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Fig 1. Mangrove distribution in aquaculture landscape

Mangrove Damage vs Succession: An Opinion on the Journey of Mangrove Investigation Studies in Subang Regency Coast Area

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Scientific Significance Statement: Mangroves are species that live in coastal tropical forests that are widespread in Indonesia. Unfortunately, the threat of unsustainable land use is so massive today that it threatens the sustainability of the function of the mangrove ecosystem. This happened in the northern coastal area of Subang Regency, the damage occurred due to land conversion carried out by coastal communities. However, the coastal landscape of the study area still has a future for mangrove sustainability. In several areas in the study area, rehabilitation areas were found and mangroves experienced natural success, especially for the mangrove species Rhizophora Sp.

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MANGROVE ECOSYSTEM

Tran *et al.* (2022) explained that mangroves are a species that thrives in the intertidal ecosystem zone with an astronomical location between 40°S and 30°N throughout the world. This species is able to tolerate high salinity levels and thrives in areas affected by fresh water, specifically in river delta landscapes. Its growth is accelerated by sedimentation, so that it can spread widely and provide space for the life of marine animal species. Gnansounou *et al.* (2022) and Susilo *et al.* (2017) explained that mangroves are able to provide ecosystem services and produce economic services for surrounding communities.

Based on previous reports, Indonesia is the country with the largest mangrove area in the world (Jia *et al.* 2023). The Ministry of Environment and Forestry of the Republic of Indonesia informed that the national mangrove area reached 3.36 million hectares. On a regional basis, Asy'Ari *et al.* (2022) stated that the mangroves of West Java Province have an area of 933.54 ha which are spread across the north coast area (dominantly) and a little on the south coast area.

Such a large mangrove area should also have great potential which can be felt by local communities without having to sacrifice the ecological function of the ecosystem. Unfortunately, the condition of mangroves in Indonesia poses a huge threat, especially unsustainable land use in coastal areas, which can change the physical condition of mangrove forests. Especially the use of pond land is one of the factors causing the destruction of mangrove forests in the world (Jayanthi *et al.* 2022; de Lacerda *et al.* 2021). On this occasion, it is important to conduct a scientific study review of the study location, namely Subang Regency, to reveal the actual conditions of the mangrove forest which directly borders the local community activity area.

MANGROVE DAMAGE

The coastal ecosystem of Subang Regency is a land use area in the form of fish farming. This is land use that has a detrimental impact on the mangrove ecosystem. Through the survey carried out, it was found that the mangrove area had been converted into pond land. The local community uses coastal land for fish and shrimp farming, and some for fishing services. Destruction of mangrove species in this area by clear cutting or cutting down part of the mangrove stands. This can be seen in Figure 2.

Fig 2. Mangrove damage

Mangrove destruction activities in the study area are common activities found in Indonesia. According to Ilman *et al.* (2016), that cases of mangrove exploitation in Indonesia have occurred since 1800 due to the opening of ponds for cultivating brackish water shrimp and for harvesting wood. The same case also occurred in the Mahakam Delta region, around 62% of the 110,000 ha of primary mangrove forest in 1994 experienced damage until 2015, with an average loss rate each year reaching 4.5% (Aslan *et al.* 2021).

Damage to mangroves on the coast of Subang Regency requires and necessitates rehabilitation activities. This is to restore the condition of the ecosystem which has been damaged so that it is not optimal in protecting the coast, especially community land and coastal rural houses. Economic losses will threaten coastal communities, especially for pond land owners, if they do not pay attention to the natural barriers that protect the coast.

MANGROVE SUCCESSION

The damage to mangroves on the north coast of Subang Regency also provides a warning to communities around the coast about the importance of mangrove forests. Mangrove forests are generally referred to as natural barriers that limit and protect and reduce coastal disasters, including tidal floods and tsunamis. In the study area, it was found that there were areas where rural housing areas experienced tidal flooding and several fields were found submerged by the ferocity of the sea. This has attracted the attention of coastal communities and local governments.

Fig 3. Mangrove succession

In the case of the Subang Regency study area, mangrove areas were found that were experiencing a natural succession process. This mangrove succession occurs on abandoned pond land. Sedimentation in pond areas makes it easy for mangroves to grow in pond landscapes. Figure 3 illustrates the presence of species from the genus Rhizophora that grow in the former pond area. Parent species produce propagules which are key to the natural succession and dispersal of species (Wang *et al.* 2019). Van der Stocken *et al.* (2019) explained that the distribution of mangrove propagules can respond to changing climatic conditions by adapting to surrounding conditions in finding suitable habitat for long-term survival. However, in cases in pond areas, propagules grow in the area around the parent mangrove or can be said to not spread widely in the sedimentation area. This is due to external factors, namely the wind will blow the propagules until they reach obstructing objects, for example the parent root area or the pond embankment area. This causes many mangrove saplings to grow in the root area or in the coastal areas of the pond embankments. Several previous studies have also explained that mangrove propagules will follow the direction of water flow and wind direction until they reach an area suitable for their habitat (Di Nitto *et al.* 2013; Yun *et al.* 2022). Van der Stocken *et al.* (2013) explained that wind is a factor that influences the distribution of mangrove propagules. The research also explains that the limiting factor in wind pushing against propagules depends on a combination of propagule density and morphology and surface roughness. This oceanographic process is important in the distribution of mangroves, where it can connect and separate mangrove populations (Triest *et al.* 2021). A scheme of the direction of distribution of mangrove propagules can be seen in the diagram in Figure 4, and was developed by Van der Stocken *et al.* (2019).

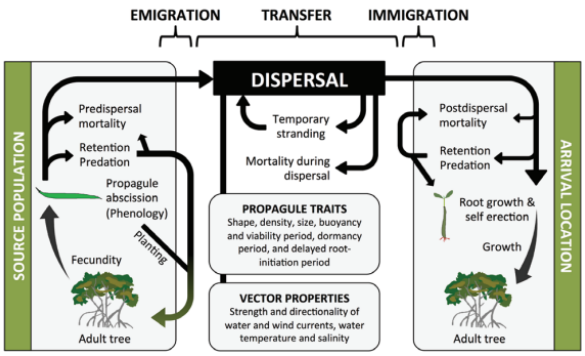

Fig 4. Mangrove dispersal (Van der Stocken *et al.* 2019)

In its natural cycle, the distribution and growth of mangrove propagules also poses a threat from propagull-eating predators. This is because the contents of mangrove propagules are a source of food for predators, namely crabs. Pribadi *et al.* (2014) explained in their research that mangrove species from the genus Rhizophora, especially the *Rhizophora stylosa* species,

have an average level of propagule predation of up to 61.06%. However, if the mangrove forest area has several mangrove species, this allows natural predators to select food. Van Nedervelde *et al.* (2015) explained that *Avicennia marina* propagules are preferred by crab predators compared to other large propagule seeds. This is a challenge for mangrove species in spreading propagule seeds in coastal areas.

The natural dynamics that occur in the mangrove ecosystem are interdependent natural cycles. On the other hand, mangrove succession will increase space for the ecosystem to express its ecological function. In general, mangroves have vital ecosystem functions for the surrounding ecosystem. Especially coastal ecosystems, mangrove forests provide natural food areas for fish, shrimp, crab and other marine animal species (Walton *et al.* 2021; Cuenca *et al.* 2015; Hemmati et al. 2021; Nugraha et al. 2020). Marine species take advantage of high tide conditions and obtain food with exploration in the mangrove root area.

POLICY RECOMMENDATION

The distribution of mangroves in Subang Regency poses a serious threat as a national issue. The damage has occurred on a massive scale, mainly due to the clearing of pond land without considering the environmental impacts it causes. Efforts to restore mangrove ecosystems that have experienced damage by means of rehabilitation and restoration have become a global issue which has become one of the mainstays and a solution to help reduce the climate crisis (Murdiyarso *et al.* 2015; Murdiyarso and Ambo-Rappe 2022; Arifanti *et al.* 2022). Land use in the form of pond businesses should require more attention, in management so that it does not only pursue national production targeted by the Indonesian government. On the other hand, the mangrove rehabilitation activities targeted by the Indonesian government are very ambitious in global eyes, reaching 600,000 ha of mangroves by 2024 (Sasmito *et al.* 2023). His research also revealed that only around 193,367 ha of mangrove area resulting from rehabilitation, or only 30% of the national target. This is very difficult homework for the Indonesian government to be accountable for its targets.

Coastal rehabilitation efforts, especially mangrove areas, consume a very large budget, making it an extraordinary challenge in ecosystem restoration programs. According to World Bank calculations in 2022, the Indonesian government requires restoration costs of around USD 3,900 ha^{-1}, and this is the highest restoration cost above the global average cost (World Bank 2022). The costs are very large, this requires the contribution of all parties, the community, local government, entrepreneurs and industry are very important in contributing to restoring coastal ecosystems, especially mangrove ecosystems. This mangrove restoration effort is considered to provide more benefits, namely helping absorb CO_2 up to 0.32 $PgCO_2$ globally (Jakovac *et al.* 2020). In addition, Sasmito *et al.* (2023) also explains that mangrove rehabilitation efforts can contribute to reducing national emissions in the land sector by around 16%. Land use in coastal areas, especially for fish farming, can also be aligned with conservation efforts, where conservation efforts can provide economic potential for conservation with fisheries production reaching 22,861 US$ $hectare^{-1}$ $year^{-1}$ (Yamamoto *et al.* 2023). Therefore, support from all sectors is very important so that ecosystem restoration can be achieved with rehabilitation efforts and sustainable land use.

CONCLUDING REMARKS

Mangroves have various ecosystem roles for coastal communities and the surrounding ecosystem. Land use in the form of fish ponds poses an extraordinary threat to the 3.36 million mangroves in Indonesia. Especially in the study area, Subang Regency, is an example of a case of systematic destruction with the aim of clearing land for fish farming. On the other hand, this area still has a bright future where there are still rehabilitation areas that allow for the restoration of coastal ecosystems. Natural succession occurs in several places, especially in pond areas due to sedimentation which provides suitable habitat for mangrove growth. The distribution of mangrove propagules is the key to successful rehabilitation which is characterized by rapid distribution in the surrounding area without being influenced by distance. It is hoped that the results of the assessment of the condition of mangroves in the coastal areas of Subang Regency will be taken into consideration by the local government in seeking to restore the ecosystem by rehabilitating damaged areas of mangroves in the pond landscape. This can support the government's efforts in the mangrove rehabilitation target of 600,000 ha of mangroves.

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