

Distribution, Abundance, and Sustainable Challenge of Mangrove Among Coastal East Nusa Tenggara

Willem Amu Blegur^{1*}, Erny Poedjirahajoe^{2*} and Azwar Maas³

¹Doctor of Environmental Science, UGM, Indonesia

²Forestry Faculty, UGM, Indonesia

³Agricultural Faculty, UGM, Indonesia

*Corresponding author

Willem Amu Blegur and Erny Poedjirahajoe, Doctor of Environmental Science, UGM, Indonesia and Forestry Faculty, UGM, Indonesia.

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ABSTRACT

Big Islands provide more sites for flora and fauna to live on them, and vice versa. Actually, Nusa Tenggara is an archipelago that contains some big islands and so many small islands. Naturally, biodiversity will be impacted as a result of abiotic factors on small islands that lack habitat sites. Similar to the mangrove ecosystem, research in these areas had to be inferred. Mangrove is one important ecosystem laid in the coastal area of Nusa Tenggara with ecological and economic values. Investigation about interaction and correlation among abiotic components that influence biotic ones, such as mangrove vegetation and others, just like crabs, fish, shrimps, birds, and so on. We collected the data as primer data in Nusa Tenggara coastal areas and analyzed it, combining it with secondary data and using land use changes after some periods of intensive anthropogenic activity to estimate the pressure inside the mangrove ecosystem and how to deal with mangrove conservation in some islands connected to human activities surrounding them.

Keywords: East Nusa Tenggara, Mangrove Conservation, Potential Usage

Introduction

Mangroves are one of the habitats found along the coast. The mangrove ecosystem's sustainability is controlled by interaction between abiotic and biotic components such as salinity, fresh or tidal water, and mud thickness [1]. The interactions between these components are classified as ecological components. This interaction potential is facilitated by the presence of mangrove species, which results in mangrove zoning. Mangrove zonation is defined by the presence and abundance of distinct species in each zone, such as *Avicennia* sp. and *Sonneratia* sp., in the front zone, *Rhizophora* sp., in the middle zone and *Bruguiera* sp., and *Ceriops* sp., in the back zone [2,3]. In addition to complete zoning, there is an associate zone with *Nypah* sp at the back.

Every ecosystem on Earth has distinct traits that support its role or function both inside the ecosystem and in connection to its

surroundings. Naturally, the mangrove ecosystem serves as a protector of coastline and /or river estuaries. This reinforced by the presence of a powerful mangrove root system, which include support roots, pencil roots, and buttress roots. Mangrove mud and root systems also help to filter water on land before it enters the sea. Mangrove development in the roots, stems, branches, and leaves serves as a carbon storage or sink [4,5]. The mangrove environment is supposed to play an ecological purpose, as previously mentioned.

Aside from that, mangrove ecosystems have some economic values. This economic element is related with human presence, activity, and population. Human expansion has also begun to impact with the mangrove ecology. People can take and sell mangrove wood for construction and charcoal. In addition, mangrove fruit is utilized to make juice and chips [6]. We hope for a balance between ecological dan economic roles. Furthermore, there are other advances in mangrove ecosystems, including ecotourism, edu-tourism, and silvofishery.

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Mangroves are naturally distributed and abundant in the equatorial region which has two primary seasons, the rainy season and the dry season as well as the location having four seasons. The latest world map (GMW v4.0), developed by the Global Mangrove Watch, provides a sixfold improvement in spatial resolution, from 25 meters to 10 meters. It maps 147,256 km² of mangroves in 2020 [7]. Once again, the physical and chemical characteristics of this habitat will influence the distribution and abundance of species in the mangrove ecosystem [8]. This also occurs in the Province of East Nusa Tenggara.

East Nusa Tenggara is situated between 80-120 SL dan 1180-1250 EL. The climate in East Nusa Tenggara Province is primarily tropical and dry. Aside from that, karst landforms cover much of the region, and numerous islands contain active volcanoes. There are rivers on some Big Island, including Timor Island, Flores Island, Sumba Island, Alor Island, and Lembata Island, however these rivers are influenced by karst, so the run beneath the ground surface, influencing water supply even more. Beside from that, the Province of East Nusa Tenggara contains a large number of Small Islands. At some spots, the river flow appears as spring on the surface and flows from the upstream to downstream portions of the river.

The river's downstream portion on the coast supports the mangrove ecology. As previously said, the distribution and abundance of mangroves are regulated by the availability of fresh water, specifically rivers that interact with seawater [9,10]. Several little springs along the shore provide fresh water to the mangrove ecology. Several major islands have rivers, whereas many small islands do not. However, there are a few small islands with dug wells.

The Big Island has more habitats for organisms while the Small Islands has fewer ecosystems [11]. The number of habitats on the Big Island is more diverse, as are the species and individuals in the mangrove ecosystem. On Small Islands, the mangrove environment has fewer species and individuals. However, mangrove species' ability to resist abiotic conditions can mitigate this characteristic, especially when there is interference from human activity.

Material and Methods

We collected data while doing research in Flores Island and Timor Island, located in East Nusa Tenggara Province. Plot sampling implemented in 20 x 20 m width for at least 12 plots. Meta data analyze from similar studied dan discussed about mangrove in East Nusa Tenggara Province. Species identification using Handbook of Mangrove in the Philippines-Panay and based on experienced and also local knowledge.

Results and Discussion

Mangrove Zonation

Mangrove zoning can be defined as small habitats for specific types of mangroves. Each variety is tolerant to physical and chemical elements found in the habitat, such as salinity, pH substrate, and the decomposition process by microbacterium in mangrove ecosystem.

The mangrove ecosystem is divided into three primary zones depending on waterlogging or salinity differences: the front

zone, middle zone, and back zone, with an extra zone called the mangrove association zone [12]. The coastal or proximal zone, namely the mangrove zone at the front that meets sea water, is approximately 10-75 meters broad and is commonly seen in *Avicennia marina*, *Sonneratia alba*, *Rhizophora stylosa* and *Rhizophora mucronata*. Mud was found in the middle zone, specifically the mangrove zone between the front and back zones, as well as *A. officinalis*, *S. caseolaris*, *R. apiculata*, *Bruguiera cylindrica*, *B. gymnorrhiza*, *B. parviflora*, *B. sexangular*, *Ceriops tagal*, *Aegiceras corniculatum*, and *Lumnitzera littorea*. The back or distal zone, namely the mangrove that borders the land area, is usually found the mangrove type such as *Heritiera littoralis*, *Xylocarpus granatum*, *Excoecaria agalocha*, with some associates mangrove for example *Achantus ebracteatus*, *A. ilicifolius*, *Acrostichum aureum*, *A. speciosum*, *Nypah fruticans*, *Derris trifolia*, *Osbornea octodonda*, *Barringtonia asiatica*, *Cerbera manghas*, *Hibiscus tiliaceus*, *Ipomea pes-caprae*, *Melastoma candidum*, *Pandanus tectorius*, *Pongamia pinnata*, *Scaevola taccada* and *Thespesia populnea*.

Furthermore, mangrove zones, which relate to the primary type of vegetation that develops from the water to the land, can be separated into four categories: *Avicennia*, *Rhizophora*, *Bruguiera*, and *Nypah* [12,13]. The *Avicennia* zone is the outermost zone, facing the sea, with highly salinity, sandy and coral substrate, and pencil shape roots. The *Rhizophora* zone follows the *Avicennia* zone and feature grassy substrate, low to high salinity, tides that occur in turns, and supporting roots. The *Bruguiera* zone is located behind, with a muddy and wet substrate, low salinity and a buttress root system. The *Nypah* zone is a transition zone, often known as an ecotone, between mangrove and land vegetation.

In the East Nusa Tenggara region, mangrove ecosystems have an incomplete zone. Typically, only the front and middle zones are formed, but in some areas, there are enough middle and back zones to be found. On the other hand, on coasts that experience relatively high waves, only the back and association zones are found. The zoning that occurs is not complete, and the number of mangrove species that exist or inhabit the zone is small.

The combination of abiotic and biotic components that comprise mangrove zonation influences the number of species, as well as the small number of individuals. As previously stated, mangrove distribution and abundance are regulated by the presence of fresh water and salinity, tides, and the availability of substrate or mud. There is a scarcity of fresh water on several major and small islands in the East Nusa Tenggara region, so the supply of the fresh water to estuaries is limited. This will influence the reaction of the type of mangrove that grows, so that the distribution of mangroves on the beaches of these islands is not always even, but rather with growth gaps or growing separately. Again, this is due to extremely high salt pressure, which causes just certain species to develop while others do not. Another aspect is the presence of a moderately thick substrate or thick mud as a habitat [13] such as *Rhizophora* spp. Because of the relatively large waves hitting the shore, as well as the lack of water flow that conveys mud and settles on the coast, this section of the coast will be mud-poor. Of course, this will limit the varieties that can live. *Rhizophora* sp., requires enough mud to grasp with the help of the supporting roots; nevertheless, if the existing mud

is thin, *Rhizophora* sp., *Bruguiera* sp., and other forms of mud-requiring plants will emerge.

Mangrove Species Identification

The number of mangrove kinds is used to calculate the number of mangrove species found and living in the mangrove ecosystem. This differs from the individual count, which refers to the total number of individuals that grow and develop in a given species of mangrove. Both differ in mangrove type such as *Avicennia* sp., *Sonneratia* sp., *Rhizophora* sp., *Bruguiera* sp., *Ceriops*., *Aegiceras* sp., *Lumnitzera* sp., and the number of individuals is proportional to the number of individuals growing in that type group [14-16].

Ideal environments for a mangrove ecosystem are those in which the comparatively large number of species corresponds to the relatively high number of inhabitants. This will increase the likelihood of offspring rotation of reproduction. If a growth form is discovered, many seedlings are predicted to survive and develop into stakes and poles, eventually becoming mangrove trees [17,18]. Once the mangrove reproductive system matures

in the tree’s growth form, it will continue to produce offspring, beginning with flowers and fruit. When the fruit ripens, it forms a propagule that can be grown into a new mangrove seedling. The next step is a rotation of mangrove offspring.

This optimal state is undoubtedly influenced by the interactions between abiotic and biotic components in the mangrove ecosystem. Assuming that the abiotic and biotic circumstances are optimal for mangrove growth and development, the number of varieties and individual numbers of mangrove will be maintained of increased. In truth, as previously stated, the abiotic and biotic components of mangrove do not necessarily promote the growth and development of the species. The Atambua coastal area contains only three varieties of mangroves: *Avicennia* sp., *Rhizophora apiculata* dan *Sonneratia alba* [19]. The Atambua coast has three observation stations: Motaain Beach, Pasir Putih Beach and Kolam Susuk Beach. Atambua coast is one of the coastal on one of the Big Island, namely Timor Island. Despite their relatively high individual counts, these three beaches had very few individuals counts (Table 1).

Table 1: Species and Individuals Mangrove in Atambua Coast

| No | GF | Scientific Name | Local Name | Family | Individuals Count | | |
|----------|---------|---------------------|----------------|----------------|-------------------|-----|------|
| | | | | | S1 | SII | SIII |
| 1 | Trees | <i>Avicennia sp</i> | Bakat | Acanthaceae | 0 | 0 | 8 |
| 2 | Trees | <i>R. apiculata</i> | Lima Naru | Rhizophoraceae | 22 | 43 | 32 |
| 3 | Trees | <i>S. alba</i> | Bakat Ua Boruk | Sonneratiaceae | 52 | 63 | 28 |
| 4 | Pole | <i>Avicennia sp</i> | Bakat | Acanthaceae | 0 | 0 | 6 |
| 5 | Pole | <i>R. apiculata</i> | Lima Naru | Rhizophoraceae | 28 | 31 | 42 |
| 6 | Pole | <i>S. alba</i> | Bakat Ua Boruk | Sonneratiaceae | 10 | 21 | 17 |
| 7 | Sapling | <i>Avicennia sp</i> | Bakat | Acanthaceae | 0 | 0 | 2 |
| 8 | Sapling | <i>R. apiculata</i> | Lima Naru | Rhizophoraceae | 8 | 10 | 24 |
| 9 | Sapling | <i>S. alba</i> | Bakat Ua Boruk | Sonneratiaceae | 5 | 10 | 14 |
| Subtotal | | | | | 125 | 178 | 173 |
| Totally | | | | | 476 | | |

Keterangan: S1= Motaain, SII= Pasir Putih, SIII= Kolam Susuk, GF= Growth Form (Source: primary data 2021 with permission Blegur, et al., 2021)

The same phenomenon was seen on the coast of Flores Island (one of the Big Island) as well as on the Small Island, Ontoloe Island. Research conducted to identify mangrove varieties on Flores Island and Ontole Island, specifically in the Wolo Tado Nature Reserve, Riung Nature Reserve, and Riung Island 17 Nature Tourism Park, discovered that the number of individual counts was likewise low [13,20]. The types found are shown in Figure 1.

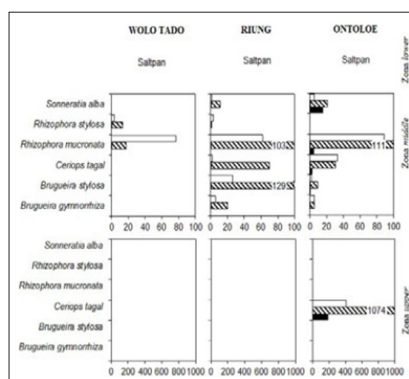


Figure 1: Number of Species and Individuals in Wolo Tado NR, Riung NR and Ontoloe. Saltpan is flat area of salt after sunheat, formed naturally (Source, Primary Data, 2017 with Permitted by Blegur et al., 2017)

Mangrove Ecosystem Advantages

The mangrove ecosystem is important to life on Earth. The mangrove ecosystem serves three main functions: structural, ecological, and economical, respectively. Each of these advantages should ideally be interconnected and complement one another. This indicates that one benefit will reinforce or be influenced by another.

Structurally mangrove ecosystem plays some important benefits or role just like in reducing coastal abrasion and erosion, as well as suppressing or mitigating the flow of tidal floods and sea waves. When the tsunami struck Aceh in 2004, it was revealed that mangrove ecology along the shore had been damaged or degraded [21]. As a result, when a tsunami strikes, the tsunami waves wreak devastation.

Ecological benefits and roles include the mangrove ecosystem's ability to store carbon in its roots, stems, and leaves. Carbon in the atmosphere is then absorbed and transformed by plants, including mangrove species, allowing them to grow and thrive. This causes carbon in the air to be stored, lowering carbon levels in the atmosphere, perhaps [22,23]. The mangrove environment also helps to maintain the hydrological cycle and purify water. The regular water cycle or process begins with evaporation (water on the surface and in plant parts), followed by the formation of clouds, dropping as rain, being absorbed into the soil, and generating water flows below the ground surface. This regular cycle continues on a constant basis and contributes to the mangrove ecosystem's resilience. The vegetation in the mangrove ecosystem affects both water evaporation and rainfall. Furthermore, rainwater enters and circulates through the mangrove environment. If rainwater flows contain pollutants (coastal and sea water), the mangrove ecosystem can absorb and even eliminate the pollutants before they enter the seawater flow. The existence of microorganisms capable of eating pollutants contributes significantly to the interaction of mangrove abiotic and biotic components. Floods occur when massive amounts of water flow. Flood flow can be eliminated to a specific quantity so that it does not create disturbance or reduce the possibility for damage to a greater extent [24]. Some bacteria have capabilities to faster decomposition processing in mangrove ecosystem [25].

The mangrove ecosystem on the coast of East Nusa Tenggara, with its variety of species and individuals counts in many locations, plays an ecological role that requires attention. The mangrove environment along the coast of Atambua and Malaka is influenced by river water from the Benenain River Basin, which transports water and muck, generating mud deposits that maintain the mangrove habitat. However, huge river flows have resulted in coastal flooding. Moreover, if sea levels rise during the rainy season, tidal flooding will occur along Malaka's coastline. Human intervention has made some of these areas marginally worse, such as the construction of fish pond, shrimp ponds, and salt ponds. Of course, more research is needed to ensure that anthropogenic activity is not a potential problem that really harms the ecosystem, but rather that it is controlled in such a way that it continues to benefit the environment.

The economic usage of an ecosystem has both direct and indirect value, including mangrove ecosystems [26]. Direct value or

use refers to the value that can be directly obtained from the ecosystem, such as taking wood for firewood, picking fruit for eating, and collecting various fishery products such as fish, shrimp, and crabs. Indirect value or use refers to value that can be received indirectly, such as a sense of beauty and aesthetics resulting from the presence of beauty trees and animals in the mangrove ecosystem such as indigenous and migratory birds. It can also be utilized to assist the carbon, hydrological, and nutrient cycles. The mangrove ecosystem's expanded purpose includes both edu-tourism and ecotourism. They are undertaken to explore more parts of the mangrove in order to gain additional benefits while still ensuring the mangrove's long-term viability [27,28]. Nowadays, tourism provides less benefit and has a detrimental influence on our environment, such as trash, waste water, and air pollution. After visiting the gorgeous spot, people appear a terrible attitude by bringing waste in the wrong location. Visitation has occasionally caused harm to the tourism sector due to trampled and destroyed sites. Next, silvofishery is used to maintain coastal areas in harmony with the environment, such as fish ponds, shrimp ponds, and salt ponds. Humans who developed them must ensure that their ponds not only produce revenues but also preserve ecological or environmental sustainability without causing devastation [29,30].

At present, the mangrove environment on the East Nusa Tenggara coast provides immediate benefits such as the collection of wood, fish, shrimp, and crabs. Indirect uses include supporting the ecological role in the hydrological and carbon cycles. It has recently been converted into a tourist destination and research domain. The concepts of tourism and research are then extended to include ecotourism and edu-tourism. There are places that are attempting to grow into ecotourism and edu-tourism destinations, such as the Oesapa mangrove region in Kupang City. Nevertheless, further management is required. There are various locations that have the potential to become ecotourism and edu-tourism destinations, thus a more in-depth study including all stakeholders in the region is required, as well as compliance with applicable regional and national regulations. In the mangrove environment, fish ponds, shrimp ponds, and salt ponds all work together, although some farmers in East Nusa Tenggara are still unaware of this. The community lacks knowledge, but if there is a manufacturing, it must conduct environmental assessments before launching the factory.

Mangrove Ecosystem Sustainability Challenges

The mangrove ecosystem is expected to be used in a sustainable manner that aligns with sustainable development goals. This means that the mangrove environment provides benefits that can be used today and in the future. Future generations will continue to profit from structural, ecological, and economic advantages. Of course, this will not occur by itself.

The benefits of a sustainable mangrove environment necessitate a thorough investigation involving the community, government, academics, capital owner, and other parties who are not immediately touched by mangrove ecosystem management. This involvement must be carried out by putting aside each party's sectoral egos. Then, this engagement is not just sectoral, but also holistic participation [<https://youtu.be/49UHBYA2W10>].

Each of the parties mentioned above has their own capacities. This capacity may be related to the commitments held, as well as the rights or rewards that can be received by fulfilling the obligations. The community, government, academics, and capital owners are all responsible for maintaining the mangrove ecology. Although the levels might vary, examples include government restrictions that must be followed by the government, society, academics, and capital owners. We can discuss more about how obedience is. Yet, the parties generally obey. On the other hand, these parties have rights in the form of advantages, such as the ability to preserve the structural, ecological, and economic functions of the mangrove ecosystem if they follow the regulation. The mangrove ecology in this site has not declined or been destroyed, but rather increased in individuals and species within each zone.

The mangrove ecology along the coast of East Nusa Tenggara is likewise facing challenges that should not be underestimated. The fact that the species and individual counts are lower than those in other ecosystems in the island of Kalimantan, Sumatra, Sulawesi, and Papua is evident. However, the challenges of sustainable management are comparable. If the community, government, academics, and capital owners fail to interact and synergize, the mangrove environment in East Nusa Tenggara would suffer. Returning to the example, the location of the mangrove tourism area in Oesapa. Existing species and individual counts are still limited. The zero is also incomplete. As a result, if you ignore anthropogenic influences such as the presence of tourist while failing to maintain the environment, such as not discarding trash in the proper location the Oesapa mangrove ecosystem would drop. The desire to pay, also known as willingness to pay (WTP), requires more research.

Conclusion

Mangrove coverage is a distinctive ecosystem including in East Nusa Tenggara Province. There are less individuals and species founded in some islands even though Big Island (Timor Island and Flores Island) or Small Island (Ontoloe Island) including Acanthaceae (*Avicennia* sp), Sonneratiaceae (*Sonneratia alba*), Rhizophoraceae (*Rhizophora apiculata*, *Rhizophora mucronata*, *Rhizophora stylosa*, *Bruguiera gymnorrhiza*, *Bruguiera stylosa*, and *Ceriops tagal*). The distribution and abundance could be leveraged to provide structural, ecological, and potential economic advantages such as ecotourism and edutourism. To investigate the benefit we must invite to engage the community, government, academics, capital owners and other stakeholders affected and influenced by the sustainability of mangrove environment in East Nusa Tenggara.

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Conflict of Interest

The authors declare no conflict of interest.

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