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The Estimation of Potential Yield of Water Hyacinth: A Tool for Environmental Management and an Economic Resource for the Niger Delta Region

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Abstract: Water hyacinth has seriously infested the waters of the Niger Delta region, cutting across the fresh water aquatic environment of the states that make up the Niger Delta states. However, there is hardly any comprehensive empirical study towards estimating the potential yield of this weed, which though an environmental nuisance, has enormous economic uses. It is only when a realistic estimate of the annual yields available of the weed in the region becomes available, that a considerable investment in its economic utilization can be undertaken. This research was conducted using remote sensing techniques (GIS) via satellite imagery analysis and reconnaissance surveys to conduct a yield assessment survey of the weed in the region. The principal yield parameters of interest focused on by this research are its mass (weight) and extent of spread (distribution) in the region. The distribution and level of abundance of water hyacinth within the Niger Delta region were equally assessed using a combination of both satellite imagery data and extrapolation methods developed exclusively for this study. Satellite imagery data from National Space Development and Research Agency were processed as a basis to evaluate the estimated surface area coverage of water hyacinth across the region. Standard indices from literature were then used as a bench mark to combine with the satellite imagery estimates in determining the approximate total abundance of the water hyacinth in the region. Names of major rivers and creeks where this weed occurs were also identified through satellite imagery. The study arrived at a total biomass estimate of the weed in the region to be **3,225,000** tons/for the region/year. The study concluded that such yield value annually is adequate to invest in large facilities that could be used to economically utilize the weed and also indirectly control its myriad of environmental problems in the region.

Key words: Estimation, Potential, Yield, Water Hyacinth, tool, Environmental Management.

1. Introduction

Aquatic weeds can pose a whole lot of problems to the environment as well as humans. Among the aquatic weeds, water hyacinth (*Eicchornia crassipes*) is the most widespread and notorious aquatic weed that is said to be found in almost all parts of the world. It has infested many water bodies across the globe, leading to numerous socio- economic and environmental problems [1]. Similarly, dense mats of free-floating vegetation block boat traffic and prevents swimming and fishing as well as keeps sunlight from reaching the water column thus preventing emergent and submerged plants from photosynthesizing [1]. Water hyacinth control is a necessity, for humans as well as for other aquatic creatures and the environment as a whole. Water hyacinth (*E. crassipes*) is a fast growing perennial free floating aquatic macrophyte. It is a member of weed family (*Pontederiaceae*) and its name *Eichhornia* was derived from well known 19th century Prussian Politician J.A.F. Eichhorn [1]. Water hyacinth (*Eichhornia crassipes*), is a common feature in many water bodies in Nigeria particularly in the Niger Delta. Often, this plant covers large proportion of the water bodies thereby reducing the water utilization potential.

The plant is capable of producing large standing crops in a relatively short period of time. It is capable of producing about 150-200 tonns per hectare per year of the plant biomass [2[1]2[2]]. In fact, it has been reported that two water hyacinth plants can grow into 1,200 off springs in 120 days. It is a free-floating aquatic plant, which grows up to 1m in height and has thick, waxy, rounded glossy leaves, which rise above the water surface on stalks [2[1]2[2]]. The plant can reproduce vegetatively by short runner stems (stolons) that radiate from the base of the plant to form daughter plants and it also reproduces sexually through the seeds. The thick and spongy leaf stalks help to keep the plant buoyant [3]. Several features of the biology of water hyacinth contribute to its status as one of the world's worse weed problems. Among these are its enormous potential for growth, production of huge quantities of biomass and adaptation to different nutrient

and environmental conditions. Although water hyacinth normally floats on the water, it can survive on mud when water levels are low, enabling it to persist through dry seasons. It can survive a wide range of temperatures, a wide range of nutrient levels in the water, and a wide range of acidity and alkalinity, which enables it to colonize many habitats [2[1]2[2]].

2. Project Location

The project cuts across the entire nine (9) Niger Delta state of Ondo, Delta, Bayelsa, Rivers, Abia, Akwa Ibom, Imo and cross River. The satellite imagery assessment for the distribution and abundance of the weed covered the entire Nine (9) Niger Delta states. Other specific trials such as experimentation on use of water hyacinth as animal feed was carried out in a private; Universal Farms Ltd, Ughege village, Kilometer 12, Benin Sapele Road, Edo state with the water hyacinth gotten from Ologbo River which is about 18 kilometers from the farm. The use of manual method for clearing the weed, as a means evaluating its effectiveness practically were carried out in the following states of the Niger Delta namely: Edo, Delta, Rivers, Bayelsa, Akwa Ibom and Ondo states. The Rivers that were sampled are: Ologbo in Edo, Ere and Bomadi rivers in Delta, Oluwa in Okitipupa LGA of Ondo state, Mbo River in Mbo LGA of Akwa Ibom state, River Nun at Ogbia LGA of Bayelsa state and The Kolo Creek which is a tributary of the River Nun. The Creek is close to the Mbiama Community in Rivers state. The locations are well drained and have roads that are accessible all year round. The figure 1 is a map showing the project locations as well as sample areas.

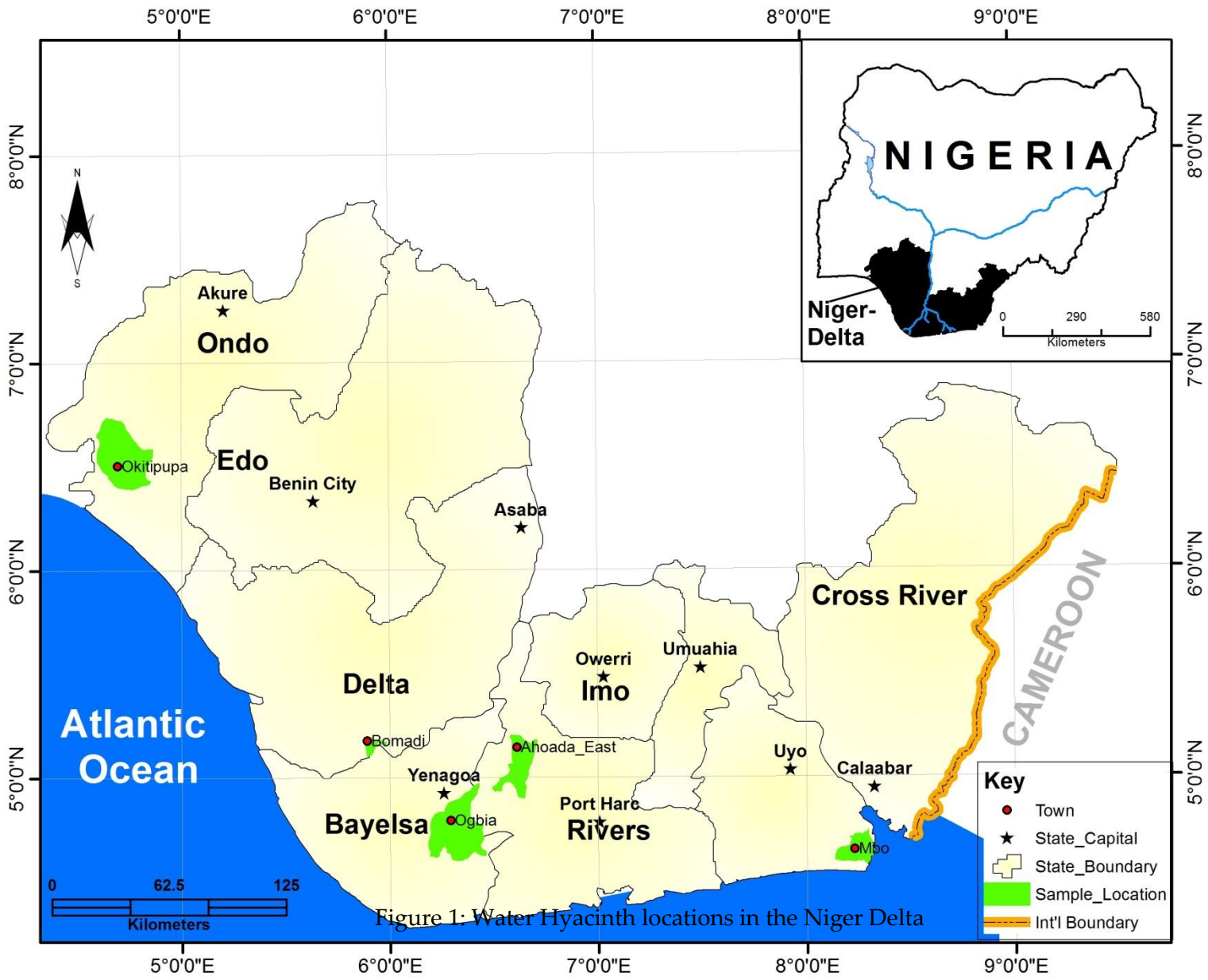


Figure 1: Water Hyacinth locations in the Niger Delta

3. Ecological Factors Affecting Water Hyacinth Population

Water hyacinth is a plant that grows best in warm waters rich in macronutrients [4]. Optimal water pH for growth of this aquatic plant is neutral but it can tolerate pH values from 4 to 10 [1]. This is very important fact because it indicates that *Eichhornia crassipes* can be used for treatment of different types of wastewater. Optimal water temperature for growth is 28 - 30 ^{o}C. Temperatures above 33^{o}C inhibit further growth [4]. Optimal air temperature is 21-30 ^{o}C and they cease to grow when water temperature is above 40^{0}C or below 10^{0}C [5]. If the plant stays in the water for more than 12 hours at temperature of -3 ^{o}C, it will destroy all the leaves and at temperature of -5 ^{o}C during the period of 48 hours will destroy the whole plant [5]. *Eichhornia crassipes* can survive 24 hours at temperatures between 0.5 and -5 ^{o}C, but it will die at - 6 to -7^{o}C and cannot be grown in open where average winter temperature drops under 1^{o}C. Low air humidity from 15% to 40% can also be limiting factor for undisturbed growth of water hyacinth. *Eichhornia crassipes* tolerates drought well because it can survive in moist sediments up to several months [6]. Salinity is the main obstacle for growth of water hyacinth in coastal areas. According to studies by [6] the production of this aquatic macrophyte in relation to different effluent salinity values. They also tracked the plant's reactions to high levels of salinity by observing symptoms of a different intensity. They concluded that production of water hyacinth was reducing and necroses on leaves and bulbous petioles were occurring earlier with increase in salinity concentration.

4. The Plant - Water Hyacinth *(Eichhornia crassipes)*

The plant water hyacinth is made up of seven species which comprise the genus *Eichhornia*. The mature plant consists of long, pendant roots, rhizomes, stolons, leaves, inflorescences and fruit clusters. The plant can grow up to 1m high although 40 - 60cm is the more usual height. The inflorescence bears 6 - 10 lily-like flowers, each 4 - 7cm in diameter. The stems and leaves contain air-filled tissue which give the plant its

considerable buoyancy. The plants reproduction is both sexual (through seeds that are viable up to thirty years) and asexual (through stolons) which radiates from the base to form daughter plants [7]. The broad, thick, glossy, ovate leaves of water hyacinth may rise above the surface of the water as much as 1 meter in height. The leaves are 10–20 cm across, and float above the water surface. They have long, spongy and bulbous stalks. The feathery, freely hanging fibrous roots are purple-black. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with six petals. Out of the seven species of water hyacinth, the commonest species of water hyacinth in the Niger Delta is *Eichhornia crassipes*. It is distinctly divided into three (3) parts; a fleshy leaf (leaves) that form the basis of photosynthetic accumulation, a greenish semi-succulent stem and a rather brownish fibrous root network. The root is usually submerged under the water and forms the propellant part of the weed [8]. A typical stand of Water Hyacinth and mat of water hyacinth are shown in Plates 1. and 2. respectively.

Plate 1: A stand of Water Hyacinth

Plate 2: A mat of Water Hyacinth during bloom

4.1 Taxonomy

There are about seven species that make up the genus *Eicchornia* e.g. *E. speciosa, E. natans, E, azurea, E. crassipes,* among others. It is only two of these species namely, *E. crassipes and E. natans* that are found in Africa and *E. crassipes* is the most abundant species in Nigeria [9]. *E. crassipes* can be distinguished from other floating and mat forming aquatic plants by its highly glossy leaves, the almost one sided swelling of its petioles and by its showy purple flowers. It is distinguished from *E. azurea*, which must root to the substrate, and it is therefore confined to shallow ponds and the edges of lakes and rivers [2²]. The *E. natans* is rooted along the stem with submerged leaves arranged along narrow/thin ribbons of some centimeters. Towards the tips of the petiolated leaves, there is a limb curved into heart-shaped structure; 1.5 –2.5 cm, which floats on the surface. This feature distinguishes it from *E. crassipes.* According to [4] there are the following water hyacinth taxonomic classifications.

Division - *Magnoliophyta*

Class - *Liliopsida*

Subclass - *Commeinidae*

Superorder - *Commelinanae*

Order - *Pontederiaceae*

Family - *Pontederiaceae*

Genus - *Eichhornia*

Species - *crassipes*

5. Origin and Distribution of water hyacinth in Nigeria

Water hyacinth is also reported to have originated from South American in the early 1880s [4]. Its first appearance in North America was at the end of 19th century (1884). About the same time it was spotted in Egypt [10] where it invaded many of African rivers and lakes such as Lake Victoria. Thereafter, water hyacinth spread to many tropical and subtropical countries [11] usually with catastrophic socio - economic and ecological consequences. The consensus is that Water Hyacinth entered Nigeria from Benin Republic via the Badagry Creeks [12]. The exact time and place of introduction has been debated, but the plant is native to South America, and therefore reached the Niger Delta due to human activity, movement by wind and ocean currents. It has spread prolifically, due to lack of natural enemies, ineffectiveness of the conventional control measures, an abundance of space, favourable nutrient and environmental conditions.The distribution of water hyacinth is aided by wind movements and water currents. According to [12], the plant entered Nigeria through the Nigeria -Benin Republic Border (e.g. Badagry – Seme - Idiroko borders). This is because the Badagry and Seme-Idiroko creek links the coastal creeks of Benin Republic to Nigeria.

6. Origin and Distribution of water hyacinth in Niger Delta

Water hyacinth entered Nigeria waters through pot-novo creek in Benin Republic in September 1984 according to [3] and since then it has been spreading. The South-Western Lagoon complex is linked through one channel or the other to the various southern rivers connected to Nigeria's Atlantic coastline where the mouths of these

rivers intercalate to form the fan shaped lower part of River Niger in the Delta Region of Nigeria. Some of the major Rivers within the Niger Delta include Rivers Benin, Escravos, Forcados, New Calabar, Nun, Bonny, Sombreiro etc. Because these rivers are linked in one way or the other, the plant invaded the Niger Delta through these aquatic routes. Considering this hydrological catchments networking scenario, there is the concern for its present as well as future potential spread over all the Rivers within the Niger Delta in particular and Nigeria in general. In Nigeria today, water hyacinth has invaded virtually all the coastal river systems of Nigeria–Benin, Escravos, Nun, Forcados Rivers, among others [9]. In the main channel of the River Niger, the water hyacinth has been observed as far up as the Kainji Lake and upstream of Yelwa River to where the River Niger enters Nigeria form the North-western border. Massive luxuriant mats have been found along River Ase, a major tributary of the River Niger within the Nigerian Agip Oil Company (NAOC) oil fields at Kwale and Okpai in Delta State. The down south of River Niger's major bifurcation into Forcados and Nun Rivers at Onya/Asamabril Biseni, it has been recorded along these two River Niger branches and their distributaries – Patani, Bomadi, Isampou, Ekeremor, Ojobo, all along Bomadi creek. It has also invaded Rivers Ethiope and Warri [9]. In Rivers and Bayelsa States, observations of the mats of the plant have been made along the River Niger's Ase – Azagba-Anieze-Isukwa-Odugiri-Agwe-Oniku-Ndoni-Ogbogene-Obiafu-Utuechi, axis (Ogba/Egbema LGA of Rivers State).The same observation has also been made in the Joinkrama –Akinima, Mbiama, Emelego and at the [9].

Plate 3: Mat of matured water hyacinth in bloom

Studies by [13] reported the distribution of water hyacinth in Rivers State (Rivers Niger, Orashi, Santa Barbara, Sombreiro) etc. The rivers systems are high – energy environments and are subjected to considerable wave and current actions that are influenced largely by rainfall conditions in the fresh water axis. Furthermore, [13] reported that water hyacinth infested virtually all the river systems in Rivers State. Their occurrence and biomass distribution as shown by elevated values indicate that the plant has established and entrenched substantially in the water bodies in such a manner that it constitutes serious ecological threat, especially to the natural and endemic economic species. Despite the differences in the water quality characteristics between the rivers systems, the plant exhibits luxuriant growth in all the water bodies [13]. This suggests that the environment is conducive for its development and or that the plant has wide ecological tolerance for growth and development. It is this ability to grow in a wide range of nutrient concentrations and environmental conditions that gives the plant impetus to compete and outgrow the indigenous plants.

Generally the upper reach sectors of the river systems had considerably higher biomass, which tend to suggest that river's width and current flow may be some of the major controlling factors as entanglement is limited in wider areas of each river system. This

observation could also suggest that the distribution and biomass of the plant were not due only to the physicochemical quality of the water bodies

7. METHODOLOGY, FININDINGS AND DISCUSSION

7.1: Estimation of Water Hyacinth Abundance in Niger Delta.

In this section the different scenarios of different levels of water hyacinth infestation were assessed using both satellite imagery and direct observation through reconnaissance surveys. Also, the distribution and level of abundance of water hyacinth within the Niger Delta region were equally assessed using a combination of both satellite imagery data and extrapolation methods developed exclusively for this study. Satellite imagery data from National Space Development and Research Agency were processed as a basis to evaluate the estimated surface area coverage of water hyacinth across the entire Niger Delta region. Standard indices from literature were then used as a bench mark to combine with the satellite imagery estimates in determining the approximate total abundance of the water hyacinth in the region. Names of major rivers and creeks where this weed occurs were also identified through satellite imagery.

7.2: Scenarios of Different Levels of Water Hyacinth Infestation: The satellite imagery of water hyacinth clearly shows how massive the problem of this plant can be. Hence it is often described as an invasion and reinvasion shortly after controls had been effected as illustrated from a very high resolution satellite imagery (About 2 meters) as captured from Lake Chivero, Zimbabwe (Figures 2, 3 and 4 respectively).

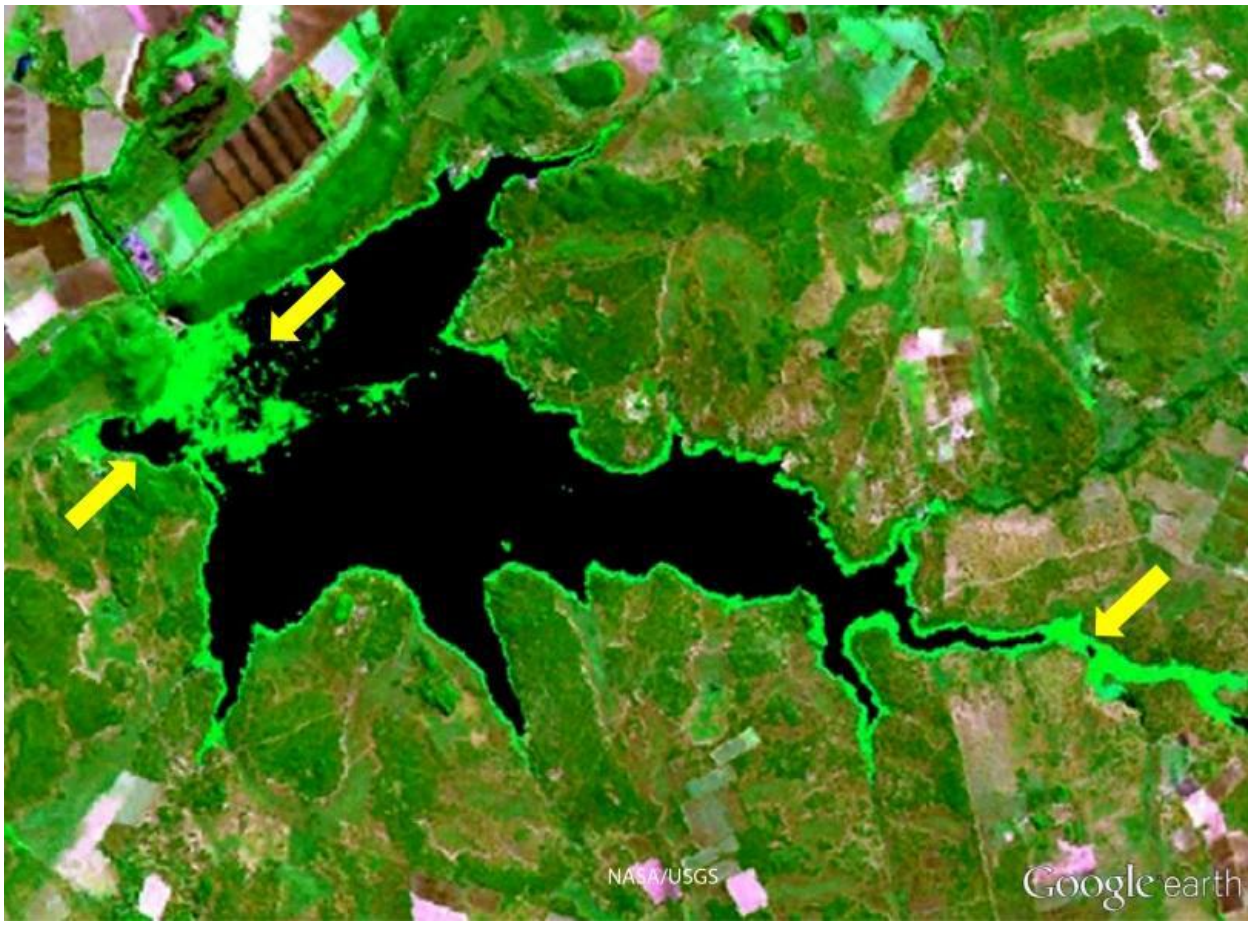
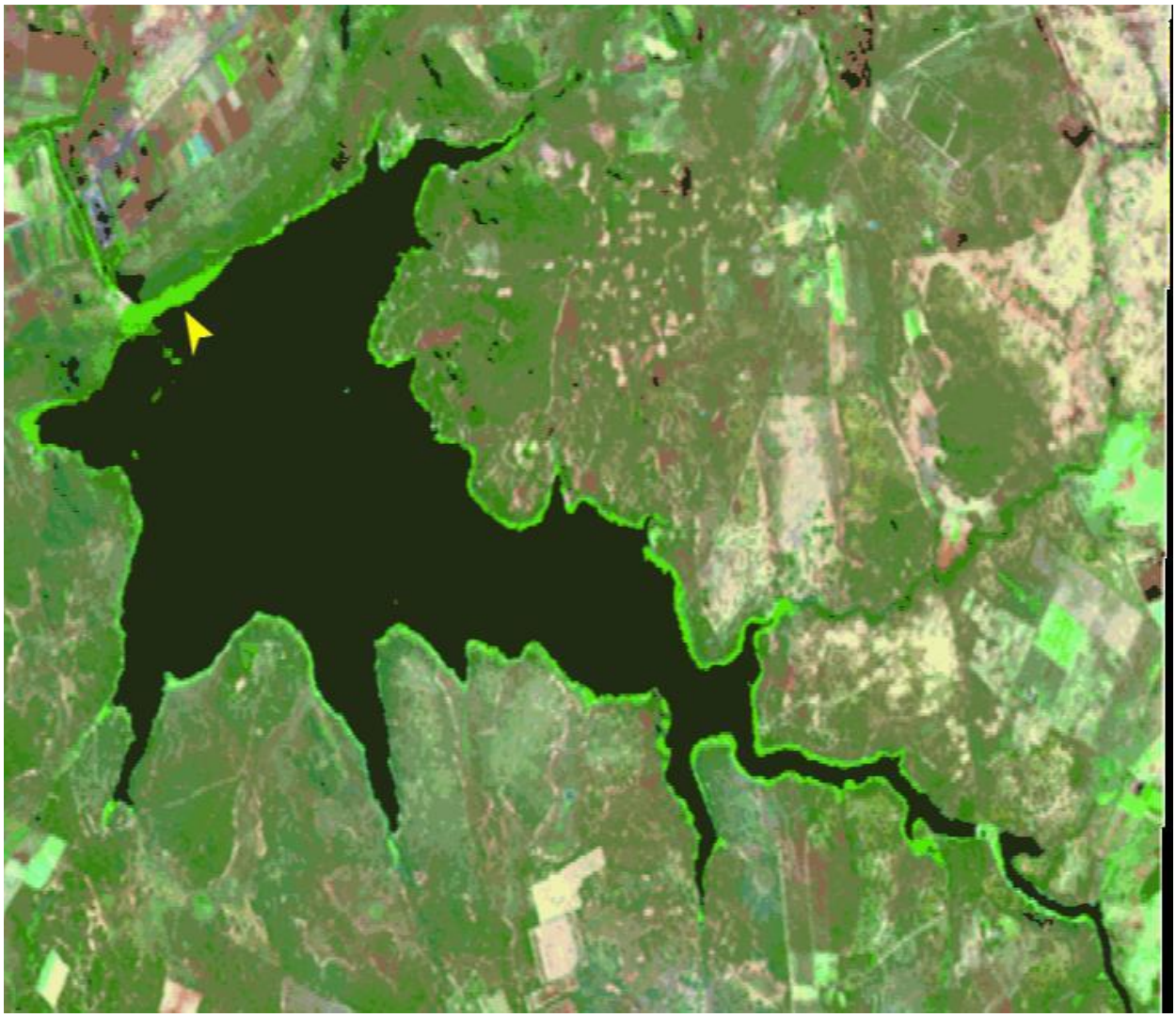


Figure 2: Satellite imagery showing invasion of water hyacinth on Lake Chivero, Zimbabwe; Adapted from [14].

Figures 3: Satellite imagery showing control of water hyacinth on Lake Chivero, Zimbabwe; adapted from [14].



Figures 4: Satellite imagery showing re-invasion of water hyacinth on Lake Chivero, Zimbabwe; Adapted from [14].

8: FINDINGS AND DISCUSSIONS (Distribution and level of abundance of water hyacinth within the Niger Delta)

During the reconnaissance visit, it was observed that the different rivers and creeks have different levels of water hyacinth infestation ranging from low, medium and high levels as shown in Plates, 4. 5, 6 and 7 also Figures 5 and 6 confirms the assertion.

Plate 4: Low infestation of water hyacinth

Plate 5: Medium infestation of water hyacinth

Plate 6: High infestation of water hyacinth

Plate 7: High infestation of water hyacinth

8.1 Water Hyacinth in Niger Delta

The knowledge and insight into the geo-hydrologic and geo-morphologic characteristics of the region of Niger Delta, is a good way of illustrating its potential for extensive distribution of the water hyacinth weed. The weed being an aquatic plant has tended to be very successful in colonizing virtually all fresh water bodies of Niger Delta where the prevailing physico-chemical characteristics (especially fresh water of around

neutral pH), the temperature, current and nutrient availability are favourable. According to [12] they justifiably chronicles the Niger Delta geo-hydrologic and geomorphologic characteristics as one that predisposes the region to extensive distribution of water hyacinth."The Niger Delta is the fan-shaped area of about 70,000 square kilometers in the southern part of Nigeria, through which river Niger and river Benue empty into the Atlantic Ocean. It is basically a huge floodplain, formed primarily by centuries of silt washed down by the rivers Niger and Benue and crisscrossed by a web of creeks that link together the main rivers of Benin, Bonny, Brass, Cross, Forcados, Kwa-Ibo, Nun and other rivers and streams". "The Niger Delta region is situated at the apex of the Gulf of Guinea on the west coast of Africa and on the Nigeria's South–South geopolitical zone. The Niger Delta, which is home to some 31 million people occupies a total area of about 75,000 km^2 and makes up 7.5% of Nigeria's land mass"[12]. The Niger Delta land mass of approximately 20,000 square kilometers is considered to be of wet land of various water systems i.e.; streams, rivers, tributaries, swamps and other variants of deltaic environment from which this intricate network of aquatic systems, eventually empties into the Atlantic ocean [12]. Water hyacinth can reproduce via vegetation by short runner stems (stolons) that radiate from the base of the plant to form daughter plants and it also reproduces sexually through the seeds. The thick and spongy leaf stalks help to keep the plant buoyant [3]. Several features of the biology of water hyacinth contribute to its status as one of the world's most problematic weed problems. Among these are its enormous potential for growth, production of huge quantities of biomass and adaptation to different nutrient and environmental conditions.

Although water hyacinth normally floats on the water, it can survive on mud when water levels are low, enabling it to persist through dry seasons. It can survive a wide range of temperatures, a wide range of nutrient levels in the water, and a wide range of acidity/alkalinity, which enables it to colonize many habitats [2²]. In fact, it has been reported that two water hyacinth plants can grow into 1,200 off springs in 120 days. It is a free-floating aquatic plant, which grows up to 1m in height and has thick, waxy, rounded glossy leaves, which rise above the water surface on stalks. The plant is capable of producing large standing crops in a relatively

short period of time. It grows in mats up to 2m thick which can reduce light and oxygen penetration, change water chemistry, affect flora and fauna and cause significant increase in water loss due to evapotranspiration. The plant can grow and survive in lakes, streams, rivers, ponds, ditches and in any water way. It obtains its nutrients from the water column Water hyacinth (*Eichhornia crassipes*) can live and reproduce floating freely on the surface of fresh waters or can be anchored in mud. Plant size ranges from a few inches to a metre in height. Its rate of proliferation under is extremely rapid and it can spread to cause infestations over large areas of water causing a variety of problems. It also causes problems for marine transportation by entangling propeller shaft of the water crafts and also impedes intakes of water for hydro power and irrigation schemes. The plant is now considered a serious threat to biodiversity as most of the freshwater systems in tropical countries are infested with water hyacinth which causes serious environmental problems. All efforts to control the growth and spread of these weeds have failed and hence the concept of eradication through economic utilization i.e. seeing it as a resource material rather than a nuisance [2[2]].

Water hyacinth was introduced into the tropics including the Niger Delta as a non-endemic plant during the 17th and 18th centuries through a variety of routes. As they were non - endemic, there were no natural control mechanisms such as insects and fishes that feed on them [2[1]]. This factor, coupled with their fast growth rate and high capacity for survival has resulted in their rapid and unchecked growth filling up the entire water bodies. The present situation is mostly anthropogenic or man-made. A major portion of the fertilizers that are used for agriculture ultimately find its way into the nearby water bodies and cause eutrophication or nutrient enrichment, favouring the growth of water hyacinth. The preceding review of the geo-hydrologic characteristics of the Niger Delta environment as chronicled in the following reported reports on certain aspects of research of the region, clearly illustrates its inherent potentials as a viable environment for the extensive thriving of water hyacinth. Except for the saline environment, virtually both interconnected and isolated creeks, streams, rivers and

other forms of water bodies that water hyacinth has been introduced into in one way or another supports the growth of the weed.

8.2: Estimated Yield of Water Hyacinth in Niger Delta (tonnes perannum)

Water hyacinth is capable of producing about 150-200 tons/hectare/year of the plant biomass [2[1]2[2]]. Figure 1 earlier mention shows the estimated area of coverage for water hyacinth in the waters of the entire Niger Delta and Bayelsa state respectively. The areas that the weed covers within the entire Niger Delta is as shown in the satellite imagery (Figure: 5). Whereas the weed is found in virtually every suitable aquatic environment of the Niger Delta, its distribution on a state by state basis varies. The areas of coverage on a state by state basis are exemplified for Bayelsa state as shown in Figure: 6.

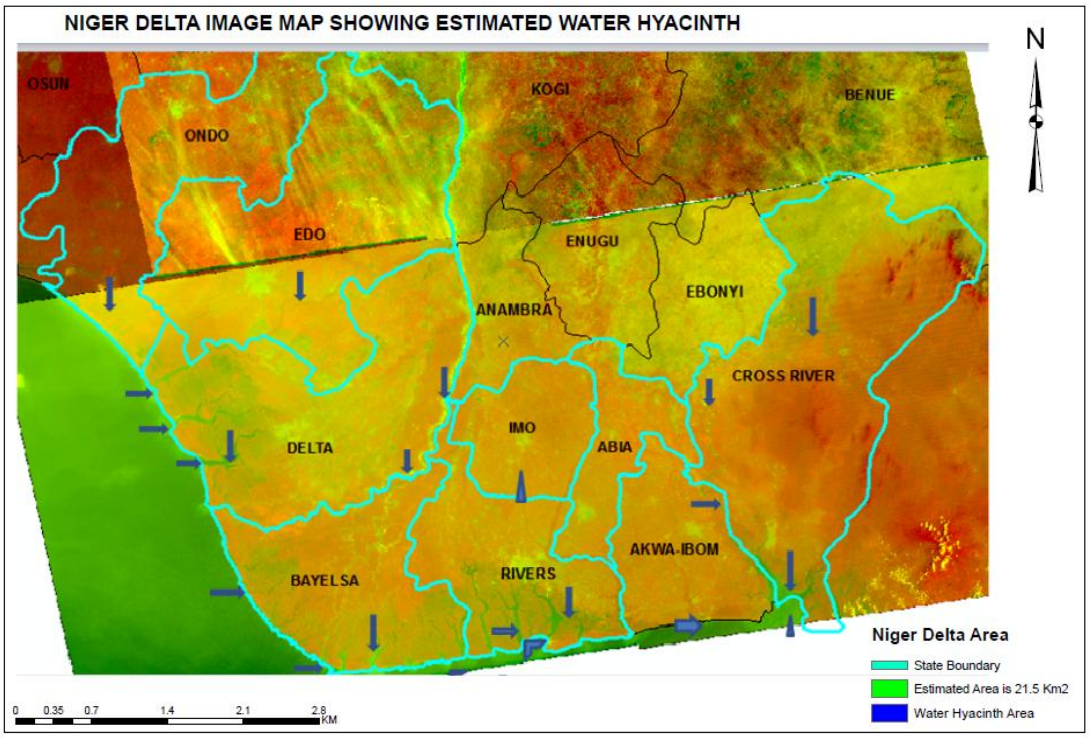


Figure 5: Satellite Imagery of Niger Delta showing areas covered by water hyacinth across the entire Niger Delta state. Adapted from[15].

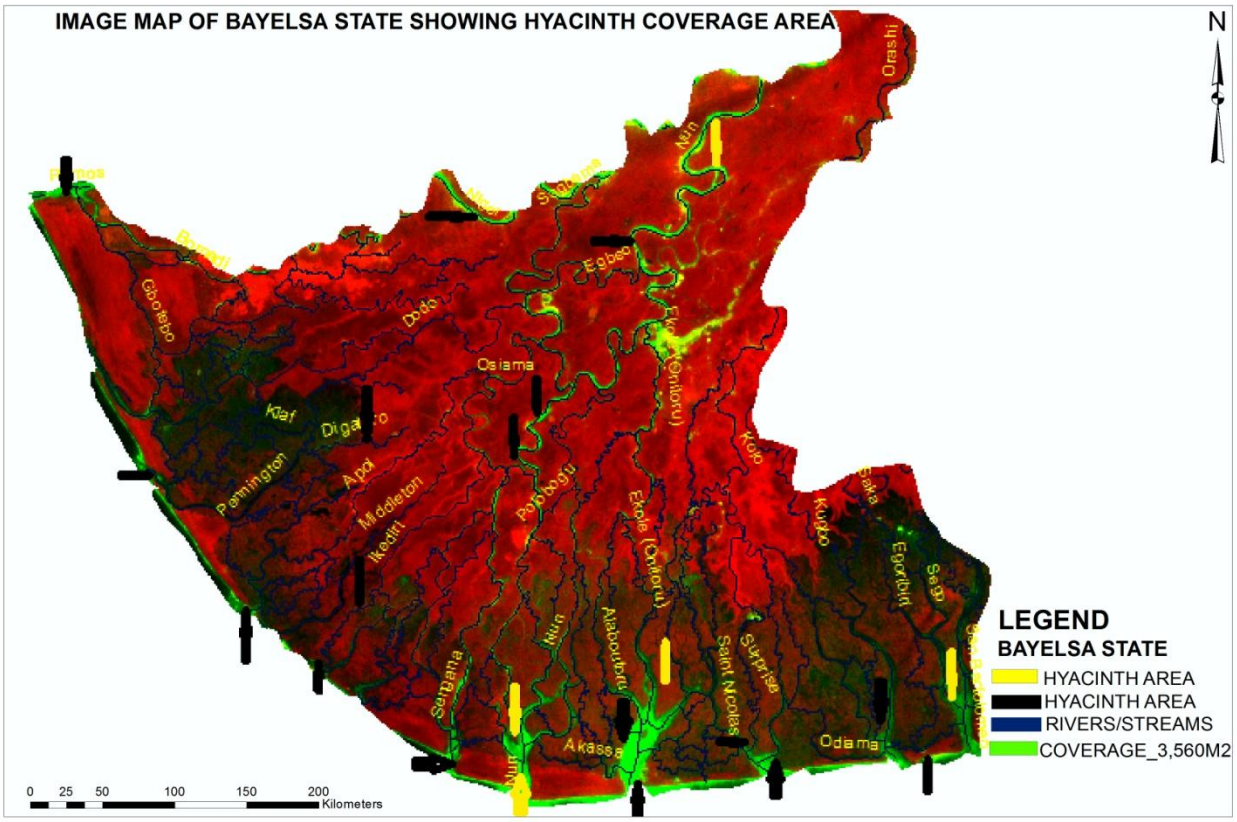


Figure 6: Satellite Imagery of Bayelsa showing areas covered by water hyacinth. Adapted from [15].

8.3: Summary of Extrapolation Method

Applying the principle of extrapolation therefore, the following estimate in terms of the estimated biomass of water hyacinth within the region is as follows:

1. Taking the lower limit of the average yield of water hyacinth per annum of 150 tonnes, the following extrapolation procedures was applied to derive the total annual tonnage yield estimates of water hyacinth obtainable within the Niger Delta region.
2. Since 1 hectare $m^2 = 0.01\ km^2$
3. Therefore to convert $215Km^2$ to Hectares = 215/ 0.01 = 21,500*hectare*s m^2

4. Since it has been established that water hyacinth is capable of producing about 150-200 tons per hectare per year of the plant biomass [2[1]2[2]].
5. Taking the lower limit of 150 tons per hectare per year of the plant biomass;
6. Therefore total water hyacinth plant biomass estimate for the Niger Delta =
7. (150 tons per hectare per year of the plant biomass X 21,500m^2 *hectare*s) =

3,225,000 Tons per Entire Niger Delta areaPerYear.

9: Conclusion and Recommendation:

Water hyacinth is considered the worst and most damaging weed in the world because of its very rapid rate of growth and its adaptability to a wide range of nutrient and environmental conditions. This gives the plant the advantage to compete and outgrow other economic indigenous plants with its consequent adverse economic and environmental effects. Considering the hydrological catchments networking scenario of the Niger Delta in particular and Nigeria in general, there is the palpable fear of its present as well as future potential invasion of all the Rivers within the Niger Delta and the entire country. This paper focused on the estimation of the potential yield of water hyacinth and its use as an environmental tool to harness the enormous potentials of the weed. The research has shown in section **9.3** using the extrapolation method that the quantity of water hyacinth available in the Niger Delta portends enormous potential for harnessing water hyacinth as a feed stock for biogas production and other uses on a commercial scale. However, there is the need to undertake a detailed evaluation of the area (i.e. inventorization) with the major objective of identifying physically all rivers and creeks infested with water hyacinth and the areas of coverage.

Acknowledgment

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