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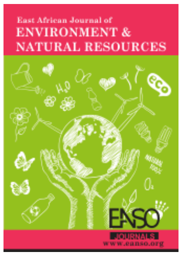

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Original Article

Water Hyacinth, an Invasive Species in Africa: A Literature Review

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ABSTRACT

Water hyacinth is without a doubt the water invader that causes the most harm to water bodies. Water hyacinths originated from Eastern Mediterranean, West Asia, and Central Asia; they are cultivated and loved worldwide. According to reports, water hyacinth has anti-inflammatory, antifungal, and antibacterial properties. The plant extracts can also be used to treat cholera, sore throats, and snake bites, as well as to scent hair. Water hyacinth Pontederia crassipes (Eichhornia crassipes) has proliferated rapidly in African inland waters, posing numerous threats to fisheries by reducing the existence of some species; water quality by lowering levels of dissolved oxygen; human health and the environment by introducing various disease-causing pathogens and harbouring dangerous animals. The hyacinths further impact human activities by blocking waterways for fishing and destroying habitat for some fish to bread properly. Tourism and navigation are also affected by limiting access to recreational areas, especially for boat cruising. Fishing; effects on fishing activities and effect on plankton production, which is the main food. Different control methods have been utilised and others suggested in Africa, although it has not been fully controlled as it is highly reproductive and still a menace in African inland waters. The most commonly used control measures are biological and physical controls. As a recommendation, all methods should be used in water bodies to reduce its spread as quickly as possible although with caution on chemical methods. In relation to water hyacinth and its effects on terrestrial animals, there is still a need for much research to still be done; however, it is an aquatic plant that is not wanted in many places does not mean it should be eradicated. Its use to produce biogas could be helpful in reducing the challenges that come with it.

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INTRODUCTION

Worldwide, the use and management of water hyacinth, an invasive species in Africa, continue to be a major problem despite being a common problem. Environmental preservation, socioeconomic growth, and public health in the affected areas face a tremendous challenge due to the lack of comprehensive policies and workable methods to address the water hyacinth invasion. Therefore, it is urgently necessary to close the knowledge-to-action gap by creating novel strategies that not only limit the spread of water hyacinth but also maximise its potential as a useful resource for sustainable development in Africa (Damtie et al., 2021).

Globally, water hyacinths are destructive invasive alien species (IAS) that originated in Asia and some parts of South America's Amazon basin as an invasive alien species (Osei et al., 2021). It has since spread swiftly over the world, severely damaging all tropical and subtropical countries (Yudistira et al., 2020). The hyacinth has been reported in the Caribbean, Central America, North America, Africa, Asia, and Europe (Honlah et al., 2019, Zhou, 2021).

In Africa, water hyacinths are among the top 100 most aggressive alien species among the ten worst weeds in the world (Ongore et al., 2018, Turyasingura et al., 2022). Water hyacinth *Pontederia crassipes* (*Eichhornia crassipes*). There is a research gap addressing the precise ecological and socioeconomic effects of water hyacinth infestations in various regions of Africa, despite the fact that the available literature recognises water hyacinths as one of the most invasive alien species and among the top 100 worst weeds globally. Only a few studies (Higgins et al. 2019; Egoh et al. 2020) have attempted to comprehend the specific impacts of water hyacinths on ecosystem services, biodiversity, water quality, and the socioeconomic well-being of communities in particular African nations. To effectively minimise the negative consequences of water hyacinth invasions in Africa, context-specific management techniques and policy interventions must be developed in order to close this research gap (Potgieter et al., 2020).

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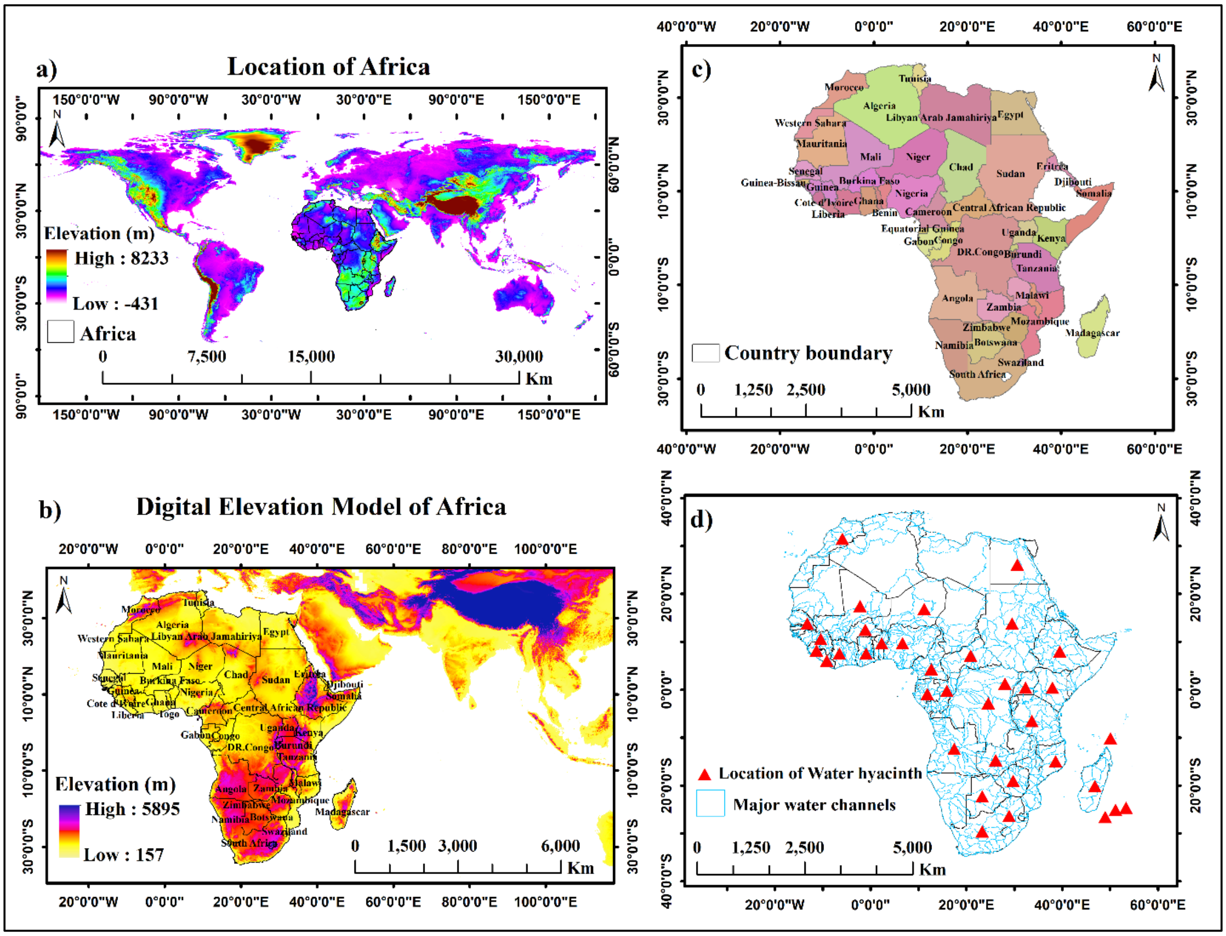
Table 1: Scientific classification

Kingdom	**Plantae**
Clade	Tracheophytes
Clade	Angiosperms
Clade	Monocots
Clade	Commelinids
Order	Commelinales
Family	Pontederiaceae
Genus	Pontederia
Species	Crassipes
Binomial name	Pontederia crassipes

Source: Authors 2023.

The plant species are common and plentiful in inland freshwater bodies, such as lakes, rivers, streams, ponds, and wetlands. The application of regional strategies that make use of water resources along with excess flow from upstream to downstream consumption has the potential to help water managers improve the management of water hyacinth infestations (Hirwa et al., 2022). This plant species has distinctive characteristics that include spires of purple blooms featuring clustering petals and waxy, dense foliage that resemble a vast canopy: (1) Air-sac-equipped petioles that assist the animal staying buoyant in water; (2) stalk comes in a range of sizes, measuring between 15 centimetre to 20 centimetre in length and breadth; (3) high environmental tolerance, fast reproduction, extensive dispersal capacities, and rapid growth rates; (4) continuous flowering throughout the year, which results in the release of more than 3000 seeds each year and a seed with a 20-year lifespan (Omondi et al., 2021, Ongore et al., 2018, Najmi and Watanna 2018, Turyasingura et al., 2022, Matindi et al., 2022) (5) the capability to flourish at various water depths due to its roots' free-floating nature close to the surface. Hyacinth rapidly establishes in higher temperatures, nitrogen, and phosphorus (Reddy et al., 1990), whereas excessive salinity inhibits its growth, causing sluggish growth and even mortality. For these reasons, it is only more common in freshwaters (Galbraith et al., 2005).

Figure 1: Position of water hyacinth



a) Location of Africa along with a Global DEM, b) Altitudinal distribution map of Africa, c) Distribution of countries in Africa, d) Spatial distribution of water hyacinth in Africa with major river channels.

Source: Authors 2023.

In the case of Africa, the water hyacinth was primarily introduced to Africa by human activity as an aquarium plant (Turyasingura et al., 2022, but later mistakenly discharged into water bodies (Abraham & Kurup, 1996). Since its introduction in Africa, the plant has been evidenced to be harmful to aquatic organisms. The rapid spread of hyacinth in Africa is due to a lack of naturally occurring competitors and/or predators (Echiegu et al., 2018). The spread is enhanced by anthropogenic activities (Turyasingura, Hannington, et al., 2023), such as runoffs from agricultural activities and human waste provide the water with nutrients, accelerating the rate of the organism's growth (Ojo et al., 2022).

However, water hyacinth is a danger in most of African countries it has been introduced to; it is also difficult to eradicate (Nwamo et al., 2022). Its rapid growth of up to 3 hectares per day and the potential of two of its plants to multiply into 1200 plants in 120 days have caused public concern over its invasion (Dersseh et al., 2022). The hyacinth in Africa affects great lakes, including lakes Victoria, Kyoga, Albert, Malawi, Tanganyika, Tana, and Naivasha, with detrimental effects (Eldardiry & Hossain, 2021; Falchetta et al., 2019). Its presence in the various lakes has been linked to a variety of negative effects, including a decrease in fish harvest from the 1990s to the early 2000s, including irrigation, boat cruising and disrupting water flow in channels (Gonzalez et al., 2023; He et al., 2022; Hill & Cilliers, 1999). According to an empirical study, the hyacinth colonised Zimbabwe water bodies in 1937, Ethiopia in 1956, and Mozambique in 1946, whilst in Tanzanian notably the Sigi and Pangani rivers, became colonised in 1955 and 1959, respectively (Aloo, 2019).

The invasive species appeared in late 1990 around Lake Pagani Victoria, which was able to flourish due to an increased nitrogen content (Honlah, Yao Segbefia, et al., 2019). Ten years after making its debut in 1989, the weed had spread to all of the neighbouring water bodies covering up to 20,000 ha, raising public concerns (Simiyu et al., 2022). Its rapid growth in Lake Victoria increased by 3 hectares per day (Karouach et al., 2022), attributed to the presence of high nutrients, high reproductive ability and longevity in seed viability and a dearth of competitors in the same environment (Lubembe et al., 2022).

Figure 2: Prior to and following the invasion, respectively, in Nyanza Gulf (October 2018).

The plant has also grown to occupy a bigger area in most of Ethiopia's water bodies, including Lake Tana, Lake Ellen, and Gambella region. For example, it was not until 2011 that Lake Tana's first record, made in the 1990s, was formally classified as ecologically harmful. In Ghana, severe rains cause runoff to transport nutrients from both treated and untreated sources, such as sewerage, wastewater, and fertilised agricultural areas (Simiyu et al., 2022), into water bodies, increasing the phosphate and nitrate nutrient loading, which in turn promotes the growth of water hyacinths (Mideksa et al., 2022). The Volta River Basin's water flow has been significantly curtailed due to the construction of dams for hydropower, irrigation, water collection, and aquaculture, creating ideal circumstances for the hyacinth to predominate (Nassali et al., 2020).

According to Rommens et al. (2003), Tano Basin in Ghana is one of the most prominent water bodies that has been impacted by water hyacinth. It is widely distributed in essentially all of the river bodies in Nigeria. In the fishing communities around the Niger River in Mali, where 99% of their activities depend on the water system, its consequences have been felt widely (Nwamo et al., 2022). From the literature, the study advances our understanding of the water hyacinth as an invasive species in Africa. The study may add to our understanding of the ecological, economic, social, and health effects of water hyacinth by synthesising fresh research findings. As a result, we may have a thorough knowledge foundation that may direct our future research efforts and guide our use of evidence-based decision-making (Lubembe et al., 2022; Lubembe et al., 2022).

Effects of Water Hyacinth

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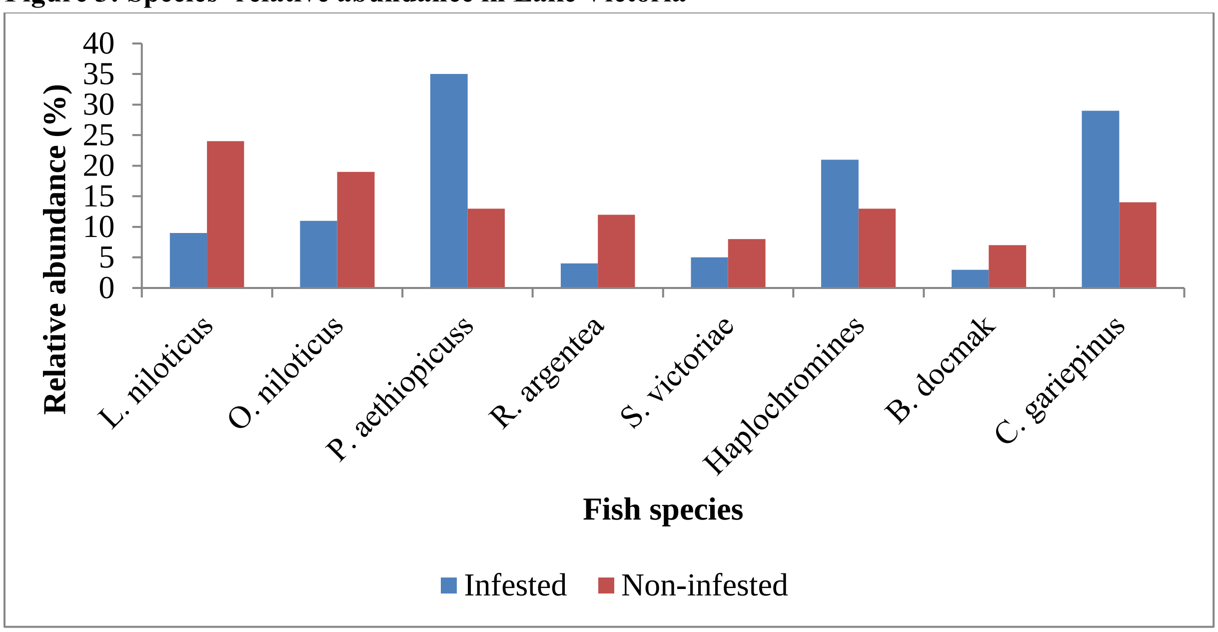
Effect on Fisheries

Species richness, habitats, native species, and variety are all primarily devastated by alien invaders on a global scale (Nyboer et al., 2022). Water hyacinth has significantly reduced the overall aquatic richness of freshwater bodies by outcompeting nearby species for nutrients (e.g. oxygen and light) [44, 45]. Hyacinth runners have reduced the amount of plankton which fish consume and resulting in low fish output owing to a shortage of food (Cohen et al., 2019). Due to hyacinth competition, the abundance and output of native algae in Lake Victoria have decreased. Therefore, fish species that depend on it are shown to have limited food (Honlah, Yao Segbefia, et al., 2019). The plant has caused major problems in the Winam Gulf, where fish catches have dropped to 14% from 59% (Reed et al., 2022), and some fish species are lessening as a result of the loss of breeding and feeding sites (Reed et al., 2022) leading to food insecurity.

Nonetheless, fish could find shelter, hide from predators, and still find food in areas infested by weeds as opposed to non-infested areas where the diversity was low, as in the case of haplochromine species, the diversity was higher in weed-infested areas (Kumar et al., 2021). Additionally, in Lake Victoria, the Nile perch changed their diets to include vast quantities of insects linked to water hyacinth, which likely resulted in a decline in catch because the fish were compelled to adapt to what the environment could offer. Fish diversity was higher in the littoral zones of Lake Chivero in Zimbabwe, where hyacinth was present than where it wasn't, which was related to the refuge and food the fish found, resulting in minimised fish harvest (Yongo et al., 2021).

Figure 3: Species' relative abundance in Lake Victoria



Source: (Waithaka et al., 2020).

Water Hyacinth and Water Quality

Water hyacinth has posed a hazard to water bodies, primarily to dissolved oxygen levels (Waithaka et al., 2020). Large water hyacinth mats impede water stratification, which would typically allow dissolved oxygen to move down to benthic plants and fishes by reducing oxygen intake on the water surface due to shading on the water (Yongo et al., 2022). It prevents fish from producing as much carbon dioxide, which increases the photosynthetic

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activities of underwater plants, which aid in the release of oxygen into the water (for instance, Lake Victoria's water underneath reported low dissolved oxygen as low as 0.1 mg/l, making them inhabitable for most fish species, including Nile perch, which needs dissolved oxygen >5 mg/l). Low levels of dissolved oxygen and predation have also caused high levels of mortalities in most water bodies (Nwamo et al., 2022). Dead hyacinth mat also consumes a lot of dissolved oxygen, which results in the creation of methane and other greenhouse gases. Due to lower wind activity and decreased oxygen exchange across the air-water interface, temperatures in water hyacinth-infested sections is higher than temperatures in non-weed-infested locations.

Effects on Animal Health and Environmental

Large water hyacinth mats in water bodies prevent stratification, generating worries about human health and the environment in general. Hyacinth widespread leads to garbage build-up near the edges of water bodies. Impeding the majority of human activities. It also provides protection for big animals like crocodiles, hippopotamuses, and snakes, which hide in dense mats and are only seen when they come under attack (He et al., 2022). The water body system becomes favourable for the reproduction of many endemic species like snails and mosquitoes that are responsible for diseases like malaria and cholera because the water gets stagnant.

The mats that continue to float convey new parasites, pests, and viruses from one side of the water body to the other, potentially changing the environment and eradicating local species, which may later lead to the development of a new illness. Also, the slowed water flow provides space for the large development of the parasites, plagues, and vectors that are present. According to empirical studies, between 1994 and 2008, the Nyanza province in Kenya, which borders Lake Victoria, saw a higher number of cholera cases, 37% of the entire population, and this was associated with the growth of hyacinths (Yara, 2019). Malaria attacks were frequent among those living close to water bodies that were hyacinth-infested (Ahmed, 2019).

Effects on Water Bodies Activities

Agriculture and fishing have been hampered by water hyacinth, which has also choked waterways. This occurred at Kisumu port, Kenya's major maritime port on Lake Victoria and a historic regional commerce route connecting Kenya, Tanzania, and Uganda. As only ships weighing over 700 tons could break through the water hyacinth mats, this made it difficult to access, especially with tiny boats. Many operations have been halted because not everyone could afford the high fuel costs for the large vessels, which made transportation difficult (Waithaka et al., 2020).

Regarding fisheries, it has restricted access to some species' breeding, nursery, and feeding areas, which is why production has continued to decline. This makes it difficult for fishermen to engage in fishing, as well as for scientists to conduct stock takes that consider the species already present in the water bodies involved (Karouach et al., 2022). For instance, the dense mats in Lake Victoria have blocked access to fishing grounds and reduced fish catches on the Kenyan side of the lake by 45%. Lake Tana has also recorded instances of this (Hill & Cilliers, 1999).

Water hyacinth, which plugs irrigation channels, decreases water flow from 40% to 95% in the agricultural industry. This could result in significant floods as well as increased evapotranspiration, which in turn results in significant water loss. The increased losses of evapotranspiration by water hyacinth in Lake Victoria affected the flow of water in the Nile by up to one-tenth. Moreover, it obstructs rivers, which leads to floods that destroy numerous homes (e.g., in Bwene and Bonjo settlements in the Wouri River Basin in Cameroon) (Cho & Tifuh, 2012). Additionally, Kafue Gorge in Zambia observed a decline in water for power production due to evapotranspiration and turbine obstructions,

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resulting in a loss of revenue collection for the power supply company of roughly US$ 15 million every year. This has occurred in numerous large hydropower projects worldwide. For instance, cleaning input screens at Owen Falls in Uganda has been expensive, costing US$ 1 million per year.

Effect on Tourism, Sport, and Navigation

Tourism is impacted by the water hyacinth infestation because it restricts access to the stunning views of the estuaries. Due to water hyacinth prevalence, small boats that are utilised for exploration find it impossible to access inland waterways. Only extremely massive, powerful machines can pass through. Navigation is impeded by dense water hyacinth mats that form impenetrable barriers (Honlah, Appiah, et al., 2019). As a result, local businesses that rely heavily on tourism-related revenue are impacted. In addition, water hyacinths hold germs and parasites that infect tourists, leading to a variety of illnesses such as severe malaria and making it challenging for tourists. For instance, Lake Victoria has lost its appeal for swimming, sunbathing, and water sports like windsurfing, sport fishing, and sailing as a result of the mat (Williams et al., 2017). Due to the dense matting, spot fishing for *Oreochromis niloticus* could no longer be done, which has caused a fall in species richness in Lake Victoria. This is also the situation, according to reports, in the Wouri River Basin, Cameroon, where monthly tourism and navigational activities decreased by 75% (Kenfack Voukeng et al., 2019). Dense water hyacinth mats have an impact on transportation because they slow down boats and require more engine time to cover the same distance. This raises the expense of operating the vessel.

This is likewise the situation in Lake Tana, where just two ports, Tana Cherkos and sections of Gorgora were seriously affected at the time of the survey, but the key informants also stated that as its proliferation increases, movement in the lake may become impossible. The majority of water transport activities in Nigeria’s Delta were halted because boats and other vessels could not get through the water hyacinth (Allen, 2023).

Effects on Fishing Activities and Equipment

Fishers use a lot of effort to push through the mats and time at the same time, use more fuel than usual. Thereafter, fishers also use a lot of time cleaning their nets and repairing them each time they come out of their fishing grounds. For this reason, therefore, a good number of fishermen resist going back to the fishing grounds leading to low tons of fish landed. This has been reported in Lake Victoria and Lake Tana too (Dersseh et al., 2019). In the lake, fish production has dropped simply because the hyacinth has blocked ways of reaching or accessing fishing grounds. Some landing sites have remained neglected in the lake; hence it has negatively affected income generation among the fishing communities. In Lake Victoria, fish catches have reduced by 45% due to blockage of ways of accessing the fishing grounds and increased post-harvest losses. This is similar to other studies done in sub-Saharan African water bodies (Njiru et al., 2018). For example, rendering to Voukeng et al. (Kenfack Voukeng et al., 2019), the mean daily fish catch per fisherman in the Wouri Basin in Cameroon declined by 90% after infestation by the hyacinth compared to catches before infestation.

Additionally, water hyacinth’s impact on small lakes are making them fully extinct, which causes them to dry up, and an example of this is the Aba Samuel water source near Addis Ababa (Gedefaw & Gondar, 2018). Lake Tana’s fish populations have decreased as a result of the water hyacinth’s encroachment of the edge of the lake, river mouths, and wetlands (Gebremedhin et al., 2018). As a result, the lake is no longer receiving a flow of water from the rivers, which in turn prevents the flow of nutrients that the fish need to survive (Admas et al., 2020). Additionally, different fish species’ output has been impacted by the hyacinth in different ways. For instance, fishermen in Lake Tana observed a

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serious decline in catches of *Oreochromis niloticus* and *Labeo barbus*, which they related to the destruction of spawning areas and entanglement by the hyacinth when they are moving. This was also the same scenario in the Wouri River Basin in Cameroon, where eight species had low production; *Oreochromis niloticus and Labeo barbus* were among them. In Lake Tana, catfish were not affected by hyacinth proliferation (Karouach et al., 2022), which was dissimilar to the findings in Cameroon.

Equally, in Lake Victoria, the resurgence of native fish species, which are more tolerant than catfishes, haplochromines, *P. aethiopicus* and *O. niloticus*, was experienced in the fish catches in water hyacinth-infested areas. In Nigeria, water hyacinth has led to a reduction in fish catches, particularly mudfish and tilapia, which were found along the shores which later led to the loss of livelihood. In the Delta regions of Nigeria, water hyacinth has limited access to landing sites, disrupts breeding sites, reduced species diversity, poor quality of fish, decreased fish production, and increased operation cost, leaving fishers jobless (Abraham & Kurup, 1996; Hill & Cilliers, 1999; Reddy et al., 1989).

Effect on Plankton Productivity

Water hyacinth physically restricts sunlight and oxygen exchange by having broad leaves on the water's surface, which prevents the growth of both emerging and submerged plants. As a result, floating species predominate the macrophyte community in the littoral zones, whereas submerged species are rare or absent in bodies of water like Lake Victoria. Similar outcomes were seen in Lake Naivasha, where submerged and rooted floating leafed macrophytes were prevalent in shallow areas before the expansion of water hyacinth in the lake (Echiegu et al., 2018) but disappeared following its arrival. For instance, reduced phytoplankton productivity in the water column was shown by lower chlorophyll-a at the sites containing water hyacinth.

Water hyacinths face competition from other water-growing organisms like plankton. In addition to reducing the level of light that immersed plants may fail to carry out photosynthesis, it also decreases the amount of oxygen that is readily available in the environment (Gebremedhin et al., 2018), which is essential for plants and animals. Second, because it occupies a large area, it outcompetes other species, alters invertebrate populations, influences fisheries, dispenses with native plants and animals, and adds to sediment loading. Additionally, water quality and other plankton, such as the organic algae in Lake Victoria, have been reduced by stopping it from spreading- due to the presence of water hyacinth. The local fish that usually eat algae as their primary source of food are suddenly put in a difficult situation in the lake (Echiegu et al., 2018).

WATER HYACINTH MITIGATION

Reducing the nutrient output mainly from domestic activities into the water bodies

The algal blooms of the water, which are largely brought on by anthropogenic activity such as agricultural operations, promote the rapid expansion of water hyacinths. When the conditions are precise, it can utilise nitrogen and phosphorus, which allows it to multiply quickly. According to Turyasingura et al. (2023), rising temperatures and decreased rainfall all have negative effects, including reduced stream flows in significant water catchments, lower groundwater recharge rates, decreased inflows into water storages, and worsened droughts. This is attributed to the surface runoff from agricultural farms that transports nutrients together with sediment and pesticides, increasing risks to the freshwater quality and bolstering hyacinth. The current findings agree with the study conducted by Turyasingura et al. (2022), who found that a significant variety of diversity can enhance ecological stability by allowing species from one functional group in one ecosystem to temporarily sustain another chromophore in another ecosystem. In light of these realisations, it follows that developing resilient livelihoods is essential for

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enhancing the health and efficiency of socio-ecological systems as well as a method of ensuring food security (Chavula, 2021).

For instance, contamination, which is the main cause of the emergence of water hyacinths in Lake Victoria, has been triggered by pollution from cities and industries, soil erosion, and nutrient runoff (Williams et al., 2017). Appropriately managing nitrogen, sediments, and pesticides during the agricultural sector and minimising degradation may help to minimise end-of-catchment loads and boost the adaptability of the hydrological bodies of water (Turyasingura et al., 2023). Even though phosphorus and nitrogen are found in nature, agricultural practices like fertiliser application are particularly harmful since they release more of them into freshwater bodies, speeding up the spread of water hyacinth (Najmi & Watanna, 2018). The best course of action is to limit agricultural inputs and only employ phosphate and nitrogen that are sufficient and will be swiftly used by water hyacinth (Mideksa et al., 2022). Moreover, Karouach et al. (2022) claimed that switching from inorganic to organic fertilisers could help reduce pollution from organic sources.

Eradication Methods

Physical Control Methods

The use of physical procedures, including both manual (by human effort) and mechanical removal (with pitchforks, harvesters, chaining, shredder boats, dredging process, nets, and barrier fences) (Ajithram et al., 2022). For removing water hyacinths from water bodies, physical management methods are the most environmentally benign option, but they are also the most expensive. The high cost can be reduced, nevertheless, by validating the retrieved hyacinth biomass because it is used in multiple ways (Karouach et al., 2022). However, depending on the species' invasion pathway degree, extent, or spread, as well as this method's efficacy in tiny water bodies, it may or may not be effective.

The majority of developing countries, including South Africa, Kenya, and Malawi have employed the techniques (Pell et al., 2013). It was started as a program on Lake Chivero in Zimbabwe in the early 1990s, but the strategy was not as successful as it may have been, given how quickly water hyacinths reproduce. This forced them to use motorised means, including bulldozers, conveyors, crusher boats, and demolition boats. Although expensive, the process was necessary because the prodigious hyacinth could not be eliminated, but it was clear that the hyacinth population had decreased (Pell et al., 2013).

In Lake Victoria, Uganda, mechanical techniques were used, but the outcome fell short of expectations (Karouach et al., 2022). Both manual and mechanical methods were utilised at Lake Tana, Ethiopia, but the manual approach was more prevalent since there was labour available, particularly from young people, even though it was ineffective (Pell et al., 2013). The physical technique was introduced in Egypt, Tanzania, and Nigeria between 2000 and 2002, but it proved ineffectual. Though dangerous, physical control techniques could result in hyacinth proliferation since the seeds could disperse across the water and germinate. Some hyacinth plants tend to sink and begin to decompose, which lowers the levels of dissolved oxygen and triggers the formation of phosphorus. This will speed up the eutrophication process, which will encourage the growth of water hyacinth (Karouach et al., 2022).

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Figure 4: Water hyacinth in Lake Victoria being manually removed

Chemical Control

Chemical herbicides like Paraquat, Diquat (6,7-dihydro dipyridyl pyrazinediumon), Glyphosate (isopropilamine salt of N-phosphomethyl glycine) (Cerveira Júnior & de Carvalho, 2019), Amitrole, 2, 4-D acid, have been used to control water hyacinth populations all over the world (Ganorkar et al., 2021). Ghana, Nigeria, South Africa, Zambia, and Zimbabwe have all reported using chemical controls. However, the usage of chemicals (2,4-D and glyphosate) in East Africa has raised environmental issues (i.e., pollution in water bodies) (Karouach et al., 2022). Despite the effectiveness of some chemicals, such as herbicides, the indigenous have been put in danger. Long-term use has the potential to impair water quality and endanger aquatic life. If the quality of the water is compromised, it also has socioeconomic repercussions, which leads to limitations on their use in several countries. If the hyacinth population is weak and a pressing issue needs to be remedied, herbicides can be used. As a result of repeated use, pesticide-resistant weeds may emerge, decreasing their efficacy. Also, chemicals generally lack specificity and may wind up affecting all aquatic life, including humans, which may have more detrimental health effects (Hill & Cilliers, 1999).

Biological Control

Natural enemies of the water hyacinth, such as plant diseases, insects, fungi, and parasites, have drawn more attention in recent years (Abebe et al., 2021). By using biological control, the profusion has been reduced to a manageable level, making things simpler. Fish and other aquatic plankton can diminish hyacinth, but they were ineffectual (Kenfack Voukeng et al., 2019); therefore, two South American weevil insect taxa (*Neochetina eichhorniae and Neochetina bruchi*) and species of water hyacinth moths were introduced (*Niphograpta albiguttalis and Xubida infusella*) (Abebe et al., 2021).

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Figure 5: Two species of the water hyacinth weevil

Neochetina bruchi

Neochetina eichhorniae

Figure 6: A pyralid moth: *Niphograpta albiguttalis*

In general, the utilisation of biological control became effective in most African countries like Egypt and Uganda by reducing plant size, vegetative reproduction, and flower and seed production; the weevils weaken water hyacinths. As they continue to feed, adult weevils leave behind rectangular scars on the leaf's surface that expose it to aridity, which decreases the plant's growth and reproduction rate. It typically takes 3-5 years for Neochetina spp. to effectively control water hyacinth by biological means. Neochetina spp. has been used as a biological control in Africa, with success rates of 90% in South Africa, high effectiveness in Benin in Lake Azili and 90% in Zimbabwe. Da Groote et al., 2003; Agjee et al., 2016; Jones, 2009. After the beetles were introduced to Lake Victoria in 1997, the amount of hyacinth decreased by over 85%, from nearly 20,000 hectares to fewer than 3,000 in 2006. In Southern Benin, they released two weevil species (*Neochetina spp*.) and one moth that completely grazed on water hyacinth between 1991 and 1993. By 1999, even the local residents had noticed a decline.

Climate Change

According to IPCC (IPCC, 2018), the consequences of climate change could worsen, therefore it might

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be a technique to reduce hyacinth, but in conjunction with other strategies such as a decrease in nutrients flowing into water bodies. For instance, water hyacinth development is constrained by high salinity levels (Hossain et al., 2022). As predicted, the water bodies may become more acidic and may not have the right circumstances for the weed to thrive. The plant thrives at neutral pH but can also go as far as 4–10. Rising sea levels, ocean acidification, increasing temperatures, an increase in water salinity, changes in rainfall patterns, and hazardous blooms are just a few of the repercussions of climate, which calls for capacity building (Benzougagh et al., 2023). This is in line with the study conducted by Turyasingura (Turyasingura et al., 2022) who mentioned that building capability is required to support the development of solutions that take the terrain into consideration and this, in turn, protects water resources. Examples include design principles for green infrastructure that are subject to discussion and change by the social-ecological network in the region where the people are active. According to (Katel et al., 2023), a practical approach, including crop diversification, crop rotation, soil conservation, improved irrigation practices, and the use of alternative water sources, is essential to prevent water resources and maintain food security. Hence, addressing these challenges will require a collaborative, multi-stakeholder approach that engages different actors, including farmers, researchers, policymakers, and private sector players.

CONCLUSION

To stop the spread as rapidly as feasible, combining all of the strategies should be a top priority. There are many ways to manage water hyacinths, including reducing the amount of pollutants and nutrients that get into the lake. This will help to reduce the level of eutrophication, or "nutrient overgrowth", in the lake. Another crucial aspect to consider is keeping invasive species out of water bodies. To guarantee the safety of a country's natural species, appropriate consultations must be performed prior to any introductions, whether unintentional or intentional. The correct processes must be followed unless the introductions are accidental. Similar to other nations outside of Africa, reduction via utilisation can be supplemented with other techniques. Establishing local-level platforms and methods for correct balance and collaboration between government sector investment advisors required to work on farming, water, environment, forestry, and fisheries are some urgent priority activities are important, especially in reducing water hyacinth. Extension reforms are also required for the lengthy reform of and boosting rural advisory systems. Also, as an encouragement, awareness should be raised about the diverse applications of water hyacinth and how successful other countries have been in utilising it. Uses like wastewater treatment and environmental restoration, as in Nigeria (ii) An alternative fuel and energy source, similar to those in Malawi and South Africa, which are expected to produce 10 MW of electricity each year. (iii) Semi-industrial uses and consumer goods, as those in Nigeria and Madagascar. (iv) Use in agriculture and as animal food 13.74 percent crude fibre and 14.97% to 16.04% ash. All this can create employment for the public as well as help reduce the hyacinth in water systems returning them back to their normalcy if taken positively.

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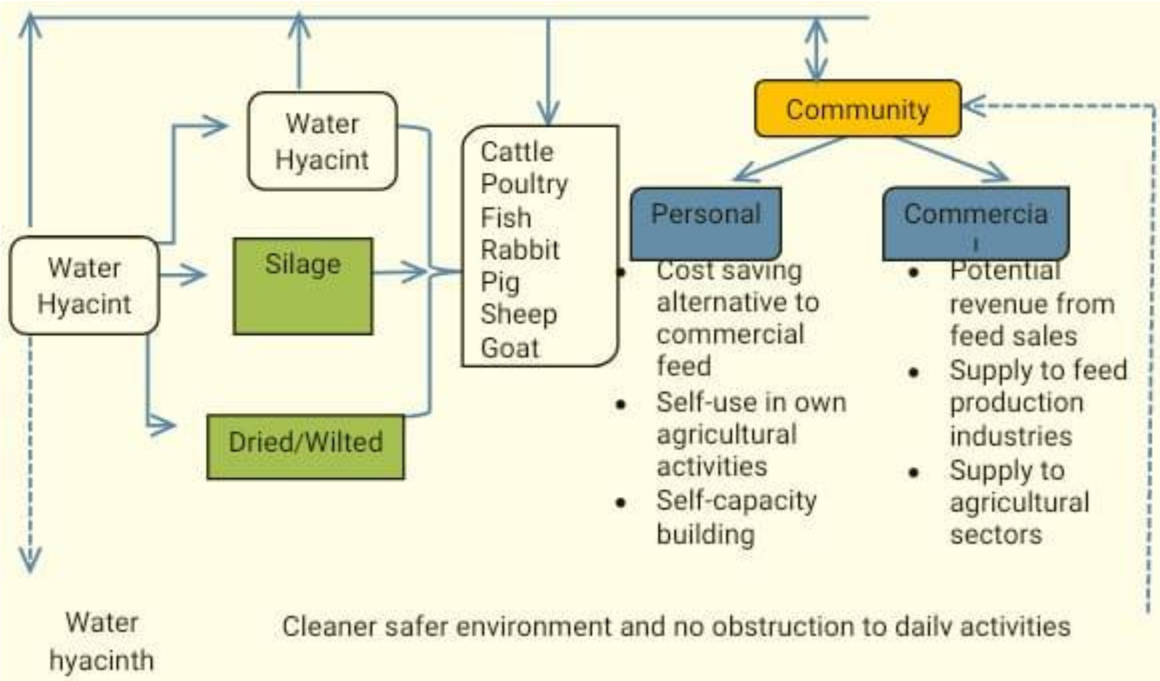
Figure 7: Benefits of water hyacinth, including its possible use as animal feed:



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