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Review Article

Climate Change Induced Water Hyacinth Growth Impact on Water Transportation and Coastal Ecology in Nigeria at the Gulf of Guinea

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ABSTRACT

Water hyacinth (*Eicchornia crassipes*) is one of the aquatic weed that is highly pervasive with global concern, and is leading obstructers of water craft especially at tropics. The weed has been a major transportation problem at the Nigerian coastline and inland waterways. This paper carried out an assessment of the growth, the spread, and its economic effect on the country's transport sector. It also assessed the relationship between the global climate change, water eutophication and the water hyacinth propagation as a result of anthropogenic activities using secondary real–time data and search engine for relevant case. Environmental Management Plan (EMP) principles and trend analysis were also used in the analysis. The paper re-established the fact that the weed has the potential of producing about 150-200 tonnes of the biomass in a year per hectare, and that by the year 2050, about 50 million of the weed biomass conservatively would have grown across the nation's water bodies going by the continuous increase in temperature and eutrphication. It is therefore recommended that both ministry of environment and transportation should develop a strategic multi-sectoral action plan to tackle the menace nationwide.

Keywords: Climate change; Eutrophication; Gulf of Guinea; Inland waterways; Transportation; Water hyacinth

INTRODUCTION

Water transportation has been adjudge as the most cost-effective means of moving bulky, perishable, and weighty products across long distances generally known as cargo movement. Maritime and inland waterways transport is of major significance in the global economy, as it handles about 80% of worldwide trade, thereby influencing a lot of industries. In fact, the global water transport market has grown from about $507.75 billion in 2021 to $537.07 billion in 2022 and projected to $650.21 billion in 2026 with a growth rate of 4.9%. While the inland water freight market is projected to $22.29 billion in 2025 at a cumulative growth rate of 4.5% [1]:

In spite of these projected growths, Water-Hyacinth (WH) is increasingly becoming a threat to water transport across the globe as it tends to clog watercraft routs and limits even small canoe traffic, recreational, and aquatic eco-services utility.

The dense canopy produces by the weed across the river surfaces, shade-off the incoming radiant energy required by local submerged aquatic species from flourishing, and thereby dominates the entire habitat. The activities of the weed together with the prevailing global climate change tend to exacerbate the local ecosystem stressor. The growth of this weed is however determined by a) Total Phosphorus (TP), b) Total Nitrogen (TN), c) Water surface Temperature (T), d) Salinity, pH, and e) Water dept which place and time dependent [2,3].

WH is known to have many species of Eiccornia (*E. Crassipes, E. Speciosa, E. Azurea,* and *E. Natans*), but the *Crassipes* species with glossy, purple leaves and inflated petioles is the most common in Africa. Their roots are active in ponds and at river banks that are shallow in substrate metabolism. But the roots, stems, and leaves of *E. Natans* are submerged in water bodies [4], as in Figure 1. Researchers have revealed that WH has moisture biomass of: 95.5%, nitrogen 0.04%, ash 1.0%, P_2O_5 0.06%, K_2O 0.20% and organic matter of 3.5% [5].

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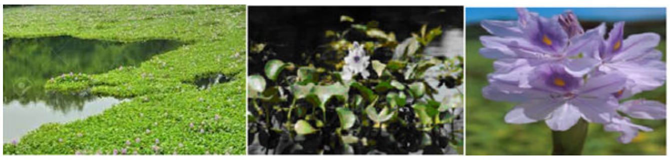

Figure 1: Water hyacinth colony leaves and flower.

Before the 70's, WH can be said to be strange to Nigerian water ecological system as it came just as an ornate plant in the 80's, and now became a weed in more than 20 states of the federation. In fact, it has covers Lagos Lagoon around Ajah area, Lagos Islands, Ikorodu, Badagry, and Oworonshoki a total area of about 1,500 to 2,000 hectares [6,7]. Also rivers, lakes and creeks in Delta State have been invaded to about 12,000 hectares, thereby negatively affecting the livelihood of about 40 million people in the region [8].

This paper therefore is aimed at examining the nexus between the Global climate change and water eutrophication on the growth of WH and its impact on water transportation in Nigeria by x-raying the genesis of the plant in Nigeria, the pattern of growth of the plant, the relationship between climate change and the growth of the plant, and the level of impact on the countries water transport.

LITERATURE REVIEW

Growth and migratory characteristics of Water Hyacinth (WH)

Man and animals are generally known as social creatures that migrate, but plants also do, as WH (also known to botanists as *Eichhornia Crassipes*) from the Amazon Basin and around Africa through human agents migrate. The origin of the plant has been traced to South American in the early 1880's [9,10], and its first appeared in North America was at the end of 19th century and almost the same period in Egypt; from where it invaded many African rivers and lakes such as Lake Victoria. It then spread too many other tropical and subtropical countries [11-13], usually with disastrous socio-economic and ecological implications. For Nigeria, it is believed that the plant entered country from Benin Republic *via* Badagry Creeks [14]. Although the plant is native to South America, it's now a dominant weed in Lagos and Niger Delta due to human and natural vectors.

Climate change and the growth of water hyacinths

Climate change factors appear to have hit the less developed nations lopsidedly as the adverse impacts are more pronounced in backward communities [15], as the atmospheric carbon dioxide has been increasing from 280 ppm at the global industrial takeoff to 400 ppm in t the millennium year, and projected to reach 439 ppm the year 2030 [16]. The ozone layer depletion due to greenhouse effect is the bane of the global climate change anomalies revealed in the form of heat wave, Ice cap melting and sea rise, tsunami, variable drought, etc. [17,18]. While some level of temperature increases enhances the growth of WH, aquaculture activities are adversely affected due to drought which necessitated the development of Hazard Analysis and Critical Control Points (HACCP) system for large scale and pollution-free product certification [19], Other form of climate change adaptation and mitigation include digital and archival fishery, and quality traceability system in response to ecological challenges.

Generally, global drivers of ecological changes include both direct (e.g., climate change, anthropogenic activities, and invasive species) and indirect drivers (e.g., demographic, economic, socio-political, scientific, technological, cultural, and religious) [20]. While the EPA's Global Change Research Program (GCRP) emphasizes the role of climate change, and land use change as global ecological change stressors. Scientists and policy-makers have increasingly recognized invasive species as a global stressor, because of their significant effect on ecosystems [21].

WH (*Eichhornia crassipes*) as aquatic plants, is said to be one of the most invasive with damaging impacts as a species of the tropics and subtropics region, it appeared to be limited by low winter temperatures, but thrive more in medium to high temperature. As non-indigenous species that encroached into the ecological communities as invasive weed do more harm than good to the host species. Climate change and variability tend to enhance the growth of these invasive species and range expansion thereby totally modifying the existing ecological setting. For instance, the altered atmospheric conditions modified the carbon dioxide concentration, precipitation pattern, increase atmospheric and ocean temperature, and nitrogen distribution are more favourable to the foreign invasive weeds [22]. In fact, studies have revealed that a single WH that is a free floating aquatic plant that grows up in height to about 1 m, with thick rounded glossy leaves, can multiply into 1,200 off-springs in 120 days, The reproduction is both in sexual (by seed) and asexually (stolon), and the spongy leaf stalk also helps in keeping the plant buoyant all year round.

WH is generally known for their comparatively high photosynthetic efficiency (1.52%) and rapid propagation than the local food plants. The yield per hectare in South America is between 350-1700. In India for instance, studies revealed that just one WH can multiply into 1200 in 120 days, and a 450 km^2 area coverage can become 14,928 km^2 in 200 days.

Human activities such as industrial pollution, urbanization, sedimentation, turbidity in shallow water bodies tends to enhance the growth of the plant, while nutrient loading due to increased agricultural intensification, or urban runoff do empower aquatic invasive plants [23]. Salinity and temperature are major growth factor, as Olivares and Colonnello [24], observed that WH survives salinities of 0.13–0.19% (w/v) but not 0.34%, and in Nigeria according to Kola [25], salinities below 0.1% (w/v) have been shown to have no effect. For temperature, Wilson et al observed that temperature of about 108°C is the minimum temperature for growth, and 25°C–27°C is the optimal, while 40°C is abnormal for the plant. The common finding in the past studies is that climate change enhances the growth of WH in many regions of the world, and it is a major challenge to water transport infrastructure in terms of new climate change mitigation, adaptation, and sustainable transport system [26-28].

Similarly, one of the most insidious effects of the plant around Kanji Lake apart from boat movement blockages is the great deal of water loss through evapotranspiration. Water loss from water hyacinth-covered waters has been reported to be up to 9.84 times higher than evaporation from open water. This water loss may reach serious proportion in the water storage capacity of reservoirs as it is said that about 405 hectares of water hyacinth displaced 1.22 × 0 m^3 of water in the Lake thereby increasing mishaps.

Nigeria for instance has significant mangrove coverage around the major river estuaries and deltaic entry into Atlantic Ocean. The major rivers cover an area of about 853,600 hectares making up 11.5% of the total surface is of the country. Deltas, estuaries, and saline wetlands cover a total surface area of about 858,000 hectares; freshwaters cover about 3,221,500 hectares [29]. These water bodies are connected and are used for fishing and for the transportation of goods and services, but the water hyacinth has taken over almost all areas of the freshwater ecosystem in the country, thereby posing serious challenges to the socio-economic and transportation sectors of the nation, hence the need for this research.

METHODOLOGY

The study area

Nigeria lies between latitudes 3°15’-13°30’ N and longitudes 2°59’-15°00’ E and has boundaries with the Gulf of Guinea to the south, the Republic of Benin to the west, the Republic of Niger to the north and the Republic of Cameroon to the east [30]. The total land area is about 923,768 km^2 of which 13, 000 km^2 is covered by rivers and lakes (Figure 2). The country has a tropical climate with high humidity and temperatures that is marked with wet and dry seasons with annual rainfall of between 1,500 to 4,000 mm in the south and 500 to 1,000 mm in the north. The country’s fast inland freshwater ecosystem spread throughout the country from the coast to Lake Chad Basin in the north.

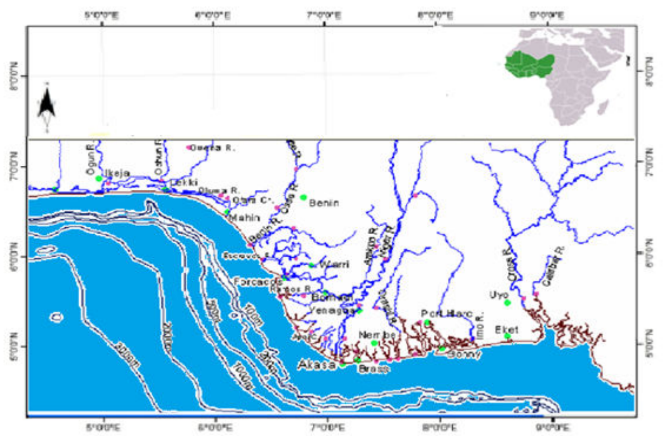

Figure 2: Nigeria Coast on the Gulf of Guinea.

Data collection mode

This study relies solely on secondary real–time data remote sensing data and reported literature on the subject area using the Environmental Management Plan (EMP) principles of is identifying and predicting impacts and suggests mitigation measures for the prevention of environmental negativities. High resolution imageries on the search engine give a comparatively sound data base for effective EPM.

The climate trend of the countries coastal area and the incidence of water hyacinth over the same period were collected and analysed in conjunction with the marine/river transport challenges. Secondary data of water pollution of the same area was collected and correlated with the growth of WH over the same year. Although there are missing data of some years, the results of the findings are still sufficient enough to account for the impact on transportation clogging.

RESULTS AND DISCUSSION

Nigerian rivers eutrophication and WH growth

Coastal marine ecosystem and fresh water bodies across the globe are majorly compromised by eutrophication processes thereby aggravating excessive plants and algal growth due to photosynthesis retardation [31,32]. The continuous discharge of slurry loaded with nitrogen and phosphorous into aquatic ecosystem tends to aggravate water body eutrophication that has direct impact on aquaculture productivity as in Figure 3. Channel catfish production typically contains high levels of nitrogen and phosphorous that encourages cyan bacteria blooms and hypoxia [33].

It is however observed that scientist in aquaculture seldom eutrophicate water bodies by injecting fertilizers to artificially increasing the biomass density of fishes. Anthropogenic activities like agricultural practices and industries are major algal bloom enhancers through their waste disposers [34,35]. Aquatic plants like WH are known to have high heavy metal, nutrient and organic pollutants abortion capacity, while also useful in water pollution control and restoration.

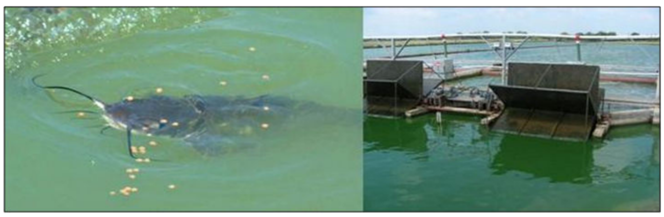

Figure 3: Aquaculture practices and water resources.

Earlier studies on water temperatures and dissolved solid in water bodies across the country on rivers like Otamiri, Owerri, and Imo corroborate this fact [36]. For example, Total Dissolved Solid (TDS) is between 6.67 and 17.83 mg/l in Ikpoba River, and turbidity level ranging between 2.33-5.83 mg/l that is above the WHO and NESTREA portable water standard of 5 mg/l More so, studies have observed that there is direct relationship between the value of electrical conductivity and TDS in water bodies. Mean while, Total Suspended Solid (TSS) for River Benue was reported to ranges between 12.55-49.57 mg/l, which was attributed to the brewery industry and the abattoir that continuously discharges effluents materials from the upper land into the river.

Also, phosphates concentration of between 0.029 and 0.245 mgl-1 and nitrate concentration of between 1.38 and 2.9 mgl-1 are known to be sufficient for the growth of algal blooms [37,38]. A high Nitrate concentration value of 3.80 mg/l was also reported in Ogun River by Jaji et al. [39] as a result of human activities. While indiscriminate applications of chemical fertilizer by farmers has been reported to have contributed immensely to high ammonia and phosphate in water bodies. The continuous global climate change and human population dynamics is another major influential factor that further negatively impacted on the freshwater quantity and quality. Water body acidification due to precipitation variability and human migration due to population growth and conflicts has led to more pressure on water bodies. There is therefore the need for water resource managers to understand how to minimize the intensity and frequency of algal and cyan bacterial blooms in water bodies for sustainable aquatic ecosystem [40].

Water hyacinth propagation and spread on Nigeria water bodies

September, 1984 was the first time when WH became noticeable along Badagry creek in Lagos. The weed initially as a sizable carpet over the water surface become pervasive in 1990. Covering virtually all the major waterways (the Niger and Benue River, and Kaduna Rivers, major natural lakes and large dams like Kanji Lake) and coastline.

According to Tola making reference to Prof. Babajide Alo the former Deputy Vice Chancellor of the University of Lagos, a member of the National Task Force on the Implementation of the Ballast Water Management Convention 2004; the invasion of WH in Nigeria was due to fertiliser waste released into the waterway by an industry based in Lome, Togo [41]. While others attributed the invasion to ballast sediment water discharged within the territorial continental shelf which should be addressed through the IMO regulations.

In an effort to relate the global climate change with the growth of WH in Nigeria, the multi-temporal projection of the country's temperature was analysed. That temperature is increasing globally; Nigeria inclusive is no longer news, but the level of preparation for mitigation and adaptation is the issue calling for attention [42]. Figure 4 is the laboratory projection analysis of temperature over the country for the next 60 years using the minimum and maximum rage of Representative Concentration Pathways (RCPs).

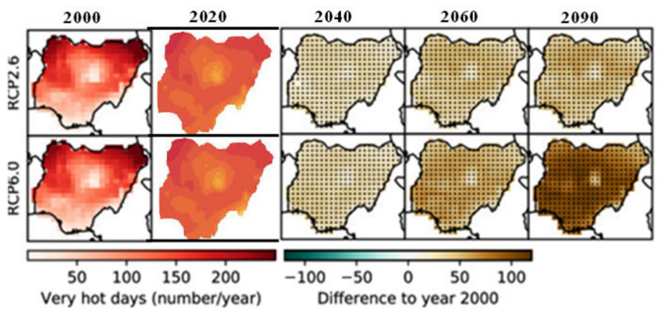

Figure 4: Temperature forecast relative to 1876 for Nigeria.

In correlating the temperature scenarios to the WH growth in Nigeria, holding the fact that studies have quested that within 8 months, 10 WH plants can propagate into 600,000 plants, masking over half a hectare space. Increase in temperature tends to favour the growth of WH because of its high rapid growth tendency and photosynthetic fixation efficiency of 1.52% compared to maize (1%), cocoa (0.5%) and ground-nut (0.29%) [43].

In projecting the global temperature analysis, two scenarios were created for the low and medium to high extreme weather conditions of Representative Concentration Pathway (RCPs) of blue and red trends. RCP2.6 (blue) for low radiation emission of less than 2°C, and RCP6.0 (red) represent medium to high radiation emission as indicated in Figure 5A. If the conservative number of the plant at the time of entry into Nigeria in 1984 is just about 150 to 200, it then means after eight months, the population will have reach 9,000,000. In Figure 5A, using scenarios of high and low, the global temperature is on the increase. The WH propagation projection from the early 80's to the year 2050 will be in the neighbourhood of 50 million weed of the plant conservatively across the nation's water bodies going by the continuous increase in temperature and eutrophication as indicated in Figure 5B.

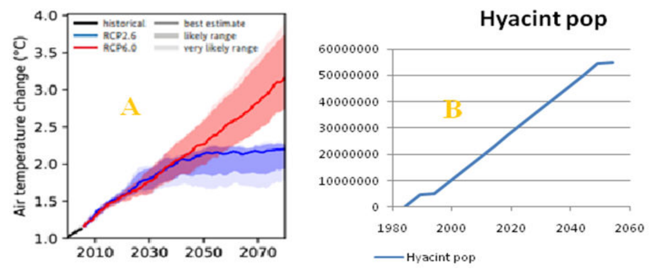

Figure 5A and B: Water hyacinth growth relationship with climate change.

Water hyacinths' impacts on water transportation industry in Nigeria

The challenges of WH invasion of waterways in Nigeria are becoming pervasive as watercrafts are being wrecked, harbours and jetties sealed with their carpet canopies (Figure 6). In fact, the country's continental shelf is not speared as the passage of marine vessel is becoming arduous [44]. The coastal Delta region of the country is not spared as several boat engines are overheated and damaged due to blade clogging and ramp destructions thereby are causing waterways businesses insolvency [8].

Figure 6: Water routes clogged by water hyacinth Nigeria waterways.

Interestingly, a comparative study of the socioeconomic impact of WH invasion on Nigeria's water transportation was carried out around Ilaje-Ese Odo of Ondo State where Weed-Infested (WI) waterway was compared with Weed-Free (WF) routes. The study revealed that fuel consumption, cost of boat repairs frequency were higher in WI than WF routes in ratio 73.3 to 28.4 litres/100 km; N436.0 to N274.1; and 6.1 to 2.0/month respectively. While the estimated lifespan of boats was lower on WI routes (2.9 to 5.5 years). Also the fixed and running costs of commercial boat transportation were said to be higher on WI than WF routes leading to hike in transport fare and even withdrawal of services in extreme cases.

For continental comparison on the economic impacts of WH infestation, Data et al. [45] carried out a study in China where they employed impact (socioeconomic and ecological) and spread indices with scale 1-4. The study revealed an impact index of 4, and spread index of 3 revealing the huge adverse environmental impact in the area. The water surface carpeting by the weed was found to be frustrating waterways traffic with damaging effect on propellers, and hampering fishing [46]. The increasing urbanization trend that is aggravating eutrophication of both inland and coastal water bodies may worsen the situation if the required mitigation actions are not urgently carried out [47].

In the past decades, the control of the water weeds which have been effective in many continents has been through bio-control agents [48,49]. The use of herbicides in conjunction with bio-control also has showed significant success in combating the weed within tolerable standards coupled with effective surveillance at a larger scale [50]. There is also the widespread use of mobile apps in countries across the world that facilitated indigenous technology like the Plantix usage in India [51,52].

National efforts toward combating the weed in Nigeria is been carried out by the National Inland Waterways Authority (NIWA) through their response to the yearning of the boat operators, by deploying swamp machines to clear the pervasive weed that has clogged navigable water channels in Ikorodu, Lagos State Adaku [53]. The commitment to achieve 10% coastal water bodies' protection in 2020 by coastal countries under the Biological Diversity Convention, and the Sustainable Development Goal 14 has not unfortunately yielded the desired goal [54-61].

CONCLUSION

WH invasion of water bodies is a global challenge, but more pervasive in tropical regions due to the supportive climatic condition. In modern day spatial interactions, the growth of the marine industry do not help matters as intercontinental Ballast Water are released indiscriminately at continental shelf and harbours without considering the fact that international ocean vessels are the vectors for the distribution of foreign aquatic weeds. This paper has examined the origin of WH in Nigeria, the factors that enhance its growth and the impacts on the nation's economy and in particular the transport sector. The remediation method across the globe and the little local measures are been discussed, while still addressing the best practices in the set out recommendations.

RECOMMENDATIONS

The following are however recommended:

- WH is a major challenge to the inland waterways and coastline in Nigeria and one of the inducers is water eutrophication from direct industry pollutants. The ministry of environment should therefore implement more stringent industrial water pollution control in the country through routinized environmental audit monitoring.
- The ministry of environment and transportation should collaborate with that of water resources in the use of mechanical infrastructure to arrest large scale WH infestation like the use of weed harvesters and excavators that must be properly disposed in conjunction with chemical substance.
- Natural biological control methods like pathogens can be deployed that is widely used to mitigate aquatic weeds infestation since 1960's, can be adopted in the country as advocated by UNDP.
- Weevil beetles (like) and WH moths (like) have proved effective demonstrated in Lake Chivero, in Louisiana, USA, and in Mexico; and even in other African countries like Zimbabwe, Benin, Lake Victoria in Kenya, Paua New Guinea,. Why not in Nigeria if there is political will.
- Purely chemical based controls of aquatic weeds like WH have been carried out by the application of substances like Glyphosate, and Paraquat when the weeds are still tender globally, this can be employed by the concern MDAs since it is more economical and faster on small scale. Although, it is not environmental friendly as reported by never.

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