCN) but this research now also confirms the great socio-economic value aquatic plants bring to our society. Given the high level of threat to these species, as recorded by the IUCN Red List (2012), the time has come to rethink our approach to the development and exploitation of wetlands.

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