Identifications of the Vulnerability Degradation of Mangrove Forest (Case Study: North Minahasa Regency, North Sulawesi Province)

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Abstract. Mangrove degradation has become a world concern in the last few years. More than half of the mangrove area in Indonesia have been converted. Due to its reason, there should be some efforts to estimate the vulnerability of mangrove forest degradation thus, the conservation and rehabilitation program will be able to run effectively and efficiently. These efforts start with collecting mangrove vegetation including; vegetation analysis (mangrove's vegetation structure and composition), level of degradation hazard analysis, and environmental parameters. This research aims to estimate the level of vulnerability of mangrove degradation in North Minahasa Regency, North Sulawesi. Obtained data can be used as the basis for policy making, monitoring changes in environmental condition, and preservation of mangrove ecosystem in Indonesia. The vegetation data collection was done by using purposive sampling and plot sampling methods in each transect. Stratified random sampling was used to collect samples. The level of degradation hazard was measured using the parameter scoring of mangrove forest vegetation existence (high, medium, low). There are 10 types of mangroves found in transects. The results show that mangroves in the research area has moderate to high degradation susceptibility based on density. The highest mangrove density only reach 1167 ind/ha and the level of diversity and uniformity are classified as low category. The most dominant type is Rhizphora apiculata. The mangrove rehabilitation process that needs to be carried out is conservation. Based on the suitability to the physical conditions and the environment, the suitable mangroves for replantation to avoid degradation are *Rhizopora sp.* and *Avicennia sp.*

Keywords: Conservation, Degradation, Density, Mangrove.

1 Introduction

The increase of human population in an area implies to the addition and variety of needs. However, the increase in these needs often has an impact on the excessive exploitation of natural resources, including the exploitation of forests. Excessive exploitation of forests leads to forest degradation that will cause damage to the ecosystem. It is accordance with statement [1] that forest degradation is the main cause of forest resources destruction in Indonesia. Forest area in Indonesia reaches 134 million hectares or around 60 percent of the total area of Indonesia [2], but however deforestation and forest degradation have caused declining of forest cover.

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Forest degradation interpretes as the missing of certain forest attributes.[3] Defines forest degradation as the reduction of forest capacity to provide goods and services, such as biomass, carbon absorption, water regulation, soil protection, and biodiversity conservation.

Mangroves are consist of trees and shrubs which is live in shore and resistant to salt. Similar to forest, mangrove has various kinds of plants [4]. Mangrove forest is a tropical coastal vegetation community, dominating by several species of mangrove trees that are able to grow and thrive in tidal muddy beach areas [5].

Mangrove forest ecosystem is type of ecosystem that is fragile (easily damged) because it is very sensitive to environmental changes. This ecosystem is open access thus, it is easily exploited by human [6].

Mangrove forest ecosystem in Indonesia currently is in critical situation because of the destruction around 68% or 5,9 million hectares from areas of 8,6 million hectares. It is need to conduct various efforts to fix that condition, one of these is through conservation. Thus, the function of mangroves in protecting the land from scours of waves and places of living and breeding of marine animals, as well as natural tourism areas, can be conducted properly [7] [8]. The causes of mangrove forest degradation Indonesia are fishing, plantation, agriculture, logging, industry, settlement, salt ponds and mining activities [9].

North Minahasa Regency is regency that has the biggest area of mangrove in North Sulawesi Province. The finding of forest damage in the location of study shows that the conservation program has not yet been conducted or has not run well. Research locations including; Munte Village, Kalinaun Village, WoriVillage, Lantung Village, and Waleo Village with assumption has the biggest mangrove areas and different ecosystem condition. The conservation efforts start from structure inventory and mangrove composition. The inventory data is obtained by mangrove ecosystem analysis. The result of vegetation analysis also illustrates the vulnerability level of mangrove in every research location.

2 Research Methods

Mangrove vegetation analysis data are mangrove structure and composition in North Minahasa Regency, North Sulawesi Province used secondary data that are the results from previous research by [10] and the vulnerability level of forest degradation from process using mangrove degradation level is based on scoring criteria (high, medium, low).

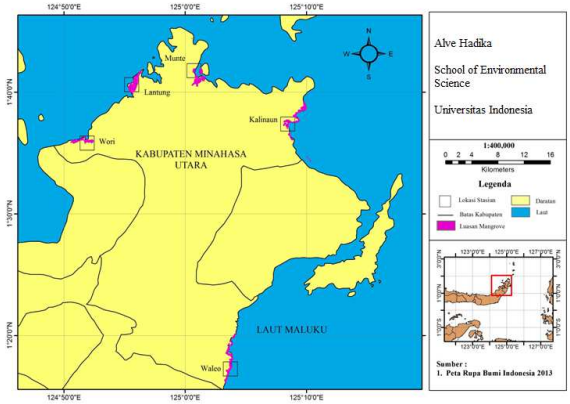


Fig. 1. Map Research Location.

The research location in Minahasa Regency consists of 5 (five) villages, these are Munte Village, Kalinaun Village, Wori Village, Lantung Village and Waleo Village. The tools used were including GPS, transect ropes, digital cameras, litmus paper, calipers, ziplock plastic, roll meters, refractometers, stationery, and fabric meters.

2.1 Mangrove Structure and Composition

The structure of mangrove vegetation composition and samples [11] was determined by sampling plots method (method of sample sampling). The samples were taken by stratified random sampling, by dividing the population or sample into certain groups (strata). The plot and sublot positions determination were conducted randomly where this has been agreed previously.

The parameters for tree category and sampling include species, trunk diameter and tree height. Seedling categories include species, number and percentage of cover. Other parameters are; general conditions of trees and environmental conditions (pH, salinity, and water temperature). The method used in determining the location of the purposive sampling method, where in each locations three repetitions are conducted. The stretched transect measured 10 m x 10 m for the tree category, 5 m x 5 m for the sapling or sapling category and a 1 m x 1 m plot for seedlings [12].

The samples of seedlings are mangrove vegetation with height <1 m in the subplot 1 m x 1 m [12]. The data will be taken in the form of species, the number of individuals and the cover percentage to the subplot 1 m x 1 m. The analyzed vegetation data refers to [11], including:

2.1.1 Density (K)

Density is the number of individuals in each unit in region/area [11]. The density value unit is ind/ha, which is obtained using the formula below:

$$\text{Density} = \frac{\text{Number of ind. of species in the whole plot}}{\text{Plot Area}}$$

2.1.2 Basal Area (BA)

Basal area is mangrove forest area covered by a tree trunk obtained from the measurement of the diameter of the trunk. The stem diameter of each species converted into a basal area using the formula below:

$$BA = \frac{\pi D^2}{4}\ cm^2$$

Whereby:
- BA = Basal Area
- π = 3.14
- D = Diameter of trunk

2.1.3 Importance Value Index (INP)

Importance value is to find how many species value domination in the mangrove area. This is obtained by adding the relative density and relative dominance values [13].

$$INP = KR + DR$$

Whereby: NP = Importance Value
KR= Relative Density
DR= Relative Dominance

2.1.4 Diversity Index (H')

Diversity index is community diversity that describes the level of species diversity of organisms included in the community [14] The diversity index value refers to Shannon-Wienner [14] with formula:

$$H' = logN - \frac{1}{N}\sum nilog\, ni$$

Whereby: H' = Shannon-Wienner Diversity Index
Ni = Number of individuals per i-th
N = Total number of species

The value of H '<2,303 means that the diversity is low, value of H' 2,303-6,908 means moderate level of diversity, and value of H '> 6,908 means high levels of diversity.

2.1.5 Uniformity Index (J')

Species Uniformity Index is a comparison between the diversity values with Ln (natural logarithm) to the number of species [15]. The Uniformity Index formula is:

$$J' = \frac{H'}{LnS}$$

Whereby: J = Uniformity Index
H'= Shannon-Wienner Diversity Index
S = Number of species

According to [16] the Uniformity Index ranges from 0-1,

Whereby: 0.6 – 1 : High species uniformity
0.4 <J '<0.6 : Medium species uniformity
- 0.4 : Low species uniformity

2.2 Analysis of Degradation Vulnerability Level

Mangrove forest degradation vulnerability level is reviewed by assessing the mangrove degradation level based on scoring (high, medium,low). More detailed explanation is listed in Table 1.

Table 1. Description : R1 = prone 1 (low); R2 = prone 2 (medium); R3 = prone 3 (high)

No.	Parameter	Level of Degradation Vulnerability		
	Vegetation Characteristics	R1	R2	R3
1.	Density			

	Tree Category	>1500	750-2500	<750
	Sapling Category	>2500	750-2500	<750
	Seedling Category	>5000	1000-5000	<1000

Source: Kaunang and Kimbal (2009) (with modification) in Aini (2015).

2.3 Enviromental Parameters

Major component is a species that is easy to adapt in mud condition or muddy sand, this substrate condition is in accordance with condition in research location. [17] states that family Avicenniaceae, Rhizophoraceae and other major species that can grow in any types of substrat. [18] added the species *R. apiculata*, *R. sylosa*, and *R. mucronata* is spread over some islands in Indonesia. More detailed explanation is in Table. 2.

Tabel 2. Environmental Parameters

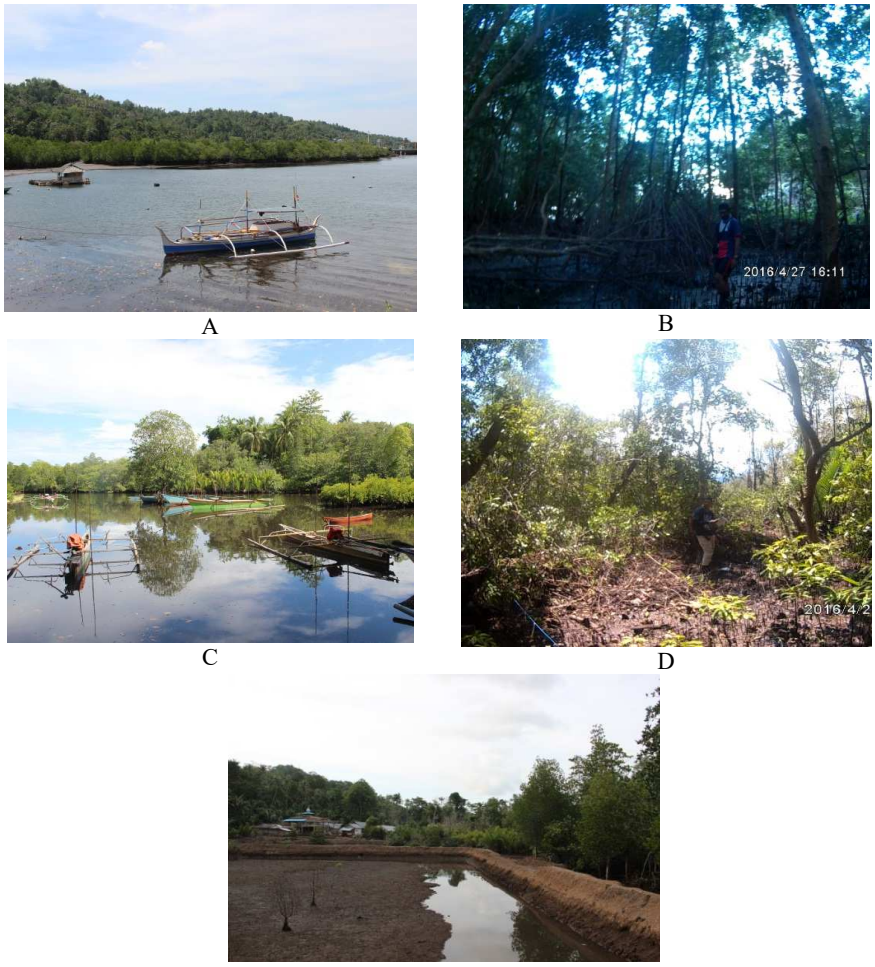
No.	Species	Salinity (ppm)	Water pH	Substrate	Air Temperature (°C)
1	*Avicennia alba*	10-30	6-9	Coral, sandy, sandy loam, dusty, dusty clay	20-28
2	*Avicennia officinnalis*	10-30	6-9	Coral, sandy, sandy loam, dusty, dusty clay	20-28
3	*Rhizophora apiculata*	10-30	6-9	Coral, sandy, sandy loam, dusty clay	20-28
4	*Rhizophora mucronata*	10-30	6-9	Sandy, dusty, dusty clay	20-28
5	*Rhizophora stylosa*	10-30	6-9	Coral, sandy, sandy loam, dusty clay	20-28

Source: Kusmana *et al*. Manual Silvikultur Mangrove in Indonesia (The Rehabilitation Mangrove Forest and Coastal Area damaged by Tsunami in Aceh) Jakarta. 2008.

3 Results and Discussion

3.1 Result

The research location represent any conditions and mangrove habitats. Munte Village is directly facing the sea, is an area which becomes port, so that the mangrove found is really influenced by high tide, while Wori Village and Kalinaun Village are villages which are close to residential settlements where mangrove is not directly facing the sea but facing the road, so that these are not directly exposed by high tides. In line with Lantung village where the location selection point is conducted close to the river, and Waleo village in swamp forest area (Figure 2).



A B C D E

Fig. 2. Research Location (A) Mangrove Ecosystem of Munte Village; (B) Mangrove Ecosystem of Waleo Village; (C) Mangrove Ecosystem of Kalinaun Village; (D) Mangrove Ecosystem of Lantung Village; (E) Mangrove Ecosystem of Wori Village.

The research location is between 1° 17' 15.42" LS - 1° 41' 46.56" LS and 124° 51' 54.69" BT - 125° 8' 26.99" BT. Mangrove ecosystem condition in North Minahasa Regency is suspected as natural mangrove, seen from the high of mangrove density and tree sizes which are relatively high (10 – 30m). The water temperature is around 28°C - 32°C and the varying salinity values is around 28 ppt – 35 ppt in the area which is close to the sea and 10 ppt in brackish area, with pH 7-8.

Table 3. Distribution of Mangrove Species by Category at Each Location

No.	Category	Family	Species	Munte	Kalinaun	Wori	Lantung	Waleo
1	Tree	Avicenniaceae	*Avicennia marina*	-	-	+	-	-
		Avicenniaceae	*A. officinalis*	-	-	-	+	-
		Rhizophoraceae	*Bruguiera parviflora*	-	-	+	+	+
		Rhizophoraceae	*B. cylindrica*	-	-	+	-	-

		Rhizophoraceae	*B. gymnorrhiza*	+	-	-	+	-
		Rhizophoraceae	*Ceriops tagal*	-	+	-	-	-
		Rhizophoraceae	*Rhizophora apiculata*	+	+	-	+	+
		Rhizophoraceae	*R. mucronata*	-	-	-	-	+
		Sonneratiaceae	*Sonneratia alba*	-	-	-	-	+
		Sonneratiaceae	*S. ovata*	+	-	+	+	+
2	Sapling	Avicenniaceae	*Avicennia marina*	-	-	+	-	-
		Avicenniaceae	*A. officinalis*	-	-	-	+	-
		Rhizophoraceae	*Bruguiera parviflora*	-	-	-	+	+
		Rhizophoraceae	*B. gymnorrhiza*	-	+	+	+	-
		Rhizophoraceae	*Ceriops tagal*	-	+	+	-	-
		Rhizophoraceae	*Rhizophora apiculata*	+	+	-	+	-
		Rhizophoraceae	*R. mucronata*	-	-	-	-	+
		Sonneratiaceae	*Sonneratia ovata*	+	-	+	-	-
3	Seedling	Avicenniaceae	*Avicennia marina*	-	-	+	-	-
		Avicenniaceae	*A. officinalis*	-	-	-	+	-
		Rhizophoraceae	*Bruguiera gymnorrhiza*	-	+	-	-	-
		Rhizophoraceae	*B. parviflora*	-	-	-	-	+
		Rhizophoraceae	*B. cylindrica*	-	-	+	-	-
		Rhizophoraceae	*Ceriops tagal*	-	+	-	-	-
		Rhizophoraceae	*Rhizophora apiculata*	+	-	-	+	-
		Rhizophoraceae	*R. mucronata*	-	-	-	-	+
		Sonneratiaceae	*Sonneratia ovata*	-	-	+	-	-
4	Others	Palmae	*Nypa fruticans*	-	-	-	+	-
			Total species	**3**	**3**	**6**	**6**	**5**

3.1.1 Structure and Composition of Mangrove Vegetation

From the research conducted in the North Minahasa Regency, it is found that there are 10 species of mangroves and 4 families of mangroves in the transects. The complete data are explained in the following table. The mangrove are found in 5 locations (villages) which are divided into 4 categories, these are trees, saplings,seedlings,and etc. All categories are found in 3 families (Table 3).

Overall, the results of research on the structure of mangrove vegetation indicate that the location is mostly dominated by *Rhizophora apiculata* and *Avicennia marina.* This is indicated by the tendency of the high importance value index (INP) of each species in each location and its dominance in all growth categories.

Table 4. Vegetation Structure Results for Each Tree Category Species

Location/Species	K (ind/ha)	BA (m^2/ha)	KR (%)	DR (%)	INP (%)
Munte Village					
Rhizopora apiculata	900	0,47	77,1	49,0	126,1
Sonneratia ovata	200	0,42	17,1	43,8	60,9
Bruguiera gymnorrizha	67	0,07	5,7	7,3	13,0
Total	1167	0,96	100	100	200
Kalinaun Village					
Rhizopora apiculata	767	0,03	92	9,4	101,4
Ceriops tagal	67	0,29	8	90,6	98,6
Total	833	0,32	100	100	200
Wori Village					

Avicennia marina	333	0,96	62,5	61,9	124,4
Sonneratia ovata	67	0,53	12,5	34,2	46,7
Bruguiera parviflora	100	0,05	18,75	3,2	22,0
Bruguiera cylindrica	33	0,01	6,25	0,6	6,9
Total	533	1,55	100	100	200
Lantung Village					
Rhizophora apiculata	367	0,14	45,8	29,2	75
Avicennia officinalis	133	0,16	16,7	33,3	50
Sonneratia ovata	133	0,06	16,7	12,5	29,2
Bruguiera parviflora	100	0,07	12,5	14,6	27,1
Bruguiera gymnorrizha	67	0,05	8,3	10,4	18,8
Total	800	0,48	100	100	200
Waleo Village					
Sonneratia ovata	567	0,82	65,38	74,5	139,9
Sonneratia alba	100	0,10	11,54	9,1	20,6
Rhizophora apiculata	100	0,06	11,54	5,5	17,0
Rhizophora mucronata	67	0,08	7,69	7,3	15,0
Bruguiera parviflora	33	0,04	3,85	3,6	7,5
Total	867	1,1	100	100	200

The density value (K) for the tree categories are categorized as the highest density found in Munte Village, while the lowest density is located in Wori Village.

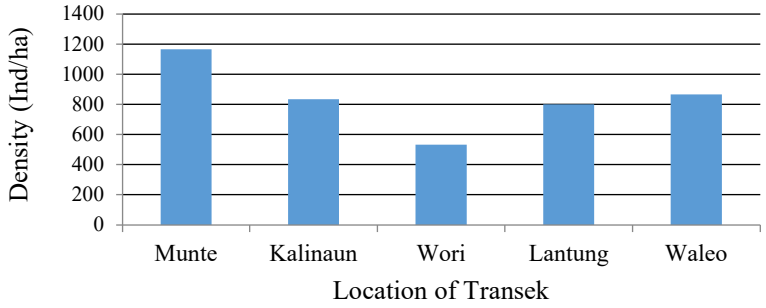


Fig. 3. Density Value of Each Tree Category Location.

The research location has low Diversity Index (H ') and Uniformity Index (J').

Table 5. Diversity Index (H ') and Uniformity Index (J') in the Tree Category

Location	H’	Category	J’	Category
Minahasa Utara Regency				
Munte	0,29	Low	0,041	Low
Kalinaun	0,12	Low	0,018	Low
Wori	0,45	Low	0,072	Low
Lantung	0,62	Low	0,092	Low
Kema	0,48	Low	0,071	Low

Each village has different dominant species in sampling categories i.e., *Rhizophora apiculata*, *Ceriops tagal, Bruguiera gymnorrizha,, Avicennia officinalis* and *Bruguiera parviflora.*

Table 6. Vegetation Structure Results for Each Sapling Category Species

Location/Species	K (ind/ha)	BA (cm^2)	KR (%)	DR (%)	INP (%)
Mante Village					
Rhizopora apiculata	2667	348,12	95,2	98,1	193,4
Sonneratia ovata	133	6,60	4,8	1,9	6,6
Total	2800	354,73	100	100	200
Kalinaun Village					
Rhizopora apiculata	1600	344,87	26,7	48,8	75,5
Ceriops tagal	3067	148,40	51,1	21,0	72,1
Bruguiera gymnorrizha	1333	213,32	22,2	30,2	52,4
Total	6000	706,59	100	100	200
Wori Village					
Bruguiera gymnorrizha	400	101,17	37,5	53,76	91,3
Ceriops tagal	133	48,99	12,5	26,04	38,5
Avicennia marina	267	24,15	25,0	12,84	37,8
Sonneratia ovata	267	13,86	25,0	7,36	32,4
Total	1067	188,17	100	100	200
Lantung Village					
Avicennia officinalis	1333	259,54	47,6	43,28	90,9
Rhizophora apiculata	1067	283,91	38,1	47,34	85,4
Bruguiera gymnorrizha	267	18,88	9,5	3,15	12,7
Bruguiera parviflora	133	37,37	4,8	6,23	11,0
Total	2800	599,71	100	100	200
Waleo Village					
Bruguiera parviflora	667	163,20	71,5	67,7	139,11
Rhizophora mucronata	267	77,93	28,6	32,3	60,9
Total	933	241,14	100	100	200

The Density value (K) for the sapling category with the highest density is found in Kalinaun Village, and the lowest density is in Waleo Village.

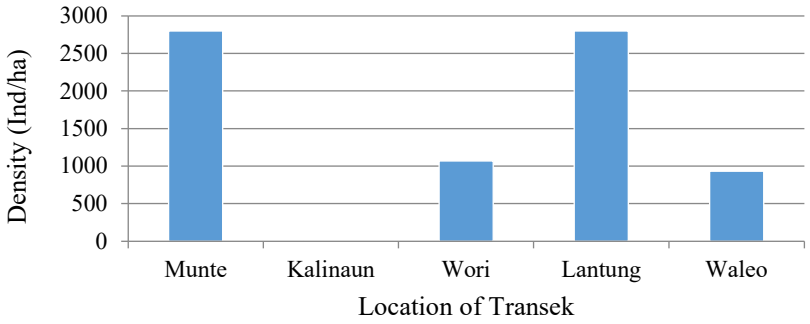


Fig 4. Density Value of Each Location of Seedling

Mangrove ecosystem for seedling category of North Minahasa Regency is shown in Table.7. Each research location is dominated by different species.

Table 7. Vegetation Structure Results for Each Seedling Category Species

Location/Species	K (ind/ha)	KR (%)	DR (%)	INP (%)
Mante Village				
Rhizopora apiculata	20000	100	100	200
Total	20000	100	100	200
Kalinaun Village				
Ceriops tagal	26667	50	60	110
Bruguiera gymnorrizha	26667	50	40	90
Total	53333	100	100	200
Wori Village				
Bruguiera cylindrica	120000	81,82	83,33	165,15
Avicennia marina	20000	13,63	11,12	24,74
Sonneratia ovata	6667	4,55	5,55	10,11
Total	146667	100	100	200
Lantung Village				
Rhizophora apiculata	3333	50	50	100
Avicennia officinalis	3333	50	50	100
Total	6667	100	100	200
Waleo Village				
Bruguiera parviflora	143333	97,73	94,44	192,18
Rhizophora mucronata	3333	2,27	5,56	7,82
Total	146667	100	100	200

The following is a comparison of Density Value (K) among locations:

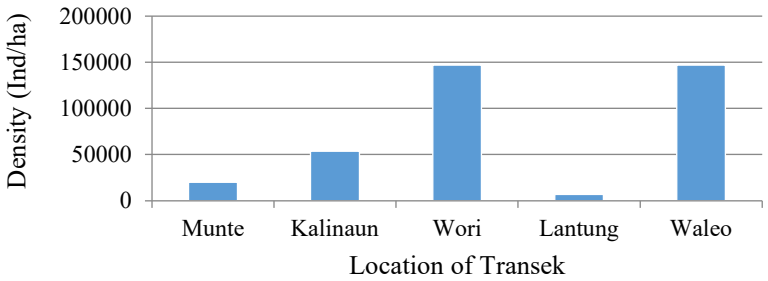


Fig. 5. Density Value of Each Location of Seedling Categories

3.1.2 Analysis of Forest Degradation Vulnerability Level and Environmental Parameters

In Table 8. It explains the tree category is in medium-high degradation vulnerability level. In Sapling category, the degradation vulnerability level is in medium-low category, and in Seedling category of all locations degradation vulnerability level is in low category.

Table 8. Forest Degradation Vulnerability Level

No.	Parameter	Degradation Vulnerability Level				
	Vegetation Characteristics	Munte	Kalinaun	Wori	Lantung	Waleo
1.	Density					
	Tree Category	R2	R2	R3	R2	R2
	*Sapling*Category	R1	R1	R2	R1	R2
	*Seedling*Category	R1	R1	R1	R1	R1

There are several ideal aspects for environmental parameters on the research location. pH found in each location obtained ideal results 7-8, but the salinity and temperature in several locations are not in ideal condition.

Table 9. Environmental Parameters

No.	Parameter	Unit	Location					Ideal
	Environmetal		Munte	Kalinaun	Wori	Lantung	Waleo	Condition
1.	Salinity	Ppt	35	30	35	28	10	10-30
	pH	-	7	8	8	7	8	6-9
	Temperature	^{0}C	28	28	32	29	30	20-28

3.2 Discussion

3.2.1 Structure and Composition of Mangrove Vegetation

Every village in research location has different mangrove species diversity. Lantung Village and Wori Village are villages with highest diversity, and the lowest diversity is in Kalinaun Village and Munte Village. Lantung Village has the highest diversity because of the natural condition of area in this location. This is consistent with the statement of [19] which states that human activity also influence the mangrove ecosystems condition in the location. These activities including development by opening mangrove area to be used as ponds, illegal logging and waste disposal into the river, either directly or undirectly can destruct the mangrove ecosystem life.

Overall in the research location is dominated by 3 species these are *Rhizophora apiculata, Avicennia marina*, and *Sonneratia ovata*. These three species are major components and species that are easy to adapt in mud condition or muddy sand, this substrate condition is in accordance with condition in the research location. This is in accordance with [17] statement that dependency on substrate types is clearly demonstrated by the Avicenniaceae family, Rhizophoraceae and other major species that have common characteristic of living on muddy or sandy substrates such as shallow muddy soils, sandy beaches or corals that have layers mud or sand. [18] Additional species *R. apiculata*, *R. sylosa*, and*R. mucronata* spread over in some islands in Indonesia, including in Sulawesi Island. Species *R. sylosa* is not found in the research location, it is suspected because there is no seed that drifting away. *R.mucronata* is only found in Waleo Village. *R.apiculata* is a species which dominates in the research location.

Substrate temperature found in the research location is around 28^{o}C – 32^{o}C, where this condition is temperature measurement which tolerated by various mangrove species, according to statement of Percival and Womersley (1975) in [20], species *Bruguiera* sp.*,* *Rhizophora* sp.*,* and *Ceriops* sp.*,* can live in temperature around 28^{o}C, it is not significantly

different with the field condition. Salinity found in the research location is categorized as high compared to brackish waters salinity in general, which is around 28 - 35 ppt,gthis is suspected in general that the research location is close to the sea. Ph factor, in the research location is around 7–8, where it is categorized as still can be tolerated for the growth of productive organisms, includes mangrove. Wardoyo (1975) *in* [21], water with pH less than 4 will cause the death of aquantic organisms, while the bigger pH that is more than 9,5 is not productive water.

The density value of tree category magrove species shows the density in each village is around 533 ind/ha – 1167 ind/ha with average density 873,4 ind/ha. This result is lower compared to the edge of the beaches in Balusu District [22] which have average density around 1027 ind/ha. This is because the species in data collection plot is dominated bythe teenage and adult mangroves which have big stem diamaters, which implies to big Relative Dominance (DR) value, Thus, it influence the mangrove density value. Basal Area Measurement of the mangrove stem is obtained based on the diameter of the stem, which will produce information about the mangrove stem cover in the location. Higher the diameter of the trunk, so the greater the Basal Area value and will reduce the density value of the mangrove thus, the dominant species are species that have a large tree diameter and or have a higher density than other species in location [22].

3.2.2 Analysis of Forest Degradation Vulnerability Level and Environmental Parameters

Condition of degradation level in mangrove areas of North Minahasa Regency according to Kaunang & Kimbal (2009) in [23] in this research is the density level of mangrove becomes the parameter of mangrove degradation vulnerability level.

Based on the result of degradation vulnerability level analysis, most of the vegetation characteristics, especially tree category. It shows the condition of medium-high degradation vulnerability level. The density level of vegetation which is low shows that the mangrove area needs mangrove conservation effort. This conservation can be conducted by rehabilitation and area protection [24]. Conservation with rehabilitation is conducted by mangrove plantation activities, while the area protection is conducted by determining areas to be protected forest, game preservation and ecotourism development areas.

Table 2 shows several types of mangrove with living environment conditions accordance for their growth. There are several types of mangrove use as magrove forest rehabilitation in the area. Based on compatibility on land conditions and its environment, type of *Rhizophora sp.*mangrove is compatible to be used in activities, river border, and area which is not directly affected by waves such as in Wori Village, Munte Village, Waleo Village, and Kalinaun Village. While the mangrove type *Avicennia sp* is compatible to be replanted in the shore area because it is resistant to high salinity like in Munte Village.

4 Conclusion

In North Minahasa Regency, North Sulawesi Province can be concluded that there are 10 types of mangroves in transects. Lantung village has the highest diversity and Munte has the highest density. In general, mangrove tree vegetation in North Minahasa Regency is dominated by *Rhizophora apiculata* with Importance Value Index (INP) around (17%-126%). Diversity Index Value (H') and Uniformity (J') tree category in North Minahasa Regency, is

includes in low category. While for the tree height is dominated by 5-10 m. The vegetation density is low shows that the mangrove area needs mangrove conservation. Mangroves that are compatible for replantation to avoid degradation are *Rhizopora sp.* and *Avicennia sp.*

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