Impact of the Invasive Water Hyacinth (*Eichhornia crassipes*) on Socio-Economic Attributes: A Review

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Received: February 8, 2019 **Accepted: October 7, 2019**

Abstract: *Water hyacinth is a free-floating, stoloniferous and perennial herb. It is native to South America and profoundly invaded the tropical and subtropical regions. It is recognized as one of the worst weeds due to its rapid proliferation rate, ecological adaptability and detrimental effects on the environment, human health and economic development. It poses serious socio-economic and environmental problems including the reduction of water quality, hindrance to water transport and recreation, hampering agriculture and fisheries and affect hydropower and water supply system. In an attempt to control the weed, deferent management strategies such as physical, chemical, biological and integrated methods had been employed in several countries. As a result, the manual removal method was used in South Africa, Nseleni River; Zimbabwe, Lake Mutirikwi; Ethiopia,Wonji-Shewa Sugar Factory and Lake Tana; and Uganda, Owen fall hydropower in Jinja at Lake Victoria. The chemical control method was practiced in Zimbabwe of Lake Chivero and in experimental site using 2-4-D , acetic acid and glyphosate; South-west Nigeria of Ere fishing channel and South Africa of larger dams and river systems by using glyphosate. The biological control was practiced in Zimbabwe of Lake Chivero through a combination of weevil and fungi; and Ethiopia, trying to control the weed using Neochetina bruchi and fungi at Rift Valley, Wonji-Shewa Sugar Factory and in a greenhouse at experimental level at Bahir Dar University. Integrated management options and awareness creation in all aspects of the weed is recommended to reduce the negative imacts of the weed.*

Keywords: Chemical control, Invasive aquatic weed, Water quality reduction

1. Introduction

Water hyacinth (*Eichhornia crassipes* Mart. Solms), is one of the world's worst perennial aquatic herb, which belongs to the *Pontederiaceae* family (Gichuki *et al.*, 2012). It has been identified by the International Union for Conservation of Nature (IUCN) as one of the 100 most aggressive invasive species (Téllez *et al.*, 2008) and recognized as one of the top 10 worst weeds in the world (Shanab *et al.*, 2010; Gichuki *et al.*, 2012; Patel, 2012). Its rapid growth rate and high adaptability to extreme conditions contribute to its high degree of invasion (Hill *et al*., 2011). Despite the fact that water hyacinth is native to the South American ecosystems, it is widely distributed to more than 50 tropical and sub-tropical countries over five continents (Bartodziej and Weymouth, 1995; Brendonck *et al.*, 2003; Jimenez and Balandra, 2007; Lu *et al.*, 2007). The weed originated from the Amazon Basin and has disseminated very quickly to many tropical and subtropical countries of Latin America, the Caribbean, Africa, Southeast Asia and the Pacific (Julien, 2000). Its improper use as waste water management and as an ornamental plant has tremendously increased its distribution worldwide (Villamagna and Murphy, 2010). The first introduction to the African continent was made in Egypt in the late 1880s (Navarro and Phiri, 2000). In Ethiopia, water hyacinth was officially reported in 1965 in Koka Lake and the Awash River (Yirefu *et al.*, 2007; Ayalew *et al.*, 2012) and infestation of Lake Tana was officially recognized in 2011(Ayalew *et al.*, 2012). Currently, water hyacinth infestation in Ethiopia has been manifested on a large scale in many water bodies of the country. The introduction and rapid spread of this weed in the Awash River Basin in *Koka* reservoir, Blue Nile River Basin in Lake Tana, and the head of Blue Nile River, Baro-Akobo River Basin in Sobate, Baro, Gillo and Pibor Rivers and Rift Valley Basins in Lake Ellen, Lake Abaya and Lake Elltoke, had created serious problems on the aquatic resources and the use of the water resources (Rezene, 2005; Taye *et al.*, 2009; Yirefu , 2017). At present, it is one of the invasive alien plants in the country (Rezene, 2005).

The success of this invasive alien species is largely due to its reproductive output. It can double its size in 5 days and a mat of medium sized plants may contain 2 million plants per hectare that weight 270 to 400 tone (Rezania *et al.*, 2015). It can flower throughout the year and releases more than 3000 seeds per year (Gopal, 1987; Rezania *et al.*, 2015) and the seeds are long-lived, up to 20 years (Gopal, 1987). When seeds may not be viable at all sites, it commonly colonizes new areas through vegetative reproduction and propagation of horizontally growing stolons. In the early stages of infestation, the weed takes a foothold on the shoreline in the areas where native aquatic plants thrive (Gichuki *et al*., 2012). However, it is not restricted to shallow water, unlike many submerged and emergent macrophytes, because its roots are free-floating near the surface (Villamagna and Murphy, 2010).

Water hyacinth causes a significant ecological and socio-economic effects (Villamagna and Murphy, 2010). The weed forms thick mats over the infested water bodies which causing hindrance to water transport, disrupting hydro-electric operations, blockage of canals and rivers, increased evapotranspiration, reducing water quality, interference with fishing, irrigation, navigation and reduction of biodiversity (Senayit *et al.*, 2004). Comprehensive estimation on economic impacts of water hyacinth in the affected areas of the Ethiopian water bodies have not been done yet. However, in Wonji-Shoa Sugar estate, from 2000 to 2013 a total of US$ 100,000 was spent to control the wed (Yirefu *et al*., 2014). Thus, controlling this aggressive weed using different techniquesis were crucial to alleviate its negative impact on biodiversity and socio-economic attributes. Globally, several control methods have been adopted to manage water hyacinth. The mechanical, manual, chemical and biological controlling methods are commonly used (Harley *et al.*, 1996; Gutiérrez *et al.*, 2000; Julien *et al.*, 2001).

2. Social Impacts of Water Hyacinth

2.1. Impacts of water hyacinth on human health

Floating mats of water hyacinth support organisms that are detrimental to human health. The ability of its mass of fibrous, free-floating roots and semi-submerged leaves and stems decrease water currents and helps increase breeding habitat for malaria causing anopheles mosquito as evidenced in Lake Victoria (Minakawa *et al*., 2008). According to Yirefu *et al.* (2007) based on the information obtained from Wonji Hospital malaria is still one of the major fatal diseases in the area that is supported by the stagnant water resulted from the impeding effect of water hyacinth. Mansonioides mosquitoes, the vectors of human lymphatic filariasis causing nematode Brugia, breed on this weed (Varshney *et al*., 2008). Snails serving as a vector for the parasite of Bilharzia reside in the tangled mat of this weed (Borokoni and Babalola, 2012). The weed also blocks access to water points and has been linked to an increase in cholera and typhoid. For example, from 1994 to 2008, Nyanza Province in Kenya, which borders Lake Victoria accounted for a larger proportion of cholera cases than expected given its population size (38.7% of cholera cases versus 15.3% of national population) (Feikin *et al*., 2010). The increased incidences of crocodile attacks have been attributed to the heavy infestation of the weed which provides cover to the reptiles, poisonous snakes, crocodiles and hippos (Patel, 2012).

2.2. Impacts of water hyacinth on water transport and recreation

Access to harbors and docking areas can be seriously hindered by mats of water hyacinth. Canals and fresh water rivers can become impassable as they clog up with densely intertwined carpets of the weed (Ndimele *et al.*, 2011). In the Wouri River Basin of Cameroon the livelihood of close to 900,000 inhabitants has been distorted (Mujingni, 2012). The entire Abo and Moundja Moussadi creeks have been rendered and impassable by the mats of the weed which leads to a complete halt in all the socio-economic activities (Mujingni, 2012). According to the report of Cho and Tifuh (2012) riparian communities in Cameroon**,** as part of their social activities like recreational benefits from the river; boat racing; swimming and site seeing were not possible in water hyacinth infested areas. Based on the study of Mujere (2016) water hyacinth was becoming a serious hazard to lake transport on Lake Victoria as large floating mats of water hyacinth form and this causes difficulty in navigation. This has grave implications such as failure to transport essential commodities from one landing site to another. In Uganda, residents of some islands such as Kasanje and Busi depend on water transport to take the sick to hospitals located in the mainland, for example, in Entebbe but when the weed blocks the way, deaths are common (Mujere, 2016).

3. Economic Impacts of Water Hyacinth

3.1. Impacts of water hyacinth to agriculture and fisheries

Dense infestations of water hyacinth restrict water flows in rivers and irrigation channels, interfere with irrigation equipment and have been known to cause structural damage to bridges (Jones, 2009). Reduced irrigation flow can indirectly cause loss on field crops but there can also be direct loss on paddy crops by suppressing the crop, inhibiting germination and interfering with harvesting (EEA, 2012; Patel, 2012). In Ethiopia, water hyacinth caused wastage of water through excessive evapotranspiration that would be used for sugarcane production (Yirefu *et al*., 2007).

Water hyacinth slows water flow by 40 to 95% in irrigation channels (Jones, 2009). In India in the Brahmaputra River, it has also blocked irrigation channels and obstructed the flow of water to crop fields (Patel, 2012). Furthermore, in West Bengal, water hyacinth causes an annual loss of paddy rice by directly suppressing the crop, inhibiting germination and interfering with harvesting (EEA, 2012). According to the report of Rakotoarisoa (2017) at Lake Alaotra, rice fields were invaded, inhibiting the germination, suppressing the crop and eventualy interfering to harvest the crop. Cultivation of teff *(Eragrostis tef)*, chickpea, grass pea and maize has been impacted around the shore in LakeTana (Erkie, 2017)**.** As cited by Endeshaw (2018) Ethiopian Environment and Forest Research Institute reported that, the water hyacinth is highly infested at the coast of Dera, Fogera, Libokemkem, Gondar Zuria and Gorgora Woredas. In cause of water hyacinth the rice production of Dera, Fogera, Libokemkem, Gondar Zuria and Gorgora were became too low because of the farm land were captured by this weed.In addition mat of water hyacinth during flooding and wave time makes rice production frustrating by totally covering the rice field and it makes the farmland more compacted due to its long root that makes the farm land difficult to plough (Dereje *et al*., 2017).

The floating water hyacinth mats limit access to breeding, nursery and feeding grounds for some economically important fish species (Villamagna and Murphy, 2010). Additionally, the dense mats could entangled with boat propellers and hence hampering fishing activities (Patel, 2012). According to Cho and Tifuh (2012) report, water hyacinth causes severe problems to fishers in the riparian communities. When weed infestation is present, access to fishing sites become difficult for riparian communities and this negatively affect the life of the community as their livelihood solely rely on fisheries. Similarly, in Lake Naivasha, water hyacinth has a negative impact on the economic status of the fisher community (Waithaka, 2013). In Lake Victoria, fish catch rates on the Kenyan section decreased by 45% because of water hyacinth mats blocked access to fishing grounds and increased costs (effort and materials) of fishing (Kateregga and Sterner, 2009). Furthermore, due to water hyacinth infestation, fishing has become almost impossible task in Nigeria (Ndimele *et al*., 2011).

According to Wassie *et al*. (2014) report,water hyacinth infestation has been covered about 34,500 ha (15% of the Northern shore of the Lake Tana). Consequently, all the fishers changed their landing site because of water hyacinth expansion and obstructs their fishing activities (Erkie, 2017). As a result, the decline of large barbs has been observed presently in Lake Tana, which is got shallower and shallower due to the worst weed (water hyacinth).

Furthermore, the catch per unit of effort of *Labeobarbus* in 2010 had sharply declined to 6 kg per trip in comparison with 28 kg per trip in 2001 and 63 kg per trip in 1991-1993 (63 kg per trip) (Brehan *et al.*, 2011). In the area of severe infestation, fishing is difficult especially around the shore area, this is because of covering the fishing gear by water hyacinth and the gill net is lost while this could strongly affect fishers that use artisanal fishing boat (Dereje *et al*., 2017).

3.2. Impacts of water hyacinth on water quality

Mats of water hyacinth prevent the transfer of oxygen from the air to the water surface or decrease oxygen production by other plants and algae (Villamagna and Murphy, 2010). Water hyacinth infested areas showed low values of dissolved oxygen ranged from 1.02 to 3.60 mgL^{-1} (McVea and Boyd, 1975; Masifwa *et al.*, 2001). The shoreline areas without water hyacinth have high mean concentration of dissolved oxygen (1.96±0.71), compared to the shoreline areas with water hyacinth (5.89±0.85) (Mironga *et al*., 2012). When the plant dies and sinks to the bottom the decomposing biomass depletes oxygen content in the water body due to the high oxygen consumption of rotting plant biomass (EEA, 2012). Dissolved oxygen levels can reach dangerously low concentrations for fish that are sensitive to such changes. Furthermore, low dissolved oxygen conditions catalyse the release of phosphorus from the sediment which, in turn, accelerates eutrophication and can lead to a subsequent increase in water hyacinth or algal blooms (Bicudo *et al*., 2007). Death and decay of water hyacinth vegetation in large masses deteriorate water quality (Ndimele *et al*., 2011). The most apparent environmental impact of water hyacinth infestations that affect the riparian community directly is the degradation of water quality by its foul smell and debris (Cho and Tifuh, 2012). The thick mats of water hyacinth lead to an increase in water turbidity due to the constant rotting of the mat base (Villamagna and Murphy, 2010). According to Mironga *et al.* (2012) water hyacinth infested area showed low pH values ranging between 6.7 -7.1, while those without water hyacinth had higher values ranging from 7.4-7.95. Free carbon dioxide was also higher in the water hyacinth infested areas with values ranging from 23.97-34.97 mgL^{-1} compared to non infested areas (3-20 mgL^{-1}) (Mironga *et al.*, 2012). However, according to the reporte of Dereje *et al*. (2017) in lake Tana, Ethiopia values of physico-chemical characters of the water in the lake were not statistically significance difference between the weed infested and non-infested sites.

3.3. Impacts of water hyacinth on hydropower plants

Water hyacinth causes high water losses through evapotranspiration and blocking turbines. The owen Falls hydropower scheme has suffered from the impact of the weed, hence plenty of time and money has been invested to clear and prevent the weed from entering the turbines, which may cause damage and power interruptions (ITDG, 1997). On Owen Falls hydropower scheme, water hyacinth caused damage to water coolers and generators, prompting the power utility company to switch off generators for maintenance, and about 15 Megawatts of electricity were lost causing power cut in an urban area of Ethiopia (Yirefu, 2014).

Many large hydropower schemes are suffering from the effects of water hyacinth. It is now a major problem in some of the world's major dams. Dams feeding the city of Harare have pronounced infestations of the weed (Mujere, 2016). The Owen Falls hydropower scheme on Lake Victoria is a victim of the weeds (Minakawa *et al*., 2008). The hydropower dams on the Shire River in Malawi also frequently forced to stop production due to clogging of the water cooling system by this weed (Wise *et al*., 2007). The Kariba dam which straddles the Zambia-Zimbabwe border on the Zambezi River and *Koka Lake* hydropower dam in Ethiopia suffer from the rapid reproduction of water hyacinth (Senayit *et al*., 2004). In addition, Ethiopian Electric Power Corporation (EEPC) has reported this plant as a problem and disrupting their operation at the three hydropower stations located along the Awash River (Samuel and Nestanet , 2014).

Studies have shown that, the dense cover of water hyacinth enhances evapotranspiration (Mailu, 2001). The rate of water loss due to evapotranspiration can be as much as 1.8 times than that of evaporation from the same surface but free of plants (Haider, 1989). This has great implication where water is already scarce. The estimated water loss due to this weed from the highly infested water reservoirs that are used directly for irrigating the fields was ranged between 393,660 to 2,945,160 m^3 (Howard and Matindi, 2003). Such impacts of the weed were also reported in different countries (Howard and Matindi, 2003). Increased water loss by water hyacinth leads especially in shallow lakes such as Lake Alaotra to a drop in water level. It is estimated that the flow of water in the Nile could be reduced by up to one-tenth due to increased losses from evapotranspiration by water hyacinth in Lake Victoria (Ndimele *et al*., 2011). Allen *et al*. (1997) also indicated that this effect can result in loss up to 13 times from that of a free water surface with a minimum rate of 2.5 times. In Ethiopia, water hyacinth caused wastage of water through excessive evapotranspiration that would otherwise be used for sugarcane production (Yirefu *et al*., 2007).

4. Management Options of Water Hyacinth

4.1. Manual/mechanical control

Mechanical control refers to the use of machinery such as mechanical mowers, crusher boats, destruction boats, dredgers and weed harvesters which are designed to physically cut, shear, shred, crush, press, lift or remove and transport aquatic plants and associated organic material from water bodies (Cho and Tifuh, 2012). Mechanical cutting and harvesting are practical for large-scale (several acres) vegetation removal because they remove plants from large areas in a relatively short time. Mechanical cutting and harvesting are non-selective and could eliminate valuable fish, plants and wildlife habitat within the target area. However, recently some 75 km of the Guadiana River in Spain was controlled mechanically (Têllez *et al.*, 2008).

Mechanical control includes harvesting by hand or machine (Villamagna and Murphy, 2010). The use of machinery to remove water hyacinth from water bodies is the most effective non-polluting control method (Mara, 1976). The main advantage of the use of mechanical harvesting is the simultaneous removal of nutrients and pollutants from the water body (Wittenberg and Cock, 2001).

Manual control involves the removal of water hyacinth by uprooting weeds with hands or cutting with cutlasses. However, the method is very risky because of the existence of some animals such as snakes, alligators and crocodiles which live underwater hyacinth mats. Furthermore, it is time-consuming and labour intensive (May *et al.*, 2003) but if implemented systematically, it may be of great value to reduce a moderate stand of the weed (Labradar, 1995). Manual removal was used in South Africa (Hill and Coetzee, 2008). According to Mujere (2016) study, manual removal of the weeds or pulling through nets using hands and/or rakes was done in Lake Mutirikwi (90 km^2) in Zimbabwe. Based on Yirefu *et al.* (2007) the management of the weed at Wonji-Shewa Sugar Factory indicated that the factory has been practicing manual and mechanical removal of the weed from the canals periodically and left to dry at the border of the canals. The fisher-folk communities around Lake Naivasha also identified key infested sites and control the weed manually (Mironga *et al.*, 2011). The Owen falls hydropower scheme at Jinja on Lake Victoria is a victim of water hyacinth’s rapid proliferation and physical removal was practiced to control the weed (Mailu, 2001). In Ethiopia, Lake Tana water hyacinth control were done physically by human hands, wooden sticks, reed boats and a few instances motorized boats (Edwards, 2013).

4.2. Chemical control

The three most commonly used aquatic herbicides are 2,4-D, Diquat (6,7-dihydrodipyridol) and Glyphosate (Martínez Jiménez, 2003). All these herbicides are absorbed through the leaves and are quickly transported throughout the whole plant, killing all parts of the weed (Lindsay and Hirt, 1999). Herbicide applications are usually less expensive than mechanical control but may have to be repeated on an annual basis (GISD, 2006); owing to the fact that once plants are removed, light penetration increases, favoring the germination of water hyacinth seeds and therefore new water hyacinth re-infestation. The limitation of this method remains its negative impact on the environment and health-related effects, especially where people collect water for drinking and washing. An additional problem of chemical control is that water hyacinth decomposes and further enriches the water and eventually algal blooms will replace the weed (Mujere, 2016).

The herbicide 2-4-D was used in Lake Chivero from 1971 to 1985, after which time, it was banned. Lake Chivero was observed to be reinfested with hyacinth 6 months after spraying with 2-4-D, due to poor transport of the chemical in the stems from the parent shoots to the offshoots (Chikwenhere, 2001). According to Uka *et al.* (2007), a few trials were undertaken at Ere fishing channel South-west Nigeria. The application of Glyphosate gave rise to total mortality of water hyacinth within 14 days. Herbicidal control, using formulations containing the active ingredient glyphosate, is still used to control water hyacinth in some of the larger dams and river systems in South Africa. Based on the experiment of Aklilu *et al*. (2018) the chemicals particularly, acetic acid and glyphosate showed better efficacy in suppressing water hyacinth tissue growth when applied at an experimental site.

4.3. Biological control

The biological control of water hyacinth began in the 1960s and involves control of water hyacinth through the use of host-specific insects, moths or pathogens which are natural enemies of the weed and imported from the point of origin of the weed (DeLoach and Cordo,1976). Biological control remains the most cost-effective and environmentally friendly technique for the sustainable control of water hyacinth (van Wyk and van Wilgen, 2002). Adult beetles feed on leaves which increase transpiration and places the plant under stress. The weevils *Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache (Center *et al.,* 1982) are two species that have provided the best results. for biological control. Other biological agents including the fungi *Alternaria eichhorniae* and *Cercospora piaropi* (Jiménez and Charudattan, 1998*)* and the moths *Niphograptaalbiguttalis* and *Xubidainfusellus* were used to control the weed (Julien *et al*., 2001). Marked successes with biological control agents have been reported from many parts of Africa and the world, notably at Lake Chivero (Zimbabwe), Lake Victoria (Kenya), Louisiana (USA), Mexico, Papua New Guinea and Benin (Gichuki *et al*., 2012).

A combination of weevil and fungal attack on water hyacinth has been applied in Lake Chivero. The weevils *Neochetina bruchi* and *Neochetina eichhornia* have been identified as absolutely specific to control the hyacinth in Lake Victoria and Chivero (Mujere, 2016). The weevils were used for the control of water hyacinth in China. A release of 1000 insects per (1000 m^2) in two sites exerted an efficacy around 90% of the water hyacinth infestation (Ding *et al*., 2001). According to the experiment of Adugnaw *et al.* (2017) in greenhouse level, *Tricothecium roseum*, *Aspergillus flaves*, *Trichoderma spp*, *Fusarium spp*, *Rhizocotonia spp*, *Aspergillus niger* and *Trichdoerma spp* fungi were promising to manage water hyacinth at above 26°C and at less than 25% humidity. The plant hopper, *Megamelus scutellaris* Berg (*Hemiptera: Delphacidae*), was the most recent agent that has been released in 2013 and impacting the plant in the cooler areas of South Africa (Hill and Coetzee, 2017). According to Yirefu (2017), *Neochetina bruchi* was considered as a promising candidate for control of water hyacinth under Ethiopian conditions. The principal drawback with biological control of water hyacinth is the time required to achieve control and in tropical environments, this is usually 2 to 4 years (Wittenberg and Cock, 2001).

4.4. Integrated management

Integrated control involves the combination of two or more control methods to achieve weed reduction. Integrated management programmes are site-specific and will depend greatly on the hydrological and nutrient status of the system, the extent of the infestation, the climate of the area and the use of the water body (Julien *et al.*, 2001). This method has been succesful in Tanzania mainly through the combination of biological control, manual removal, quarantine regulations and management of nutrient enrichment (Mallya *et al.*, 2001), where there has been a significant reduction in water hyacinth plant density, from 45 to 7 plants per 0.5 m^2 and the population by over 70% within a period of 3 years (Mallya *et al.*, 2001).

Jones (2001) developed an integrated management programme for the Nseleni River system in the more tropical region of South Africa. The key elements of this approach were primarily the appointment of a champion to drive the control programme, the involvement of all interested and affected parties on the river system, the division of the river system in to management units and the implementation of appropriate control methods for each of these management units. Using this integrated approach, some 19 km of river that was previously 100% covered by water hyacinth was initially cleared using mainly herbicide application and is maintained at 5% weed cover through biological control with occasional follow-up herbicide application around sensitive sites (water abstraction localities) when necessary.

Interactions between chemical and biological control have been demonstrated. Herbicides can be used to reduce the vigour of water hyacinth but without harming the biocontrol agent. Paraquat, glyphosate and 2,4-D have all been used to enhance the effects of *Neochetina* spp. Plant growth regulators also have this potential: paclobutrazol, for example, in combination with *N. eichhorniae* gave 95% control of water hyacinth in the USA but the weevil alone gave only 24% control in the 8-month study period (Van, 1988). It is also possible to use herbicides to reduce water hyacinth populations to low levels prior to the introduction of biocontrol agents, thereby giving the agents time to become established and better able to suppress regrowth of the weed. However, extensive herbicide applications in South Africa had a detrimental effect on colonies of *N. eichhorniae* (Cilliers,1991).

Conflicts of Interest

The authors declare no conflicts of interest.

5. Conclusion and Recommendations

Aquatic weeds have become an increasing concern in all water use types. Water hyacinth is one of the top ten most invasive aquatic plant species in the world. It is arguably the most noxious aquatic weed in the world, due to its ability to rapidly cover whole waterways and efficient survival strategies in extreme conditions. It also posed significant economic, social and environmental problems. These include hindrance to water transport, disrupting hydroelectric operations, blockage of canals and rivers, flooding, causing human health problems, increased evapotranspiration, interference with fishing and reduction in irrigation efficiency.

Different management strategies such as manual/mechanical, chemical and biological methods had been used to control the weed. Accordingly, manual removal was used in South Africa; Zimbabwe Lake Mutirikwi; Ethiopia Lake Tana, Wonji-Shewa Sugar Factory and Owen fall hydropower in Jinja at Lake Victoria. Chemical control was practiced in Zimbabwe Lake Chivero using 2-4-D; South-west Nigeria Ere fishing channel by glyphosate; South Africa larger dams and river systems by using glyphosate; Zimbabwe acetic acid and glyphosate control the weed at experimental site. Biological control was practiced in Zimbabwe Lake Chivero through a combination of weevil and fungi; Kenya Lake Victoria and China by two types of weevils (*Neochetina bruchi* and *Neochetina eichhornia*) and Ethiopia *Neochetina bruchi* and fungi at Rift Valley and in a greenhouse at the experimental level, respectively.

In some countries including Ethiopia, the management and control of water hyacinth was beyond the capabilities of local governments alone. Therefore, the involvement of multidisciplinary approach like the creation of awareness to the public in all aspects of the weed; application of integrated managemet technique particularly mechanical, manual and biological control measure should be implemented. It should be designed in a way that the highest political and administrative levels recognize the potential seriousness of the weed and leads the controling team.

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