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Review: Economic impacts of the invasive species water hyacinth (*Eichhornia crassipes*): Case study of Rawapening Lake, Central Java, Indonesia

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Abstract. *Maulidyna A, Alicia F, Agustin HN, Dewi IR, Nurhidayah I, Dewangga A, Kusumaningrum L, Nugroho GD, Jumari, Setyawan AD. 2021. Review: Economic impacts of the invasive species water hyacinth (Eichhornia crassipes): Case study of Rawapening Lake, Central Java, Indonesia. Intl J Bonorowo Wetlands 11: 18-31.* Introduced species is defined as a conscious or unconscious effort to present a species of animal or plant into a new habitat. Introduced species have two pathways on their biogeographical distribution: becoming an invasive species or not becoming an invasive species. An introduced species that does not negatively impact the new habitat is not classified as an invasive species. In contrast, a species introduced that negatively impacts the new habitat is considered invasive. One problem that threatens freshwater ecosystems in Indonesia is the invasion of water hyacinth (*Eichhornia crassipes*). This introduced plant species can reproduce rapidly, both generatively and vegetatively, and form very dense masses in water bodies, such as swamps, lakes, rivers, and channels, including Rawapening Lake in Semarang District, Central Java Indonesia. This study is aimed to review the economic impacts of the invasive water hyacinth species in Rawapening Lake from two perspectives: the negative and the positive impacts so that feasible solutions can be developed. There are several negative impacts caused by water hyacinth in Rawapening Lake. The overgrown water hyacinth in the lake hinders the fishers in maneuvering the boats and fishing gears, reducing the fish catches. The extensive coverage of water hyacinth causes the reduction in soluble oxygen and blocks sunlight into the water, leading to the decline of the fish population. The rotten water hyacinth can obstruct the irrigation channels of the fields so that farmers cannot produce maximum rice harvests, and eradicating them would incur financial costs. On the other hand, there are also positive impacts of water hyacinth in Rawapening Lake. This plant can be used as raw materials to produce a variety of handicrafts in the form of bags, sandals, baskets, wallets, and furniture such as chairs and tables. Water hyacinth can also be processed in biogas production and organic fertilizers. Water hyacinth can remediate polluted water caused by heavy metals contamination with careful management. In short, economically, water hyacinth in Rawapening can be both beneficial and detrimental. Proper management of this species is necessary to maintain the sustainability of this aquatic environment.

Keywords: Economic impact, invasive plant, Rawapening Lake, water hyacinth

INTRODUCTION

Introduced species is defined as a conscious or unconscious effort to present a species of animal or plant into a new habitat. Introduced species have two pathways on their biogeographical distribution: becoming an invasive species or not becoming an invasive species. An introduced species which does not have a negative impact on the new habitat is not classified as an invasive species, while a species that is introduced and do have a negative impact on the new habitat is considered an invasive species (Caplat and Coutts 2011; van Wilgen and Richardson 2012; Gallardo et al. 2016; Schirmel et al. 2016; Courchamp et al. 2017; David et al. 2017; Thapa et al. 2018; Bartz and Kowarik 2019). The most noticeable impact of invasive species is the domination of habitat by the newly introduced species (Kumschick et al., 2015). The route of arrival and spread of invasive species can be caused by natural factors (e.g., storms, ocean currents, and climate change) and human factors, through the introduction and distribution, either intentionally (e.g., crops and pets) or unintentionally (e.g., trade, tourism, and transportation).

Nowadays, invasive species (either animals or plants) have spread to almost all types of ecosystems on earth, including mountain, lowland, terrestrial ecosystems, freshwater, and marine ecosystems, as well as archipelagic and continental realms (Mostert et al. 2013; Gallardo et al. 2015; Russel et al. 2017; Spatz et al. 2017). According to Llewelyn et al. (2011), in Australia found, the cane toad (*Bufo marinus*) is huge (up to 40 cm long), the so-called

"Toadzilla" (after the term Godzilla monster). These frogs were initially imported from Hawaii to deal with the overgrowth of local frogs. However, it turns out that introducing this species into an invasive species threatens diversity in Australia because the local frogs are depleted, the cane toad continues to exist, and even thrives because there are no predators such as crocodiles and snakes that can survive after eating it. In Europe, *Heracleum mantegazzianum*, *Lupinus polyphyllus*, and *Rosa rugosa* are all invasive plants that can produce dominant stands with a cover of more than 90% (Thiele et al. 2011). In the Americas, there are *Ampelopsis brevipedunculata*, *Cynanchum louiseae*, and *Ranunculus ficaria*, which have a high invasive rate because their growth is very fast, beating the native species (Buerger et al. 2016). Then, South Africa can spend a lot of money dealing with invasive species such as *Acacia mearnsii*, *Acacia saligna*, *Leptospermum laevigatum*, *Pinus halepensis Pinus pinaster*, and *Pinus radiata* that interfere with local biodiversity in the Nature Reserve (Gaertner et al. 2016).

As many countries face globally, Asia, especially Indonesia, has emerging invasive species problems. One of the problems facing Indonesia is the uncontrollable spread of introduced plants. These plants species are often considered as weeds, and the most dangerous weed species are those which have high reproductive abilities and cause devastating impacts both ecologically and economically (Essl et al. 2011; McConnachie et al. 2012; Mkumbo and Marshall 2014; Srivastava et al. 2014; Arp et al. 2017; Essl et al. 2017; Huang et al. 2018). One invasive species in Indonesia is water hyacinth (*Eichhornia crassipes*).

The invasion of water hyacinth occurs in many aquatic ecosystems across Indonesia, one of which is in Rawapening Lake. The presence of water hyacinth is becoming dominant nowadays and causes the Rawapening Lake ecosystem to become unbalanced. The Uncontrolled growth of water hyacinth poses a significant risk to the aquatic ecosystem in Rawapening Lake (Gichuki et al., 2012; Dereje et al., 2017; Gaikwad and Gavande 2017; Degaga 2019; Madian et al. 2019; Prasetyo et al. 2021). This phenomenon occurs because of eutrophication, a condition of increasing the nutrient content in water, especially phosphorus (P) and excessive nitrogen (N) (Clout and Williams 2009; Uwadiae et al. 2011; Zan et al. 2011; Arthaud et al. 2012; Coetzee and Hill 2012; Sood et al. 2012; Patel 2012; Chislock et al. 2013; Grasset et al. 2016; Guignard et al. 2017). The uncontrolled growth of water hyacinth will cover the water surface in the lake and block light from entering the lake, which causes biota such as fish to experience a lack of oxygen and nutrients, leading to death and population reduction (Bornette and Puijalon 2011; Mironga et al. 2011; Güereña et al. 2015; Kamau et al. 2015; Gupta and Yadav 2020). On the abiotic factor, the invasion of water hyacinth in Rawapening Lake also causes silting in the bottom of the lake.

The ecological impacts of water hyacinth invasion in Rawapening Lake can inflict negative consequences on the economy of stakeholders who rely on the lake, such as fishermen. The study on the economic impact of water hyacinth invasion in Rawapening Lake is essential for water hyacinth eradication or management solutions. Therefore, this study is aimed to review the economic impacts of the invasive water hyacinth species in Rawapening Lake from two perspectives: the negative and the positive impacts, so that feasible solutions can be developed.

THE CONTEXT OF STUDY AREA: RAWAPENING LAKE

The context of this study is in the Rawapening Lake area, Semarang District, Central Java, Indonesia (Figure 1). This is a semi-natural lake with about 2,607 hectares administratively located in the subdistricts of Ambarawa, Bawen, Banyubiru, and Tuntang (Sudjarwo et al. 2014). Rawapening Lake is located approximately 45 kilometers south of Semarang City and 9 kilometers northwest of Salatiga City, in the golden triangle between Semarang, Solo, and Yogyakarta. The lake geographically is located at 7°04'-7°30' south latitude and 110°24'46'-110°49'06'' east longitude, and it has an altitude of 460 meters above sea level.

Indonesia has ratified the Sustainable Development Goals (SDGs) and global communities for the 2015-2030 period (UNDP Indonesia 2015). One of the global agendas on the SDGs is to ensure the availability and sustainable management of water and sanitation for all. In line with this, Indonesia has developed the National Medium-Term Development Plan (RPJMN) for the 2020-2024 period, clearly stated in Chapter 7, namely building the environment, increasing disaster resilience, and climate change Rawapening Lake priority water ecosystems. This lake is protected explicitly in the maintenance, restoration, and conservation of natural resources and water ecosystems by Presidential Regulation No.18 (2020).

Rawapening Lake is utilized for various purposes, including water drinking sources, fisheries, agriculture, tourism, social and religious life, and hydroelectricity (Soeprobowati 2017). Historically, this lake was dammed by the Dutch Colonial Government in 1936 with a maximum water table area of 2,667 ha in the rainy season (November-April) and 1,650 ha in the dry season (May-October) (Sulastri et al. 2016). Currently, the lake is under intense pressures to exceed its capacity, which four prominent conditions can indicate, namely reduced fishery production, the rapid growth of aquatic plants, pollution of water sources and loss of endemic organisms, as well as silting and depletion of lakes area from its original state (Haryani 2013). Among such problems, the rapid growth of aquatic plants in Rawapening Lake is caused by the uncontrolled growth of water hyacinth.

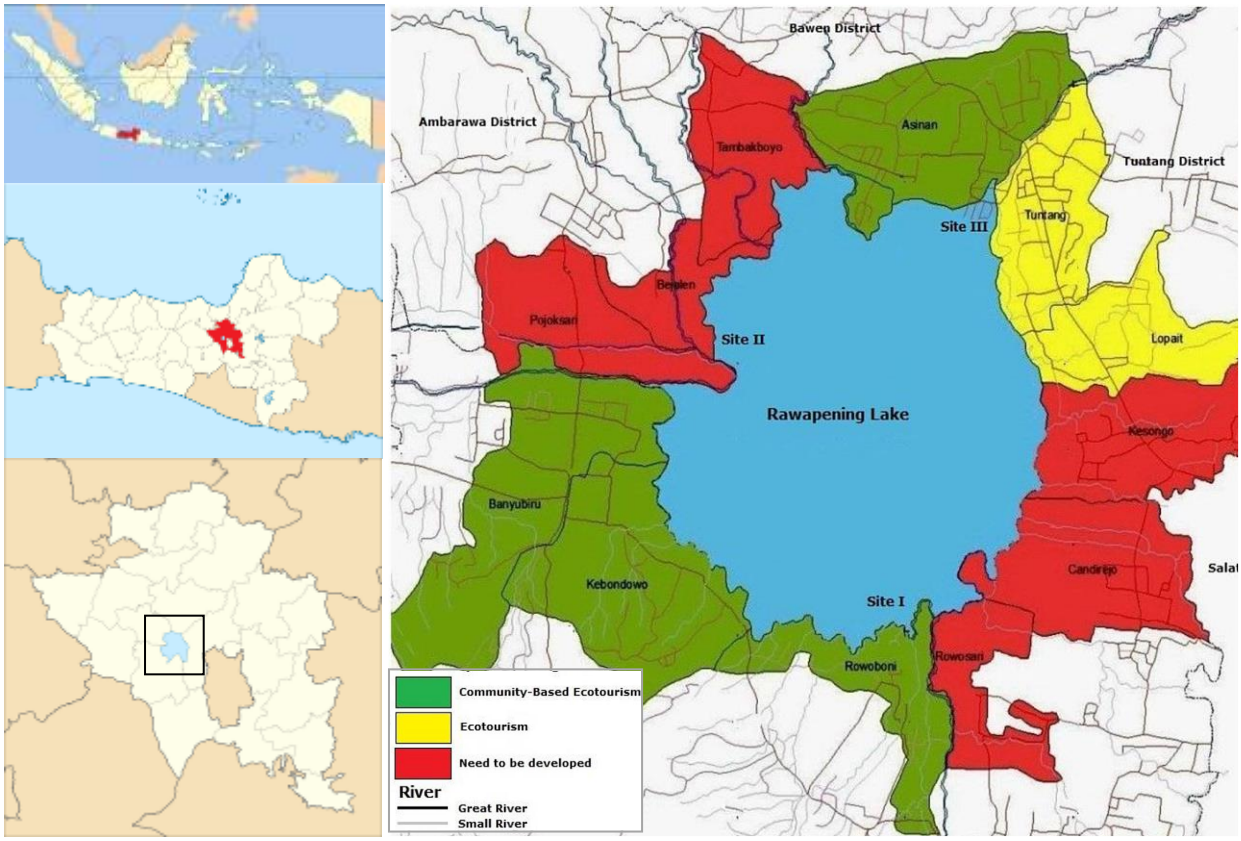

Figure 1. Map of the Rawapening Lake area, Semarang District, Central Java Province, Indonesia

INVASIVE PLANTS: A BRIEF HISTORY OF WATER HYACINTH IN INDONESIA

Flora is defined as a plant that grows and can spread from one area to another, which becomes its new habitat. A plant that historically grows in a particular area or habitat is known as native species. However, with the development of trade flows and transportation across countries and regions, there has been a change by allowing various species to move and cross long distances into new habitats as foreign species (Turbelin et al., 2017). In the context of Indonesia, the native flora is often so-called Flora Malesiana, and plant species other than Flora Malesiana are considered introduced or alien plant species.

The existence of introduced species can cause impacts in changes in the composition of local or native species. Introduced plants species can have a significant impact on an area, be it detrimental or beneficial (Kowarik et al. 2011; Lodge et al. 2012; Ricciardi et al. 2013; Simberloff 2013; Jeschke et al. 2014; Genovesi et al. 2015; Tanner et al. 2017; Hanley and Robert 2019). Several introduced plant species positively impact other species, ecosystems, and humans. Several other introduced plant species are invasive, potentially disturbing other species, ecosystems, and humans (Schlaepfer et al. 2011; Kapler et al. 2012; Blackburn et al. 2014; Roy et al. 2018; Epanchien-Niell 2017; Riley et al. 2018).

The difference between introduced and invasive species is that introduced species are not necessarily invasive species. However, all invasive species must be introduced (Gallardo et al. 2016; Schirmel et al. 2016; Courchamp et al. 2017; David et al. 2017; Thapa et al. 2018; Bartz and Kowarik 2019). Invasive species have several characteristics that make it easier for them to compete and over-dominates other species (Rakotoarisoa et al. 2015), including quick and mass reproduction biology, rapid growth and survival, ability to widespread, tolerance to a wide range of environmental conditions, ability to live with various types of food, and can cause damage to ecosystems (Pejchar and Mooney 2009; Vilà et al. 2011; Pyšek et al. 2012; Ricciardi et al. 2013; Gallardo et al. 2016; Schirmel et al. 2016; David et al. 2017; Foxcroft et al. 2017; Vilà and Hulme 2017). Invasive species can also cause socio-economic damages (Bacher et al. 2018) or affect infrastructure (Booy et al. 2017). Furthermore, invasive species management usually requires considerable financial and personnel resources (Hoffmann and Broadhurst 2016).

There are several processes in the invasion of introduced plants that influences natural communities, including competition, which affect the ecological processes in an ecosystem (Coetzee et al. 2011, 2014; Tollington et al. 2015; Solfiyeni 2016). According to Kumschick et al. (2012) and Blackburn et al. (2014), the competition is related to the interaction between two or more species in a habitat that occurs because of the exact needs, so that they compete for habitat, air, water, food, sunlight and so on. This competition will impact the underperforming species to die, be eliminated, or move to

another place. Thus, a strong invasion of the invasive plant can lead to a decrease in the population of the native plants and, in some instances, may cause local extinction.

Water hyacinth is a freshwater plant species first discovered accidentally by a botanist from Germany, Carl Friedrich Philipp von Martius, when he was doing an expedition in the Amazon River, Brazil, South America, in 1824 (Chunkao et al. 2012). Generally, water hyacinths live and grow above the wetland water surface and can also be grown among agricultural crops cultivated in wetlands. In 1894, during the occupation of the Bataaf Republic in the Dutch East Indies (now Indonesia), water hyacinth plants were first brought to Indonesia as a collection of aquatic plants (Ratnani. 2012). General Governor Thomas Stamford Raffles, who governed the Bataaf Republic in Indonesia, exported water hyacinth from Brazil, South America, and cultivated it in a pond in the Bogor Botanic Gardens (Lestari et al. 2018).

At first, water hyacinth was in great demand by Indonesians as an ornamental plant because it has flowers with purple and blue colors that are pretty striking, making it suitable as an ornamental plant for ponds. After all, it resembles a lotus plant (Figure 2) (Arham 2013). Water hyacinth plants can reproduce incredibly fast, so the presence of water hyacinth in the Bogor Botanical Garden pond has covered several existing water bodies. Due to the rapid growth (about 3% per day), the water hyacinth was then dumped through the rivers around the Bogor Botanical Gardens, spreading into waterways, marshes, and lakes throughout Indonesia and Southeast Asia. The growth of water hyacinth is uncontrolled and very fast that this plant is considered an invasive weed (Patel 2012; Frezina 2013; Ilo et al. 2020).

Nowadays, water hyacinth has invaded many freshwater bodies across Indonesia, including lakes. Besides the biological traits related to the invasiveness of water hyacinth, the invasion of these plants is facilitated with the degraded conditions of biotic and abiotic factors of the lakes. The majority of lakes in Indonesia are currently facing environmental problems such as eutrophication, sedimentation, and a decrease in the lake area, one of the leading causes of which is the invasive growth of water hyacinth (Juma et al. 2014; Soeprobowati et al. 2016; Sulastri et al. 2016; Guignard et al. 2017; Sutadian et al. 2017).

THE BIOLOGY OF WATER HYACINTH

Water hyacinth (*Eichhornia crassipes* (Mart. and Zucc.) Solms; syn. *Pontederia crassipes* Mart.) belongs to the family Pontederiaceae. It is a floating weed in tropical and sub-tropical freshwater lakes and rivers, especially those enriched with organic matters. It grows in shallow freshwater wetlands and can create pure stands. An emergent perennial aquatic plant forms rosettes of thick and spongy leaves. Flowers appear on the spike-like flower stalks. Beneath the surface water, the plant has black, fibrous roots. Rosettes are often connected to the surface water by stolons roots develop at the base of each leaf and form a dense mass: usually 20-60 cm long, although it can extend up to 300 cm. Periodically, axillary shoots develop as stolons, growing horizontally 10-50 cm before forming daughter plants. Vast populations of interconnected shoots can develop rapidly, although the stolons eventually die (Gopal 1987; Zhang and Guo 2017).

Plant sizes vary widely; seedlings have leaves only a few centimeters wide or in height, while mature plants with a good supply of nutrients can reach a height of 1 m. Plants in an open habitat tend to have short, spreading petioles with marked swelling, whereas, in dense stands, they are taller, more erect, and with little or no swelling petioles. The plant system consists of individual shoots, each with ten broad leaves arranged in a spiral, separated by very short internodes. As individual shoots develop, older leaves die, leaving pieces of dead shoots with no leaves protruding downwards (Figure 2) (Gopal 1987; Zhang and Guo 2017).

The leaves are basal and straightforward, forming a rosette around the flower stalk. Leaves consist of petioles (often swollen, 2-5 cm thick) and blades (roughly round, kidney or ovoid-shaped, up to 15 cm). The petiole base and subsequent leaves are flanked by 6 cm long stipules. Each petiole is short and consists mainly of a bulging ball that helps the plant float in the open state. The petioles become longer, thinner, and less inflated in more shady conditions. Leaf venation is parallel, and leaf margin is smooth (Figure 2) (Gopal 1987; Zhang and Guo 2017).

The inflorescences are loose, spike-like clusters of tiny lavender, resting on the erect stalk. Each flower has 6 petals. The inflorescences are spikes that develop from the apical meristem but tend to emerge laterally due to the rapid development of the axillary shot as a 'renewal' or 'continuation' shoot. Each spike, up to 50 cm high, has two bracts below it and has 8-15 sessile flowers (4-35 rarely). The bottom 5 petals are a solid shade of lilac or lavender, but the topmost petal has a bright yellow dot surrounded by a bluish "halo." Each flower has a perianth tube 1.5 cm long, developing into six light purple or purple lobes up to 4 cm long. The main lobe has a bright yellow, diamond-shaped patch surrounded by deep purple. Once the inflorescences have fully emerged from the leaf midrib, all the flowers open together, starting at night, completing the process in the morning, and most often the following evening when the peduncle begins to bend. The flowers are tristylus. They have six stamens and one style. The fruit is a three celled capsules containing many tiny seeds. Each capsule can hold up to 450 small seeds, each measuring about 1 x 3 mm (Figure 2) (Gopal 1987; Zhang and Guo 2017)

Water hyacinth has a flexible morphology that easily adapts to habitats with specific physicochemical and biological characteristics, especially changes in root length, petiole length and shape, and shoot-root ratio. However, this macrophyte causes extensive damage due to its biology and function in aquatic ecosystems. Water hyacinth has morphological elasticity, speedy growth, changes in the chemical composition of various plant parts in multiple habitats, adaptive phenology for ecological invasion, and vegetative and sexual reproduction for persistent distribution. This aquatic perennial free-floating plant is a

harmful, unique, useful, fast-growing, and constant invasive macrophyte. The root morphology plus the fast growth rate under suitable conditions allows one hectare of water surface to be covered entirely by water hyacinth every day (Penfound and Earle 1948; Zhang and Guo 2017).

Water hyacinth reproduces by seed, budding, fragmentation, and stolon production. Seeds may germinate within a few days or remain dormant for 15-20 years. They usually sink and stay dormant until periods of stress (drought). After re-flood, the seeds often germinate and renew the growth cycle (Gopal 1987; Westerdahl and Getsinger 1988; Barrett, 1989; Sharma et al. 2016; Mathur and Mathur 2017). Daughter plants grow from stolons, and doubling times have been reported to be 6-18 days. Water hyacinths multiply rapidly, float and spread easily, and quickly cover water bodies, resulting in poor water transparency. Therefore, water hyacinth competes with other aquatic plants (floating and submerged) and algae for mineral nutrients, sunlight, space, and other resources in natural waters (Masifwa et al. 2001; Villamagna and Murphy 2010).

WATER HYACINTH IN RAWAPENING LAKE

Rawapening Lake receives water from the springs of several mountains that flow through eight tributaries (UNEP 1999). The tributaries of the lake watershed flow through the catchment area, which is widely used for agriculture and urban development, is suspected as a source of increased sediment load and nutrient content in the lake. The land uses of water catchment area in Rawapening Lake include secondary forest (12,661.65 ha), primary forest (593.48 ha), agriculture (8,974.48 ha) which consists of irrigated and non-irrigated agriculture, settlements (3,304.44 ha), plantations (480.30 ha), shrubs (529.55 ha), and water bodies (1,517.46 ha). Non-irrigated agriculture for vegetable cultivation in water catchment areas has caused erosion and sedimentation in lakes (Wuryanta and Paimin 2012).

Water hyacinth is very easy to find in Rawapening Lake because the water hyacinth population in this lake is very abundant. The speedy growth and spread of water hyacinth plants are probably due to eutrophication in Rawapening Lake waters, which can be influenced by several causes such as high levels of nutrients (nitrogen and phosphorus) and pesticides from agricultural waste, feed waste from livestock, factory waste, domestic waste, etc., that flowed into the water bodies of Rawapening Lake (Knoll et al. 2003; Soeprobowati et al. 2012; Verma and Sivappa 2017).

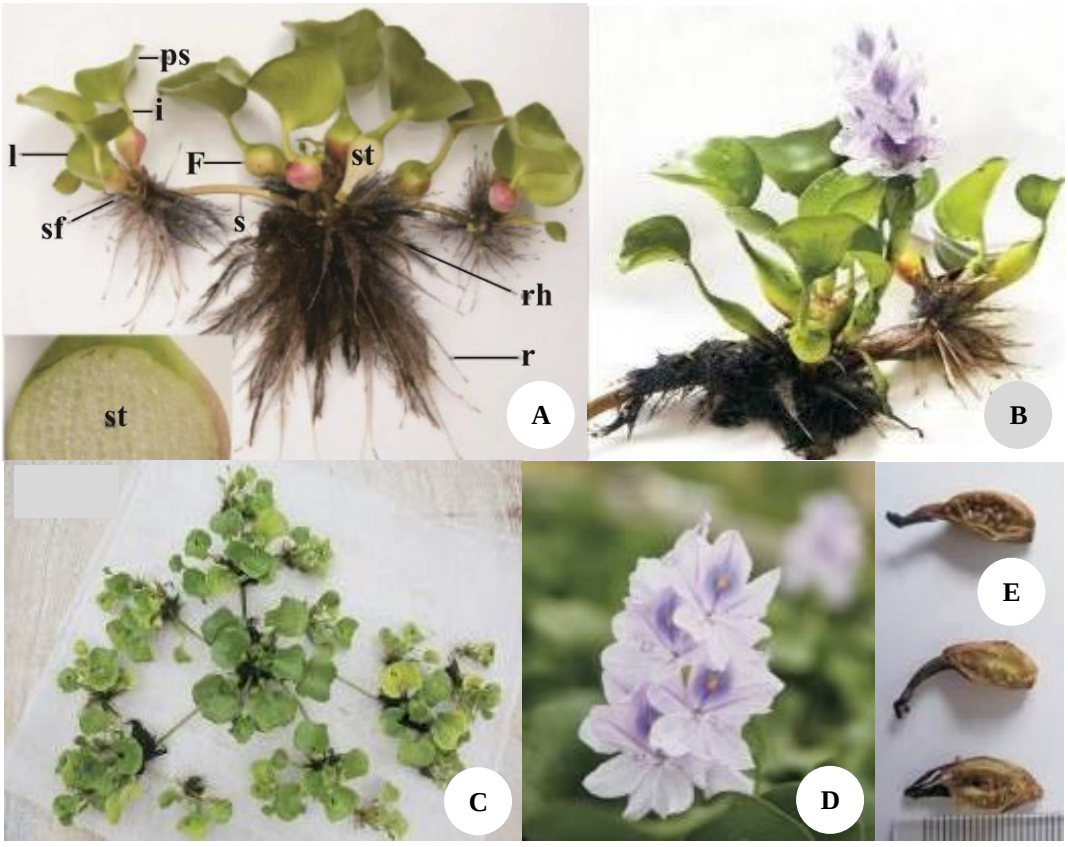

Figure 2. Morphological description of water hyacinth (*Eichhornia crassipes*). A. Young water hyacinth. l: ligule; sf: sub float; s: stolon; ps: pseudo-lamina; i: isthmus; f: float; rh: rhizome; r: root; st: sponge tissue. B. Mature water hyacinth, C. Vegetative reproduction, D. Water hyacinth in flower, E. Dehiscent capsules contain 63-153 seeds. (A-D. Photo by Lin Shang 2015; E. Photo by Ying-ying Zhang 2010)

Water hyacinth is also a significant problem that has the potential to reduce the environmental quality of Rawapening Lake, namely lake sedimentation, coverage of the lake surface by water hyacinth weeds, and increase in the volume of waste entering the lake area from several rivers that flow into the Rawapening Lake (Haseena et al. 2017; Salam and Salwan 2017; Ting et al. 2018; Yunindanova et al. 2020). Wind also affects nutrient dynamics in the lake, causing water hyacinth to float to new areas and triggering sediment resuspension that increases nutrient release in the lake (Worqlul et al. 2020).

In just a few decades, the water hyacinth invasion in Rawapening Lake has been severely increasing. In 1994, water hyacinth covered 18.45% of Rawapening Lake along with *Hydrilla verticillata* (7.69%) and *Salvinia* sp. (15.36%) (Goltenboth and Timothy 1994). In 2002, water hyacinth coverage in Rawapening Lake had reached 20-30% of the surface water areas or about 150 Ha (Utomo 2016). Between 2004 and 2005, the coverage of water hyacinth on the surface of Rawapening Lake increased from 60% to 70%, then increased again to 85% in 2006 due to the rapid growth rate of water hyacinth reaching 7.1% per year (Soeprobowati 2012).

In 2013, water hyacinth invasion reached 45% of the surface area of Rawapening Lake. This is caused by the water hyacinth growth rate being so fast, where the water hyacinth stems can produce new plants covering an area of 1 m^2 within 52 days (Utomo 2016). According to Hidayati et al. (2018), the area of water hyacinth in Rawapening Lake in 2012 was 775.49 ha, while in 2016, it increased to 990.53 ha. According to Soeprobowati (2017), one water hyacinth plant can reproduce and cover an area of water in Rawapening Lake, reaching an area of 1 m^2 within 22 days. Based on the research conducted by Prasetyo et al. (2021), the growth rate of water hyacinth must be considered so that the management of Rawapening Lake can be successful. The Relative Growth Rate (RGR) of water hyacinth in Rawapening Lake ranged from 6.40-7.26%/day. Meanwhile, water hyacinth propagation time (DT) ranged from 9.6-10.8 days. Then, 1 m^2 will be full of water hyacinth within 21 days to 28 days. The water hyacinth invasion in Rawapening Lake from year to year is getting out of control because water hyacinth is increasingly covering the lake area (Figure 3).

Figure 3. Condition of water hyacinth in Rawapening Lake in 2021 suggests that water hyacinth is everywhere in the lake

The uncontrollable water hyacinth invasion in Rawapening Lake can cause various negative impacts that affect the surrounding communities' social and economic aspects. The decrease in soluble oxygen in the water because water hyacinth blocks sunlight from entering the water causes a balance disorder in the Rawapening Lake aquatic ecosystem, leading to the decrease in fish production, the loss of endemic organisms, disturbance in irrigation, reduction in the beauty of the waters because the fallen roots will float and cause the water to look very dirty or cloudy, and others (Bornette and Puijalon 2011; Güereña et al. 2015; Kamau et al. 2015; Gupta and Yadav 2020).

The main factor that triggers the rapid growth of water hyacinth in Rawapening Lake is eutrophication due to the increase in the waters' nutrient content, especially phosphorus (P) and nitrogen (N). In addition, temperature and carbonate also significantly affect the growth of water hyacinth (Soeprobowati et al. 2016). Soeprobowati et al. (2012) stated that the eutrophic condition of Rawapening Lake has occurred since 1967, and it is tough to control the growth of water hyacinth because of its fast growth rate and ability to store seeds scattered by flooding (Júnior and Carvalho 2019). Water hyacinths also have seeds that have a dormancy up to 15 years, implying that the seeds have long-lasting regeneration ability (Ojo et al., 2019).

To eradicate the invasion of water hyacinth, biological control is most effective but can take several years to be successful (Van Wilgen and de Lange 2011; Fraser et al. 2016; Su et al. 2018). This involves using natural enemies, including plant pathogens (Dagno et al., 2012). There are several native enemies of water hyacinth, including two South American beetles (*Neochetina eichhorniae* and *Neochetina bruchi*) and two species of water hyacinth moth (*Niphograpta albiguttalis* and *Xubida infusella*) which have been effective in controlling water hyacinth populations in many countries, especially in Lake Chivero (Zimbabwe), Lake Victoria (Kenya), Louisiana (USA), Mexico, Papua New Guinea, and Benin (Williams et al. 2007; Venter et al. 2012; Gichuki et al. 2012; Dagno et al. 2012).

NEGATIVE ECONOMIC IMPACTS OF WATER HYACINTH IN RAWAPENING LAKE

The rapid growth and spread of water hyacinth in Rawapening Lake cause detrimental impacts to the economic conditions of the people around the lake, especially the farmers and fishers. In the agricultural sector, water hyacinth is a pest that disturbs agricultural crops. The bush from the water hyacinth plant becomes a nest for rats, which in the event of high tide, the bush pulls over to the agricultural land then eats up the agricultural crops (Ningsih et al. 2019). The spread of water hyacinth into drainages and sewages may cause clogging. The rotten water hyacinth plants can obstruct the irrigation channels of the fields so that farmers cannot produce maximum rice harvests (Chowdhury 2013; Kriticos and Brunel 2016). Water hyacinth that is not controlled will invade agricultural land and livestock grazing, making fodder plants and grasses lose their place of growth. Unfortunately, water hyacinth cannot be used as animal feed because it contains too much silica, calcium oxalate, potassium, and too little protein (Osumo 2001).

In the health sector, the overgrown water hyacinth provides an ideal habitat for disease carriers such as mosquitoes that cause malaria, inflicting the cost of health treatment when the surrounding community suffering the disease (Minakawa et al. 2012; Njuru et al. 2012; Honlah et al. 2019). In addition, certain bacteria can thrive in water hyacinth habitats. If left unchecked, this will have the opportunity to cause disease outbreaks for humans.

In fisheries sector, water hyacinths that covered the surface water of Rawapening Lake obstruct the activities of fishermen because water hyacinth makes it difficult and hinders the speed of the fishing boats, and disturbs fishermen when casting nets into the lake to look for fish (Ndimele et al. 2011; Patel 2012; Aloo et al. 2013). The large coverage of water hyacinths reduces the soluble oxygen in the water, causing aquatic organisms, especially fish, to find it difficult to get oxygen and eventually die, so that the fish population decreases and fishermen get only a few fish catches (Downing et al. 2012; Schultz and Dibble 2012; Witte et al. 2012; Degaga 2019). This condition is happening in Rawapening Lake which inflicts loss to the fishermen due to the decrease in fish catches (Genissa et al. 2018).

Economic losses suffered by the stakeholders of Rawapening Lake also come from the financial cost to suppress the growth of water hyacinth weeds. Because, the cost to eradicate and manage water hyacinth is expensive, there is a need for environmentally friendly efforts that incur low costs. If possible, the potentials utilization of water hyacinth can be developed to generate economic benefits.

POSITIVE ECONOMIC IMPACTS OF WATER HYACINTH IN RAWAPENING LAKE

Bioremediation

Despite the negatives economic impacts caused by water hyacinth invasion, some economic benefits have also been reported. It has been shown, for example, that water hyacinth is a good biosorbent for heavy metals contamination and it can improve the quality of water around the plant cover (Wang et al. 2012; Moyo et al. 2013; Ammar et al. 2014; Wanyonyi et al. 2014; Matindi et al.2014; Pusphe et al. 2016; Feng et al. 2017; Arenas et al. 2018; Ting et al. 2018; Sayago 2019). The remediated water that is not polluted by heavy metals can be used for various uses, for example for agricultural irrigation, so that in can increase economic income (Akinwade et al. 2013; Matindi et al. 2014; Canazart et al. 2017; Gogoi et al. 2017; Priya et al. 2018; Nash et al. 2019).

Handicrafts

Various products of handicrafts can be made of water hyacinth to generate economic value (Bruneckiene and Sinkiene 2014; Onyango and Ondeng 2015; Guna et al. 2017; Yan et al. 2017; Mitan 2019; Sianturi et al. 2019).

Communities around Rawapening Lake use the leaf stalks of water hyacinth to make various creative products that have functional value as well as environmentally friendly (Sudana and Mohamad 2020). Craft products produced by communities and enterprises around Rawapening Lake include bags, sandals, baskets, wallets, and furniture such as chairs and tables (Table 1).

The process of craft production with raw materials originated from water hyacinth begins with the drying of wet water hyacinth plants. In adding to the beauty value and economic value, it can use various methods such as embroidery (Putri and Prasetyaningtyas 2019). In its manufacture, the equipment used in the production of this craft consists of a sickle to take raw materials, a press for leveling the water hyacinth, a knife or scissors, a sewing machine to form and unite the supporting materials (cloth or leather). These art products made from water hyacinth are then can distributed either directly or through online media (with social media) so as to generate a number of profits.

Biogas

In addition, according to Bote et al. (2019), water hyacinth has a high hemicellulose content compared to other organic components, which will produce carbon dioxide and methane gas as biogas. The principle of making biogas is to use the anaerobic decomposition of organic matter, which is closed from free air to produce gas in the form of methane (CH_4). Several microorganisms, especially methane-producing bacteria, assist the anaerobic decomposition process. Anaerobic digestion is a process in which microorganisms break down biodegradable materials without oxygen (Yonathan et al. 2012). Manufacturing is done by preparing tools and materials. Tools and materials needed are biogas stove, gas generator, drum/gallon, galvanized pipe, hose. The ingredients are water, water hyacinth, cow dung. The mixture consisted of water hyacinth as a substrate, cow dung as a biostarter, and water as a nutrient.

Making biogas begins with water hyacinth chopped into small pieces measuring less than 1 cm, then water and cow dung are added according to the dilution variable. After the appropriate dilution variable, enter the mixed solution into the biodigester. The following process is to let it sit for a week for gas decomposition. Making biogas begins with water hyacinth chopped into small pieces measuring less than 1 cm, then water and cow dung are added according to the dilution variable. After the appropriate dilution variable, enter the mixed solution into the biodigester. The following process is to let it sit for a week for gas decomposition. Then, the gas produced is accommodated in a drum or gallon reservoir and the gas is flowed through a hose to turn on the stove and an electric generator. If the decay of the water hyacinth is good, the fire and electricity can continue to burn. If the decay of the water hyacinth is good, the fire and electricity can continue to burn.

According to Yonathan et al. (2012) who researched making biogas with water hyacinth with the composition of the ratio of water + cow dung: water hyacinth (2 : 1; 2: 1.5; 2: 2 ; 2: 2.5). The amount of substrate for each variable in a row are: 326.5gr; 420gr; 490gr; and 543.2gr. The amount of volume produced has increased from variable 2: 1 to variable 2: 2.5. The results obtained on the composition variable show the largest biogas production at 2:2.5 composition of 1162.97mL and the smallest biogas production at 2:1 at 12.85mL. The more the composition of the substrate, the higher the volume of biogas produced. From the results of the Gas Chromatography analysis, it was obtained, and after calculating the methane content formed was 0.03 mol of methane / 100gr of water hyacinth. From the results of this analysis, it can be concluded that biogas from water hyacinth can be used as a renewable energy source because it is proven that there is methane content in the biogas produced. However, from the results of this study, further research is still needed whether with the longer fermentation time and variations of other variables the methane gas content can still increase or not.

Biogas from water hyacinth is an environmentally friendly material at an affordable price. In that case, when we take advantage of the water hyacinth plants in Lake Rawapening, we can reduce the excessive water hyacinth population. Furthermore, utilizing water hyacinth as an ingredient for biogas is also very helpful for residents who have difficulty obtaining gas and electricity for their daily activities.

Organic fertilizer

Water hyacinth can also be processed into organic fertilizers that are marketable and also at the same time can reduce its population in Rawapening Lake (Fan et al. 2015; Yunindanova et al. 2020). In the community service activities carried out by Yunindanova et al. (2020) in the Rawapening Lake area and Kadirejo Village, Pabelan Sub-district, Semarang District, Central Java Province, they studied the practice of making compost using water hyacinth as the main raw material through the aerobic composting method. The fertilizer was made within one until two weeks with nutritional quality that meets the standards of organic fertilizers. The organic fertilizer produced from water hyacinth contains 18.93% C-organic, 1.78% total N, 1.10% P, and 1.26% K. The production of this fertilizer can generate profits from trade which can be trade enhanced by good packaging and with nutrient analysis (Sudhakar et al. 2013; Hernández-Shek et al. 2916; Goswami et al. 2017).

Table 1. Various handicraft products with raw materials originated from water hyacinth

Product category*)	Examples	Photographs
Household accessories	Baskets, tissue holder, coasters, placemats, tray box.	
Interior	Carpet, table and chair set, lamp, wall clock, rope.	
Decorative	Vase, photo frame, mirror, toys/miniature	
Fashion	Shoes, sandals, wallets, bags, necklaces	

Note: *) Based on Sianturi et al. (2019)

CHALLENGES ON THE UTILIZATION OF WATER HYACINTH IN GENERATING ECONOMIC IMPACTS

Alternative management of water hyacinth into goods that can be used as appropriate items is a good step to reduce water hyacinth populations and improve water quality. Making water hyacinth-based products can also be an opportunity for improving the community's economy. With the community around the Rawapening Lake area taking part in the production of making water hyacinth goods, this means that these people also have the right to benefit from the distribution of this water hyacinth processed product. Making handicrafts and organic fertilizer from water hyacinth is the best thing for the people around Rawapening Lake because of the cost of making it is relatively easy and does not require expensive technology.

However, there is a challenge in using water hyacinth to reduce/eliminate water hyacinth populations in Lake Rawapening while generating economic benefits. These challenges are: (i) lack of community resources because not all people can make various handicraft products whose raw materials come from water hyacinth, (ii) lack of interest in learning from the younger generation in utilizing water hyacinth so that utilization is not optimal and lacks innovation from products made from water hyacinth produced, (iii) the difficulty of constructing a series of biogas plants and the lack of research on effective biogas production and (iv) not yet comprehensive support provided by the Indonesian government in helping the community to make various handicraft products and fertilizers or other things whose raw materials come from water hyacinth.

Therefore, it is necessary to have a good relationship in establishing cooperation to reduce/eliminate the water hyacinth population in Lake Rawapening while generating economic benefits between the community and the Indonesian government so that human resources are more skilled, there is an increase in the quantity and quality of products, as well as promotion or marketing good product and reach every area.

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