

Review: Causes and impacts of anthropogenic activities on mangrove deforestation and degradation in Indonesia

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Abstract. Cahyaningsih AP, Deanova AK, Pristiawati CM, Ulumuddin YI, Kusumaningrum L, Setyawan AD. 2022. Review: Causes and impacts of anthropogenic activities on mangrove deforestation and degradation in Indonesia. *Intl J Bonorowo Wetlands* 12: 12-22. Indonesia is a country with the largest extent of mangroves in the world. However, as the human population increases the extent and quality of the mangroves is decreasing. The increasing population is in line with increase in human activities, leading to deforestation and degradation of the mangrove forests. This paper aimed to review anthropogenic activities that cause mangrove deforestation and degradation in Indonesia as well as the impacts of such anthropogenic activities on the mangrove ecosystems, and to formulate the efforts to overcome mangrove deforestation and degradation in the country. Various human activities are the primary drivers of deforestation and degradation of mangroves, including land conversion from mangrove forests into other land uses (e.g., agricultural lands, ponds, infrastructure developments and human settlements), extractive activities (e.g. mining and logging), and household and industrial activities (e.g., plastic debris, heavy metals pollutants). These anthropogenic factors have impacts on reduced mangrove forest area, changes in mangrove composition, uneven species abundance and pollution. In combination with sea level rise caused by global climate change, such activities pose devastating threats to Indonesian mangroves. Efforts to overcome these problems include increasing awareness of communities regarding the conservation of mangrove, conducting mangrove restoration programs and promoting sustainable management of mangrove, for example through ecotourism. On top of that, community participation plays essential role in sustainable management and conservation of mangrove forests in Indonesia.

Keywords: Anthropogenic activity, mangrove degradation, mangrove forest

INTRODUCTION

Mangrove ecosystem is transitional ecosystem between terrestrial and marine ecosystems located along coastlines and river estuaries and is strongly influenced by intertidal conditions. In general, mangroves grow in places with a mud and sand substrate on relatively flat or gently sloping areas, and not in places like beaches with steep and undulating terrain, and strong tides. The flat areas provide space for mangroves to grow so that the mangrove vegetation can expand (Akbar et al. 2015). The muddy and sandy mangrove habitat is also very suitable for the growth and development of several organisms that depend on mangroves (Afriza 2019).

Mangrove ecosystem plays an important role in delivering various ecosystem services. Mangrove forests store a very large carbon stock in aboveground and belowground biomass as well as in the soils in which in total it is five times greater than tropical boreal forests per unit area, implying that mangrove forests have a major influence on global climate change mitigation (Hamden et

al. 2014). Mangrove ecosystems also protect the coast from waves, winds, storms and even tsunamis. For marine biotas, mangrove ecosystems serve as habitat that supports their life and are suppliers of organic materials to provide food. Meanwhile, for local communities, mangroves provide materials for household needs such as firewood, charcoal, building materials, foodstuffs, and medicines (Nugroho et al. 2013).

Indonesia is a country with the largest extent of mangrove ecosystem in the world. A large extent of the coastal areas in Indonesia are covered by mangrove forests with various widths, ranging from a few meters to several kilometers from the coastline (Kusmana 2011). However, deforestation and degradation of mangrove forests in Indonesia have been going at an alarming rate and increasing every year. As the consequence, there is continuing decline in the function of mangrove forests with impacts of carbon emissions, biodiversity loss, increase of risk on abrasion and land subsidence, and reduction of community livelihoods (Wahyuni et al. 2014).

Mangrove forest ecosystem is a fragile ecosystem that is very sensitive to environmental changes. However, the easy access characteristic of mangrove ecosystem is prone to exploitation of its resources, leading to deforestation and degradation (Samsumarlin et al. 2015). According to Akbar et al (2017), anthropogenic activities are the major causes of deforestation and degradation of mangrove forests in Indonesia. Anthropogenic activities are human activities that can change landscape structures such as land-use conversion, habitat destruction, invasion of alien species, and overexploitation of biological resources. These activities result in changes in trophic status in mangrove ecosystem (Zulfia and Aisyah 2013). Examples of disturbances caused by human activities are tree cutting of mangroves, conversion of mangrove forests into plantations, settlements, industries, irrigated rice fields, rainfed rice fields, and fish or shrimp ponds (Mappanganro et al. 2018). Such human activities cause the degradation of mangrove ecosystem, damaging ecosystem stability and reducing biodiversity, especially mangrove organisms (Athirah et al. 2013). The decline in mangrove extent and quality is a serious threat to this ecosystem whose people depend on coastal resources. According to Schadow (2015), if the mangrove forest ecosystem is damaged, its social and economic functions will also be disturbed.

The purpose of this paper is to review anthropogenic activities that damage mangrove ecosystems in Indonesia, to find out the impacts of such anthropogenic activities on the mangrove ecosystems, and to formulate efforts to overcome mangrove deforestation and degradation in the country. We expected that this review provides a strong scientific basis for better management and conservation of mangrove ecosystems in Indonesia.

MANGROVE FOREST ECOSYSTEM

Mangroves are defined as a community of woody plants that grow in intertidal areas between terrestrial and marine ecosystems and are resistant to high salinity levels (Biswas et al. 2012; Biswas and Biswas 2019). The plant community of mangroves forms vegetation called a mangrove forest. Rahim and Baderan (2017) define mangrove forests as a variety of tropical coastal vegetation communities that are dominated by typical species of trees or shrubs that have the ability to grow in salty waters. Mangroves ecosystem has high values on ecological aspects, such as maintaining aquatic productivity, and economic aspects for the people living around mangrove ecosystems (Indrayanti et al. 2015; Widiastuti et al. 2016). Mangrove forest is one of ecosystems in the tropics and subtropics that has the largest carbon content among various ecosystems on the earth, as well as the most important CO₂ sequester in the atmosphere (Wang et al. 2021).

Mangrove ecosystem is among the complex ecosystems that have mutual relationship with the surrounding ecosystems, such as onshore and offshore ecosystems. It is known as one of the most fertile ecosystems because the litterfall of the mangroves acts as source of nutrients to the

soil and water (Diaro et al. 2012). Mangrove ecosystem is also considered one of the most valuable and productive coastal ecosystems on the planet (Himes-Cornell et al. 2018). Mangrove vegetation is regulated by several biotic and abiotic factors, such as anthropogenic impacts, nutrients, light, salinity, sedimentation, wind, and tides. Mangroves allocate most of their physiological energy to respond to high saline conditions. The availability of soil nutrients in mangroves is regulated by soil pH, and nutrients such as N, P and K (Cooray et al. 2021).

Mangrove ecosystem is affected by the tides of seawater which is suitable for the habitat of avifauna, including migratory birds. The ebb and flow of seawater in this ecosystem causes large fluctuations in environmental factors, especially temperature and salinity. As such, animals that are able to survive in this ecosystem must have great tolerance to extreme changes in environmental factors. There are around 150 to 250 species of bird species to occur in mangrove ecosystems with 65 species are categorized as endangered and vulnerable to extinction.

In Indonesia, mangrove forests are found in almost all parts of the country, spreading in 30 provinces from Sumatra to Papua. However, the existence of mangrove forests in Indonesia is threatened due to various human activities (e.g., timber cutting, overfishing and land conversion), and natural factors, such as tsunami (Purnobasuki 2011). Of the total 8.6 million hectares of mangrove ecosystems in Indonesia, some 5.9 million hectares (or 68%) have experienced disturbances (Wijaya et al. 2018).

ROLES OF MANGROVE FOREST

Mangrove ecosystems deliver various ecosystem services in the form of supporting services, regulatory services, provision services, and cultural services (Eddy et al. 2014). In terms of supporting and regulatory services, mangrove ecosystems maintain and protect tropical and subtropical marine biodiversity, global biogeochemical processes and climate change (Wang and Gu 2021). Mangrove forest ecosystem has the highest productivity level compared to other coastal ecosystems, and it also serves as habitat for aquatic biota that provides organic matters which is important in the life cycle of various types of shrimp, fish and mollusks. The detailed roles of mangrove forests are elaborated on below.

Mangroves as carbon stocks

Mangroves have the ability to absorb and store a large amount of carbon which is critical for controlling CO₂ levels in the atmosphere (Purnamasari et al. 2021), implying its critical role in reducing carbon emissions for climate change mitigation. The carbon absorbed by mangroves is stored it in stems, roots, leaves and soils. In mangrove ecosystem, soils contribute the majority of carbon stock, accounting for more than 84 percent of total carbon contained in the ecosystem (Trettin et al. 2021). For carbon stored as biomass, the capacity of carbon sequestration of mangrove forests is influenced by its

dimensional size where the larger the tree diameter, the greater the storage of biomass and the amount of CO₂ absorbed by mangrove trees (Heriyanto and Subiandono 2012). The height and age of mangrove stand also affect the absorption rate.

Biological function

Mangrove forest consists of unique biotic and abiotic components. The biological elements of mangrove forests are the main component of food for organisms that live around mangroves, such as shrimp, fish, crabs, birds and mammals. Mangroves serve as habitats for living organisms which are used as gathering and hiding places, especially for young fish, shrimp, and other marine biotas. Mangrove forests also provide an excellent site for spawning marine biotas (Kustanti 2011). The canopy of mangrove vegetation is useful as a habitat for various types of arboreal faunas, such as insects, birds, bats, and primates.

The existence of mangrove forests which act as coastal green belt influence the surrounding ecosystems (Pontoh 2011). It is proven that mangrove forest ecosystem can be useful as a protector of seawater intrusion, stabilizer of the coastline, the main point of circulation of nitrogen and sulfur, mud collection and land formation (Samosir and Restu 2017). Mangrove forests are also useful as an organic waste processor by neutralizing toxic substances caused by chemical wastes.

Mangrove root structures can improve the chemical and physical properties of soils through litter decomposition in which the organic matter of the decomposed litter fall can reduce salinity levels. Starting the food chain, mangrove leaves that fall into the water will be decomposed by microorganisms so that the results of this decomposition serve as food for small aquatic animals. The roots of mangroves become a source of nutrition for fish and invertebrates that live in the mangrove ecosystem.

Physical function

According to Utomo et al. (2017) and Ahnanto et al. (2014) mangrove ecosystems have the ability to control seawater intrusion by preventing CaCO₃ deposition by its root, holding mud and trapping sediment. This physical protection is beneficial for the surrounding communities from the damage that can be caused by big waves, strong winds, coastal abrasion, tsunamis, mud flood, and sediment traps transported by surface water flows and prevention of intrusion.

Social and economic function

Mangrove ecosystem provides social and economic benefits for coastal communities (Sondakh et al. 2019; Ritohardoyo and Ardi 2011; Gumilar 2012). The economic value of resources can be defined on how it benefits humans in the monetary term (Saprudin and Halidah 2012). The economic value that can be utilized from mangrove forests consists of direct benefits (e.g. wood and fishery products) and indirect benefits (Jumaedi 2016). The direct benefits of mangrove forests are in the form of various forest products to fulfill community needs to improve the

economy and social state of communities living around the mangrove forest. According to Riwayati (2014), the indirect benefits of mangroves for human life include nutrient providers, resistance of seawater intrusion and abrasion, and the ability to form islands and stabilize beaches.

The parts of the mangrove tree, including the roots, bark, leaves, tree trunks, and flowers can be beneficial for humans. Mangrove forests can produce wood and non-timber which can be used by the community as fuelwood, foodstuffs, handicrafts, medicines, animal feed, industrial raw materials. The bark of mangrove trees can be used as preservatives and natural medicines as well as building materials. In mangrove ecosystem, it can be found various types of fish, shrimp and crab that have high economic value. The mangrove roots or trunks can be used as protection for boats and ships by tying ropes to these parts.

Some mangrove plants that can be processed into food include Lindur (*Burquiera gymnorhiza*), Pedada (*Sonneratia* spp), Api-api (*Avicennia alba*), Nipah (*Nypa fruticans*) and Jeruju (*Achantus ilicifolius*). Mangroves also contain high calories and carbohydrates, more than some various types of food such as rice, corn, cassava. Some mangroves can also be used as natural coloring agents. Parts of mangrove plants that can be used as dyes are waste or unused plant parts, for example, mangroves in the species *Rhizophora* which can produce black, brown, dark brown, light brown, and pink colors. Another economic function of mangrove forests is as a place for fish and shrimp pond cultivation, a place for making salt fields, and source of materials for high-quality charcoal.

Indirect benefit values of mangrove forests, for example, are the provision of natural food for marine biota, barriers to seawater intrusion into land, and land expansion towards the sea (Ariftia et al. 2014). Mangroves can also be developed for ecotourism and education purposes (Setyawan and Winarno 2006a). The ecotourism activities are aimed to conserve the environment and preserve or improve the welfare of the local community. The ecotourism and education function in mangrove forests can be developed, for example by sightseeing the beauty of flora and fauna, as well as boating around the mangroves.

ANTHROPOGENIC ACTIVITIES THAT DESTROY MANGROVE ECOSYSTEMS

Mangrove ecosystem, which is located between the terrestrial and marine realms, is very sensitive to changes caused by natural processes and anthropogenic activities, such as urbanization and economic development (Wang and Gu 2021). Human activities with various forms of utilization pose threats to cause ongoing changes in mangrove forest resources (Kustanti et al. 2014; Oktavia et al. 2020). Anthropogenic activities that cause the loss of mangrove forests in Indonesia include fisheries, agriculture, plantations, settlements, industry, mining, and aquaculture (Kumar 2012; Sukwika and Putra 2018). On the other hand, human factors that lead to mangrove

degradation include illegal logging, unsustainable use, and establishment of shrimp ponds (Basyuni et al. 2012).

The larger the population community living around the mangrove forest area, the greater the rate of mangrove deforestation and degradation (Konom et al. 2019). The existence of coastal communities has interaction with mangrove ecosystem, for example, the utilization of wood extracted from mangrove for building materials (Hendrawan et al. 2018). Since most mangrove areas are under the authority of government (which are often considered open access by some people) and they are located in a sandy coastal area around the estuary which is easily accessible by humans, mangrove forests are prone to be exploited and disturbed (Heriyanto et al. 2020). Various anthropogenic activities that threaten mangroves in Indonesia are detailed below.

Land conversion

Mangrove forests have been converted into various types of land use. From 2002 to 2012, mangrove forests were lost at an average rate of 0.18% per year with a total estimate of more than 100,000 ha of mangroves have been logged over 10 years. In Indonesia, the drivers of mangrove forest conversion include aquaculture development, rapid expansion of rice farming, and oil palm plantations. The conversion of mangrove forests into aquaculture mainly occurs in Kalimantan and Sulawesi (Richards and Friess 2016). This is dilemmatic since aquaculture expansion is largely supported by the government to increase fisheries production in Indonesia (Rimmer et al. 2013). For example, mangrove forest conversion which results in degradation and deforestation due to unsustainable use of resources has occurred in the mangrove forests of Takalar District, South Sulawesi, Indonesia. The decline in mangrove area has reached 66.05% over the 33 year analysis period with the drivers is mainly due to land conversion for aquaculture. Yet, the clearing of mangroves for shrimp and seaweed cultivation in the area provides new job opportunities and generates profits for the community (Malik et al. 2017).

In Java, most of the mangrove habitat has been converted into rice fields, settlements and some river mouths have been converted into ponds, as has happened on the southern coast of the island (Setyawan et al. 2002). For instance, the conversion of land from mangrove forests to ponds occurs in Rembang, Central Java, Indonesia. In this area, many mangrove habitats have been opened to be used as shrimp, milkfish and salt ponds so that ponds dominate along the coast. Regrettably, intensive and massive aquaculture activities have resulted changes in hydrological conditions, edaphytes, and environmental pollution, leading the ponds to become unproductive, abandoned and degraded. Until now, there is no natural mangrove ecosystem left in the area (Setyawan and Winarno 2006b). Another land conversion in Central Java is in the form of rice fields, fish ponds, and salt extraction. In this area, the impacts of anthropogenic activities can be noted from the remained vegetation which shows canopy gaps and vacant land in the area (Setyawan et al. 2008).

In Kalimantan, mangrove conversion is caused by oil palm plantations which are responsible for 70% of coastal

areas degradation on the island. Oil palm plantation becomes more common and causes significant environmental concerns in coastal regions. The presence of oil palm industry, which contributes significantly to the destruction of the mangrove ecosystem, produces waste that not only contains heavy metals such as Pb, Cd, Fe, Cu, Cr, Zn, Ni, but can also lower the pH of waters and sediments and affect mangrove vegetation (Kadarsah et al. 2020). This pollution as the excess of oil palm mills occurs in many rivers and coastal estuaries in Kalimantan, affecting the function of the mangrove ecosystem.

Coastal reclamation for infrastructure development and human settlement are other anthropogenic activities that convert mangrove ecosystems. Coastal area is very dynamic and intensively influenced by anthropogenic activities. The initial goal of coastal reclamation is to control flooding in a city. In fact, coastal reclamation can result in changes in the ecosystem around the reclaimed area including the mangrove ecosystem (Puspitasari et al. 2017). Clearing mangrove forests into settlements can occur because the area is considered to be open access, being assumed that they have no owner (Ulumuddin and Setyawan 2017). The high population pressure has implications for the magnitude of land conversion activities, sedimentation, reclamation, and environmental pollution (Setyawan et al. 2003).

Mining and logging activities

Legal and illegal coal mining is one of anthropogenic activities that degraded coastal regions in Indonesia, for example in South Kalimantan. The presence of coal mining operations which are becoming more widespread, also causes disturbances in mangrove ecosystems. In addition to open-pit operation, the presence of special port for coal shipping also contributes significantly to the destruction of the mangrove ecosystem (Kadarsah et al. 2020). On the other hand, Balikpapan City, East Kalimantan is the area with the largest oil mining in Indonesia with mining activities occurring on the coast and offshore. Oil mining activities in the area often result in oil leaks from tankers and oil pipelines causing damage to several mangrove forests in Balikpapan Bay (Anwar et al. 2021).

Logging of mangrove trees is another anthropogenic activity that destroys mangrove ecosystem. Moreover, illegal logging of mangroves creates devastating impacts on mangrove forest ecosystem. Several types of mangrove vegetation are used by community as firewood, charcoal and wood for building materials (Malik et al. 2017). Mangrove logging in Dumai, Riau, Indonesia mostly uses mangrove species including *Rhizophora*, *Xylocarpus*, and *Bruguiera* (Mulyadi and Amin 2016). Several mangrove areas in Central Java also suffer from logging activities (Setyawan et al. 2008). Fairly massive logging activity in the mangrove habitat in Central Java is indicated by the vegetation which is undergoing secondary succession and a large number of vacant lands. The composition and structure of the vegetation where the importance index of young plants is relatively high suggest that the stands do not reach a climax (Setyawan et al. 2005a). The vertical and horizontal vegetation diagram shows that the

ecosystem is dominated by young mangrove plants and there are many canopy gaps.

Household and industrial activities

Human activities, such as household and industrial activities, also threaten mangrove ecosystem, for example in Dumai, Riau, Indonesia. Such activities in the coastal area contribute to contamination and pollution of the ecosystem around the mangrove area. The pollution is caused by waste from residences, hotels, and restaurants. Solid, liquid, and gas wastes, as well as organic and inorganic wastes, are all produced, often contained with heavy metals. Potential sources of pollution in coastal areas due to domestic activities are also influenced by the population especially for people who do not have the technology to manage the wastes. The presence of a large population will increase economic activities while producing an increasing amount of trash (Mulyadi and Amin 2016). The garbage dumped by people will be brought by rains, entering the river and ending up in mangrove forest. This situation persisted for years with no consideration to develop waste disposal, causing more waste to be accumulated (Nombere 2019).

Another type of waste that is increasing of concern is plastic debris. Van Bijsterveldtwe et al. (2021) investigated the magnitude of the plastic trash problem in mangroves along Java's north coast of Indonesia. Plastic was prevalent in the field, with 27 plastic pieces per m² on average, covering up to 50 percent of the mangrove floor in various sites. Furthermore, the study indicated that plastic was commonly buried in the top layers of sediment, where it becomes immobile and can result in protracted anoxic conditions.

Surveys of anthropogenic waste in mangrove forests have also been conducted, and it is known that big plastic objects are discovered more frequently in mangroves than on beaches. Mangrove serves as a landfill for marine trash and a garbage trap for land-based rubbish. Plastic trash is captured by mangrove forests and may be found in large concentrations on the forest floor and in sediments. The mangrove air roots act as a filter that holds out large plastic debris (Martin et al. 2019). In general, mangroves sustain high sediment accretion rates and efficiently absorb plastic in their sediments. Microplastics with a size of 0.5 mm dominated the mangrove sediments in *Avicennia marina* mangrove forests, and it is assumed that tons of plastics have been buried in the mangrove sediments since the 1930s (Martin et al. 2020). It also showed that mangrove sediments function as long-term plastic reservoirs and that mangroves retain marine plastic debris for a long period of time (do Sul et al. 2013).

IMPACTS OF ANTHROPOGENIC ACTIVITIES ON MANGROVE ECOSYSTEMS

The damage and loss of half of the mangrove area in Indonesia is largely influenced by human anthropogenic activities. The underlying drivers of mangrove deforestation and degradation are increase in population,

increase in human needs, types of work, and people's perceptions of mangrove forests (Majid et al. 2016; Hartati and Harudu 2011). By knowing the impact of anthropogenic activities, humans are expected to be able to make efforts to manage the mangrove ecosystem. Several issues regarding the impacts of anthropogenic factors are elaborated on below.

Impact of pollution

Anthropogenic activities cause the increasing levels of pollutants in the atmosphere, particularly atmospheric CO₂ and tropospheric O₃ which are important for forest ecosystems functioning. Increased CO₂ and O₃ levels affect tree metabolism, growth, and chemical composition. Changes in chemical composition may then cascade down through the trophic levels, influencing ecosystem processes (Couture and Lindroth 2013).

Pollution that often occurs in the mangrove ecosystem includes oil pollution, heavy metals, waste from tourists, aquaculture (ponds) that produce liquid waste, agriculture, roads, industry, residential areas and mining. The impacts of pollution on mangrove ecosystem include reduced and damaged mangrove ecosystems, loss of various species of flora and fauna due to unable to adapt to pollution and disconnection of the life cycle of fish and shrimp, which in the long term will disturb and affect the balance of the mangrove ecosystem and coastal ecosystem.

Pollution that often occurs in the waters is pollution in the form of oil spills, such as tanker accidents, oil loading and unloading, port activities, etc. which can result in physical disturbances in mangrove vegetation such as yellowing leaves, falling leaves, mangrove death due to coating of mangrove roots by oil spills, and permanent damage to mangroves which causes the destruction of the nursery ground for marine biota (Prasetyo et al. 2017).

Impact of land conversion

The increasing human population causes an increase in the need for job opportunities. For people living around the coast, the available employments are in the sectors of agriculture, fisheries, fishponds, ports, salt fields, and industries which of course require a large extent of land, implying that mangrove deforestation and land conversion is unavoidable. However, such land conversions do not regard capacity and development designation, causing many negative things, such as threatening the regeneration of fish and shrimp in offshore waters, marine pollution, shallow beaches due to sedimentation and water intrusion (Rusdianti and Sunito 2012).

Anthropogenic activities have different impacts on the degradation of mangrove forests. So far, land conversion activities, such as for agricultural lands and shrimp ponds development, are the main factors of mangrove degradation. These anthropogenic activities result in the reduction of the area of mangrove forests. There is no agreement on the extent of mangrove forests in Indonesia, but land conversion such as the development of coastal agricultural land and shrimp ponds in tidal areas is considered as the main factor behind mangrove

deforestation (Rasyid et al. 2016) which accounts for 90% of the reported loss (DasGupta et al. 2013).

Oil mining activities have a very detrimental impact on mangrove forests, such as the case in Balikpapan, East Kalimantan. Oil spills can damage mangrove forests due to oil deposits brought by the ebb and flow of seawater, causing the death of mangroves because of the sensitive nature of their roots exposed to oil. On the other hand, the effects of oil spills take a long time to overcome. Apart from causing the death of mangroves, it can also worsen soil and water conditions, making it difficult to regrow mangroves naturally (Anwar et al. 2021).

In coal mining areas and oil palm plantations, many environmental changes in mangrove forests have occurred as a result of these activities as occurred in South Kalimantan. These changes include pH of the waters becoming more acidic (5.76-6), higher organic matter content in sediments ranging from 0.61-6.59%, high heavy metal Pb content in sediments and waters. This has an impact on the reduction of population of mangrove species due to death although some true mangrove species such as *Avicennia alba*, *Acanthus ebracteatus*, *Nypa fruticans* and *Rhizophora apiculata* can still survive (Kadarsah et al. 2020).

Timber cutting of mangrove forests can cause changes in mangrove composition which are likely to be replaced by species with low commercial value. Such vegetational changes cause loss on the ecological and economic functions of mangrove forests as a place to find food and a place reproduction of various kinds of marine biotas which have high economic value. In addition, changes in the composition of mangroves cause mangroves to no longer function as absorbers of the waves of seawater properly and mangroves cannot withstand erosion and abrasion of seawater (Hadayatullah and Pujiono 2014). Often, timber cutting of mangroves is done illegally as occurred in East Java's mangrove forests (Rudianto et al. 2020). Mangrove forests are naturally functioned to reduce carbon dioxide concentrations, and because of the illegal logging the average carbon sequestration and storage in East Java's mangrove forests are reduced (Rudianto et al. 2020).

Impact of domestic and industrial activities

Various domestic and industrial activities that produce multiple pollutants, both solid, liquid and gas, affect the growth and life of young and mature mangrove trees. For example, mangrove areas in Dumai City, Riau are impacted by pollutants resulting from industrial activities, such as solid waste, organic and inorganic liquid waste processing, and generator residues. Besides industrial activities, mangrove vegetation is affected by wastewater and solid waste generated by domestic activities (Mulyadi and Amin 2016). According to Budiastuti et al (2016), a decrease in dissolved oxygen content in the waters of the mangrove ecosystem shows a strong indication of pollution. This pollution usually occurs due to the disposal of liquid waste from industries around the mangrove forest ecosystem. The decrease in oxygen levels occurs in an anoxic state so that organic matter undergoes anaerobic decomposition and

produces sulfides and ammonia which will be toxic to aquatic biota in the mangrove ecosystem.

Plastic wastes trapped in mangrove forests also have a negative impact. The accumulation of plastic wastes in mangrove areas creates a layer above the mangrove air roots, leading to depressed root growth and the mangrove eventually dies (Martin et al. 2019). According to Kinanti et al (2014), river estuaries in mangrove areas become waste centers so that these estuaries often become high input for organic pollutants. Chemical pollution, particularly metal accumulation and biotransformation, can be a significant factor in reducing mangrove biodiversity (Maiti and Chowdhury 2013) and an indication of altered biogeochemical cycles with a significant decrease in organic carbon in sediments (Carugati et al. 2018).

Damage to mangroves can cause mass mangrove mortality. This is due to a drastic increase in salinity and sedimentation rate, and a decrease in the water level. The underlying driver is human behaviors which cause changes in the nature of rivers due to, for example, disposal of garbage, fishing with bombs and narrowing of the river replaced by human settlements. In fact, mangroves will grow in abundance on beaches close to rivers or river deltas, because the river flows carry mud and sand which are the main media for mangrove growth (Wardhani 2011). In addition, the practice of fishing or shrimp catching that uses spread nets and moving from one place to another will damage and disturb the habitat of fauna and benthic species whose lives are relatively sedentary at the bottom of the water. All such causes will risk the death of mangroves with negative consequences such as flooding, coastal erosion, loss of catches, decreased fishery products, and loss of community income due to lost fishery resources.

Impact of sea level rise

Climate change occurs due to human activity because of greenhouse gas (GHG) emissions mainly CO₂, disrupting the ozone layer in the atmosphere to cause global warming. According to the IPCC through the Special Report on Emission Scenarios (SRES), global climate change can affect sea-level rise and cause flooding, damage to settlements, damage to fresh land supplies from coastal aquifers, and inundation of a coastal area even inland beyond the coastal boundary. Sea level rise is characterized by tidal conditions, tsunamis, storm surges, waves, and global warming (Anggraini et al. 2012).

The rises in sea level will cause a decrease in the level of sediment, limiting landward expansion of mangrove vegetation. This of course will disrupt the distribution of mangroves and threaten the existence of mangroves in the long run. Climate change also triggers the decrease in rainfall, leading to increase in salinity and salt sulfate levels in seawater and resulting in the decline of mangrove growth, reduced biophysical ability of mangrove forests due to several types of plants being unable to adapt to the drastic climate change, and increasing air temperature with consequence on the loss of marine faunas that are unable to adapt, and causes reducing water sources in forest areas (Nandini and Narendra, 2011). In addition, climate change will cause a very long drought, contributing to death in

mangrove vegetation and inhibiting mangrove growth (Subardjo and Pribadi 2012).

EFFORTS FOR SUSTAINABLE MANGROVE MANAGEMENT AND CONSERVATION

Mangrove forests have many roles in maintaining the balance of the ecosystem. Deforestation and degradation of mangroves caused by human activities can be resolved by developing strategies of mangrove management that are win-win for both humans and mangroves (Sofuan 2016). The main obstacles to mangrove management and conservation are sectoral perspective when viewing mangrove forests, weak community participation, poverty, and lack of concern for the ecological value of mangroves. These management problems are also compounded by the lack of knowledge about silvicultural techniques, potential uses, and regeneration techniques (Setyawan et al. 2003). Introducing coastal communities to environmental conservation also plays essential role in efforts to overcome anthropogenic disturbances to mangrove forests (Ali et al. 2017). Sustainable mangrove management is an alternative strategy that can be done for mangrove forests. There are various options for sustainable mangrove management, yet the main emphasis should be based on a co-management approach (Tetelepta et al. 2020) as detailed below.

Community participation

Community participation in many cases of natural resource management is fundamental for its sustainability. The involvement of community is essential in the conservation and rehabilitation of mangrove forest, including program preparation, implementation and monitoring so that people feel responsible for its long-term sustainability (Martuti et al. 2018). In the first instance, community awareness is required to not disturb mangroves (Syahroni 2016). Efforts to increase public understanding include in the form of environmental care activities. Approval and commitment from local communities are required for the management of mangrove including efforts to restore it if it is in degraded condition. Such efforts will be more successful if the community is educated to carry out restoration with a desire to do it themselves which can also provide personal benefits (Romañach et al. 2018).

The active participation of the community can help to maintain the diversity of mangroves by maintaining the mangrove habitat properly. As in the case of mangrove areas on the coast of Central Java, the community's concern for the mangroves is very high. In these areas, the government forms groups and allows the mangroves areas to be used by the communities while maintaining sustainability. This community participation is quite successful in preserving the ecosystem and mangrove diversity (Setyawan et al. 2005b).

Mangrove conservation

Mangrove conservation requires joint effort or responsibility between the community and the government (Winata and Yuliana 2016). Mangrove forest conservation

efforts can be carried out with three main things, namely the protection of life support systems, preservation of flora and fauna diversity and ecosystems, and sustainable use of biological resources and ecosystems (Yuliani et al. 2018). In mangrove conservation, integrated strategies must be conducted in line with regional development plans (Fitriah et al. 2013). The environmental management process should be carried out by looking more at the local situation and conditions so that the management approach can be adjusted to the local conditions of the area to be managed (Muharuddin 2019).

Efforts to overcome problems related to mangrove conservation require strategic and continuous steps through education and guidance that can understand the community about the importance of preserving the ecosystem. Local wisdom in the form of local knowledge can support management and efforts to overcome mangrove damage due to anthropogenic activities (Sondakh et al. 2019). Three indicators that can be used to support mangrove conservation are explained here. First, attitude; this includes social values, a strong sense of concern for natural resources, preservation and sustainable use of nature, motivation to participate in efforts protection, and participation in protection efforts. Ecological awareness in coastal communities needs to be increased by providing motivation to the community to generate a sense of enthusiasm and be able to change human or individual behavior for the better (Sulastri and Haryadi 2019). Extension also needs to be carried out for efforts in the form of practical actions taken to encourage behavior change in individuals, groups, communities, and communities to know, want to implement, and be able to solve the problems faced (Ambo-Rappe et al. 2020). Second, skill; is needed to solve problems that occur in the conservation of natural resources. Third, participation; is necessary to develop a sense of responsibility for a natural resource conservation problem so that it can take actions that are relevant or in accordance with the actual situation.

Efforts to prevent mangrove degradation can be carried out through several stages of activities, including understanding the ecology of mangrove species and communities, assessing factors that would hinder succession, understanding hydrological suitability and location of planting, knowing the level of community dependence, and understanding the traditions, perceptions and needs of the local community. Analysis of ecosystem services that exist in mangrove ecosystems needs to be done to see the balance of ecosystem services between human use and exploitable mangrove resources (Handayani et al. 2020).

Mangrove restoration

Mangrove restoration is currently promoted in Indonesia as a large extent of mangrove forest is deforested and degraded. This effort is carried out to reforest damaged mangrove areas and minimize seawater intrusion into land and coastal abrasion. When doing mangrove restoration, it is necessary to take a broader approach by integrating coastal area management, by incorporating essential elements such as ecology, socio-economic, and socio-

cultural so that it can meet the community's needs while maintaining biodiversity at large (Setyawan et al. 2004).

For example, planting mangrove trees has been carried out in Baros Village, Bantul, Yogyakarta. The restored mangroves can grow well and have many ecological, economic, social and tourism benefits for the surrounding community. This program is useful for preventing abrasion to protect agricultural areas around the mangroves. In mangrove restoration, the role of the village government, tour guides and community participation are needed so that mangrove restoration can be successful and provide benefits for environmental and socio-economic sustainability for the community (Djumanto 2020).

Afforestation and reforestation of mangrove areas can involve community in various activities, such as seedling preparation in the nursery, planting, maintenance, and utilization of conservation-based mangrove forests. Mangrove planting can be done in various coastal locations, especially in areas of ex-ponds, former mangrove habitats that have been damaged either as a result of human activity or as a result of the tsunami waves (Suriani and Bahagia 2012). For instance, restoration efforts have been carried out in several locations in the south and north coasts of Central Java, Indonesia by planting mangrove seedlings. Several sites show significant results in improving and enhancing the functions of the mangrove. In this case, the success of mangrove restoration is due to the support and active participation of the along with strong consideration on biotic, abiotic and cultural factors of the local community (Setyawan and Winarno 2006a).

Sustainable mangrove ecotourism

Sustainable ecotourism is gaining popularity nowadays including in mangrove areas. This strategy provides positive benefits for both human and mangrove ecosystem. For example, mangrove ecotourism in East Java shows that mangroves can be used as nature-based tourism and contribute to mangrove conservation. The ecotourism strategy must involve the participation of local communities so that local wisdom can improve the sustainability of the mangrove ecosystem (Hakim et al. 2017). Community awareness programs related to the importance of mangrove forests are very important to be carried out, especially for the communities who live around the mangrove forest (Pattipeilophy 2014). Counseling and training for communities around the mangroves are also necessary in order to increase community understanding on ecotourism-based mangrove forest management and to avoid damage to mangrove forest ecosystems (Nugraha et al. 2015).

In the management of mangrove ecotourism, activities related to enhancing social and economic benefits for the surrounding communities should also be taken as primary objective. This needs to be done to avoid the behavior of the people around the mangrove to not take actions that are not environmentally friendly when exploiting the mangrove forest. Therefore, increasing the social and economic status of communities around the mangroves is very necessary to meet their needs without destroying the mangrove forest

ecosystem. This point is important since local people are the main stakeholder in protecting mangrove forests.

CONCLUDING REMARKS

In conclusion, various anthropogenic activities are the drivers of mangrove deforestation and degradation in Indonesia, including domestic activities, land conversion, mining and logging activities. Anthropogenic activities can reduce the extent as well as the function of the mangrove ecosystem. The impacts arising from anthropogenic activities on mangrove forests are the reduction of mangrove forests, changes in mangrove composition, uneven species abundance, mass mangrove mortality, pollution in mangrove areas, rising sea levels, global climate change, and coastal erosion or abrasion. Solutions that can be done to conserve and restore mangrove forests include increasing community awareness regarding the importance of mangrove forests, replanting mangrove forests, and developing community participation in maintaining natural resources. Three main things that can be done in efforts to conserve mangrove forests include protection of life support systems, preservation of flora and fauna diversity as well as ecosystems, and sustainable use of biological resources and ecosystems.

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