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Land use, land cover and mangrove diversity in the Indonesian outermost small islands of Rote and nDana

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Abstract. In Indonesia which has thousands of islands, the inventory and evaluation of natural resources of islands, including in the outermost islands, should be done to provide accurate and up-to-date baseline data that can be accessed quickly to support the sustainable management of natural resources. The objective of this paper is to present part of the inventory results of natural resources on Rote and nDana islands in East Nusa Tenggara Province, Indonesia, especially regarding change in land use and land cover from 2000 to 2014 and the composition of the mangrove ecosystem at several points of measurement. Land use and land cover were interpreted from Landsat satellite imagery acquired in 2000 and 2014. Primary data of the mangrove were obtained through measurements during field surveys at four stations. The results of the research indicated that land use and land cover change in this outermost and remote island were generally static. Changes in land use and land cover appeared to be only slightly affected by the population which is still few in the area. Nevertheless, mangrove destruction has begun. Distribution in all mangrove strata (seedlings, saplings and trees) on Rote and nDana islands was not spread evenly and was different at each station observed. At stations where the substrate was sandy muds, *Rhizophora mucronata* was the dominant species. In the stations where the substrate was dominantly muddy, *Avicennia alba* and *Ceriops tagal* were dominant. On the nDana islands, the mangrove was found on a plateau of the island, with *Avicennia* spp. and *Heritiera* spp. which were the dominant species. This research describes the diversity of the mangrove in different locations at different strata. This description should become part of the database on the mangrove ecosystem in remote area.
Key Words: land use and land cover change, Landsat imagery, mangrove species, resource inventory, transect.

Introduction. Indonesia has 13,466 islands (GIA 2014; Widiatmaka et al 2015), making the country the largest archipelago in the world (AsianInfo.org 2015). In those islands, there are very diverse biotic and abiotic natural resources. Indonesian biodiversity can be listed in terms of flora and fauna as examples: the country has 515 species of mammals (12% of the world's mammals, first rank in the world), 511 species of reptiles (7.3% of the world's reptiles, third rank in the world), 1,531 species of birds (17% of the world's birds, fourth rank in the world), 270 species of amphibians (fifth rank in the world), 121 species of butterflies (first rank in the world), 2,837 species of invertebrates and 3,800 species of plants (Nandika 2005; Kusmana 2011). Although the land area of Indonesia is only 1.3% of the surface of the earth (Kusmana 2011), its biodiversity constitutes an important part of the world's biodiversity. However, not all of the natural resource diversity of these islands has been well-identified.

Among these thousands of islands, some are small and located in the outer part of the country, known as the outermost islands. Although they are small, they occupy strategic places due to their borders with neighbouring countries. As a border region, the natural resources of these islands need to be inventoried as part of the regional development of the border region. This development is essential to the welfare of people living on the concerned islands, as well as for national defence. The border region has the potential for natural resources, but has not been well managed (NABM 2014) because of the remote geographic positions of the islands. The resource potential can vary, which may include land resources, natural gas, oil, mineral materials, tropical timber, germplasm and aquatic resources. So far, this potential in Indonesia has received minimal attention (Raharjo 2012) and has not been well recorded.

Exploitation of natural resources on small islands needs to be preceded by an inventory in order to plan its use. Only after the potency of resources is known, can planning for their utilisation on a sustainable basis occur (WCED 1987). This is true for small islands because they have a limited resource capacity. Small islands tend to have limited space, restricted habitats, low species numbers, and high species endemism (Cushnahan 2001). This has been conceived jointly by various nations, as stated by the Global Conference on the Sustainable Development of Small Island Developing States (UNGA 1994). One part of the resolution stated that the sustainability of the resources on small islands is dependent on the asset management of these resources, which are generally under pressure. Therefore, efforts should be made to maintain sustainability so that exploitation does not exceed the natural carrying capacity (UNGA 1994). Resource inventory of such islands includes a variety of ecosystem types, both terrestrial and marine. The variety of ecosystem types on small islands is a potential resource for fisheries, mining, agriculture and forestry, beach, transport, tourism and other industries (Cushnahan 2001). The inventory and evaluation of natural resources of islands, including the outermost islands, must occur to provide accurate and up-to-date baseline data that can be accessed quickly to support the sustainable planning and management of natural resources of the Indonesian archipelago. This inventory is important because the ecosystems of the small islands are also ecosystems that are very sensitive to climate change (Birk 2014). Therefore, a more in-depth understanding of the resources is necessary for the preparation of adaptation by society (Smit & Wandel 2006; Mortreux & Barnett 2009).

With such a background, the Geospatial Information Agency, Indonesia, in cooperation with the Institute for Research and Community Development, Bogor Agricultural University, began to inventory several small and outermost islands of Indonesia. Two locations that were inventoried recently were Rote and nDana Islands, East Nusa Tenggara. The inventory considered biotic and abiotic components, both in terrestrial land and in water. The components of natural resources inventoried and mapped included onshore abiotic components (soil, geology and climate), terrestrial biotic components (land cover, flora and fauna diversity), abiotic components of water (bathymetry, pH, dissolved oxygen, sea surface temperature, salinity), marine biotic components (coral reefs, reef fish, benthos and sea grass beds), and cultural components. Data processing was designed with maps at a scale of 1:25,000. The resulting output of this work was a map album containing the natural resource diversity maps at a scale of 1:25,000, which was available at the Geospatial Information Agency, Indonesia. This paper presents part of this inventory activity, which is land use and land cover change over one decade. The result of the mangrove diversity measurements will also be presented.

The mangrove is an important ecosystem in coastal areas due to its environmental function. This ecosystem is important for coastal protection, delivering important ecosystem functions, goods and services (Kathiresan 2012; Lee et al 2014; Van et al 2015). In the context of small islands, the mangrove is very important for stabilising and protecting the coastal line from waves and wind (Dahdouh-Guebas & Pulukkuttige 2009; Mukherjee et al 2010; Kathiresan 2012; Lee et al 2014). Naturally, the mangrove forest is home to mammals, amphibians, reptiles, birds, crabs, fish, primates, insects and other animals (Valiela et al 2001; Nagelkerken et al 2008; Cannicci et al 2008). In addition to providing biological diversity, the mangrove ecosystem also supports the genetic pool and the whole lifecycle in the marine ecosystem. The mangrove habitat is a feeding ground for animals, and serves as a spawning ground and a safe haven from predators for a variety of juvenile and larval fish and shellfish (Cooper et al 1995; Kusmana 2005, 2014).

The extent of the mangrove ecosystem in the world, including in Indonesia, continues to decline. For example, from 1980–2005, the worldwide mangrove forest area declined by 3.6 million ha (about 20% of the total area) (Spalding et al 2010; Van et al 2015). The mangrove vegetated area in Indonesia is 3.2 million ha (GIA 2009; Kusmana 2011). Based on the data collected by the Ministry of Forestry (Kusmana 2011), the potential area where more mangroves could be planted (including mangrove vegetated areas) is estimated to be 7.8 million ha, where 30.7% is in good condition, 27.4% is moderately destroyed and 41.9% is heavily destroyed.

In their current condition, mangrove forests have been damaged and degraded. As the mangrove system plays an important role in protecting environment, any loss creates a loss of subsistence, cash-based livelihoods and ecological and conservation function (Valiela et al 2001). Mangrove growth requires a certain environment; many varieties of mangrove environments also require different growing environments. In addition to the other plant species, the land suitability may be valid for different species of mangroves (Widiatmaka et al 2014). There are many factors that determine the distribution of a mangrove, i.e. tidal currents, salinity, water temperature and substrates (Supriharyono 2000; Kusmana 2011). The ideal place for a mangrove is around a wide beach, river estuary or delta, where the river flows and contains lots of mud and sand (Dahuri et al 1996).

The management of forest resources needs to be based on mapping and inventory (Van et al 2015). One of the most used methods is remote sensing. Remote sensing and GIS have been widely used for the sustainable management of tropical coastal ecosystems (Neukermans et al 2008; Satyanaraya et al 2011; Nfotabong-Atheull et al 2013; Van et al 2015).

The objective of this paper is to present partial results of the inventory of the natural resources on the Rote and nDana islands, especially regarding change in land use and land cover over one decade (2000–2014). This paper will also present a composition of the mangrove ecosystem at several points of measurement. Such data is intended to support the development and application of database systems and area studies.

Material and Method. The study was conducted on December 2014 on the Rote and nDana Islands, East Nusa Tenggara Province. The islands are located between 122°30”-123°25” E and 10°20”-11°00” S (Figure 1). The research area has a dry climate, with a rainfall average of 900–1,500 mm year^{-1}. The area that receives the most rainfall is located in the southern part of the islands. Rainfall decreases when moving toward the northern part of the region.

Land use and land cover were interpreted from Landsat satellite imagery acquired between 2000 and 2014. The images used for this study include Landsat 7 ETM+ (recorded on 14 September 2000) and Landsat OLI (recorded on 13 September 2014). The supervised classification was conducted, followed by field checking. The image classification was done using ERDAS Imagine software. The land use and land cover changes were then analysed using ArcGIS software. Land use and land cover were sorted into 16 land use-land cover types following the standard imagery interpretation of Indonesian National Standard (2010).

Primary data of the mangrove were acquired through field surveys assessing the biometric data. Measurements were taken at four transect stands that were made in Rote and nDana islands: MPB, MLB and PBT on Rote Island and MPD on nDana Island. At each station, data were collected on a plot size of 20 m x 20 m for vegetation observation. At each observation point, two plots were made. In a plant community, the structure of the canopy can be classified based on the height of the canopy, respectively from bottom to top: (i) lower plants (seedlings), (ii) saplings, and (iii) trees. Each class was observed on different-sized plots. The scheme of plot measurements is presented in Figure 2.

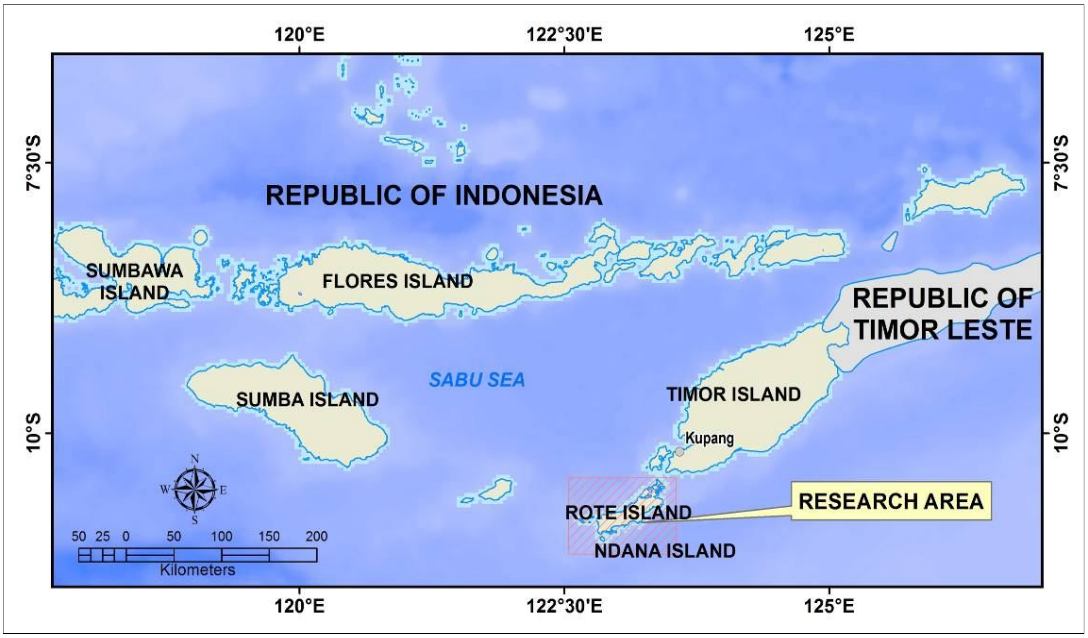

Figure 1. Situation map of the research location.

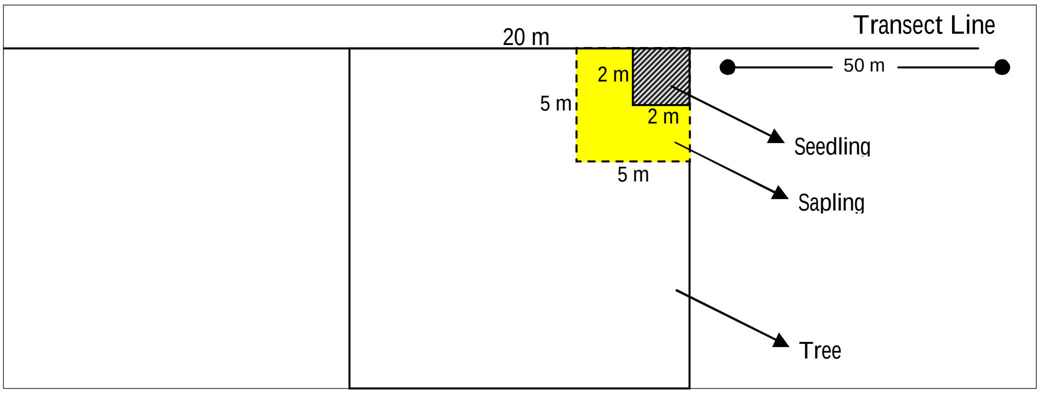

Figure 2. Scheme of plot measurement.

On each plot, measurements were made in terms of height (h), diameter at breast height (dbh) of each stand, stand number, species percentage, and tree density. Height was measured from the ground to the first branch point and the top of the tree canopy. Vegetation data were analysed to determine the value of the relative frequency, relative density, relative dominance and importance values (Mueller-Dombois & Ellenberg 1974; Cox 1996; Odum & Barett 2005). The following formulas were used to determine the structure and composition of vegetation pioneers:

$$\text{Density (D)} = \frac{\text{individual number of a species}}{\text{square meter of whole plots}}$$

$$\text{Relative Density (Dr)} = \frac{\text{a species density}}{\text{density of the whole species}} \times 100\ \%$$

$$\text{Frequency} = \frac{\text{number of plots in which a species occurs}}{\text{total number of plots sampled}}$$

$$\text{Relative Frequency (Fr)} = \frac{\text{frequency value for a species}}{\text{total area of all the measured plots}} \times 100\ \%$$

$$\text{Dominance} = \frac{\text{total of basal area of each tree of a species from all plots}}{\text{total area of all the measured plots}}$$

$$\text{Relative Dominance (Br)} = \frac{\text{dominance for a species}}{\text{total dominance for all species}} \times 100\ \%$$

Importance Value (IV) = Relative Density + Relative Frequency + Relative Dominance

Results and Discussion. The land use and land cover of Rote and nDana islands for two analysis years are presented in Figure 3. Results of the land use and land cover analysis are presented in Table 1.

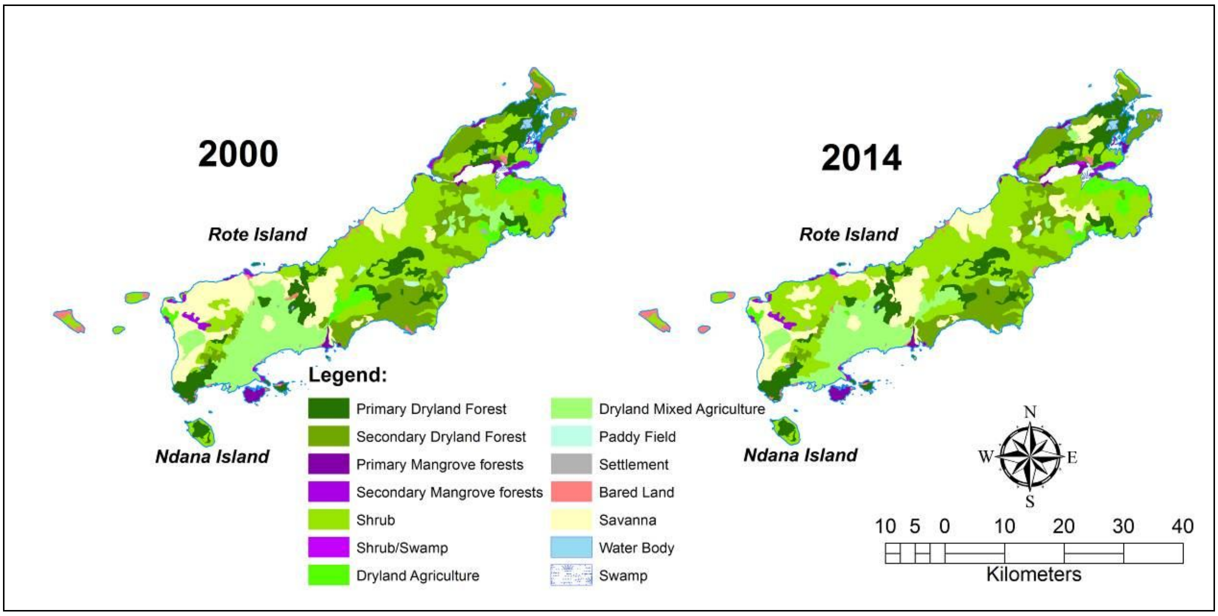

Figure 3. Result of Landsat interpretation.

Table 1

Land use and land cover of Rote and nDana islands as interpreted by Landsat TM satellite images from 2000 and 2014

No.	*Land Use/Land Cover*	*Year 2000*		*Year 2014*		*Change (2000–2014)*	
		ha	*%*	*ha*	*%*	*ha*	*%*
1	Primary dryland forest	15,291.0	11.9	15,253.3	11.9	-37.7	0.0
2	Secondary dry land forest	20,420.0	15.9	20,540.3	16.0	120.4	0.1
3	Mangrove primary forest	2,068.2	1.6	1,922.3	1.5	-145.9	-0.1
4	Primary swamp forest	114.3	0.1	0	0.0	-114.3	-0.1
5	Shrub	40,647.8	31.6	46,146.9	35.9	5,499.1	4.3
6	Settlement	441.8	0.3	468.2	0.4	26.4	0.0
7	Bared land	2,342.1	1.8	2,082.5	1.6	-259.6	-0.2
8	Savanna	19,086.4	14.8	18,576.8	14.4	-509.6	-0.4
9	Water body	522.6	0.4	602.7	0.5	80.2	0.1
10	Secondary mangrove forest	2,023.1	1.6	1,979.1	1.5	-44.0	0.0
11	Secondary swamp forest	2.4	0.0	0	0.0	-2.4	0.0
12	Shrub/swamp	0	0.0	145.9	0.1	145.9	0.1
13	Dry land agriculture	6,083.4	4.7	4,519.5	3.5	-1,563.8	-1.2
14	Mixed dry land agriculture	18,729.6	14.6	15,535.1	12.1	-3,194.5	-2.5
15	Rice field	527.6	0.4	527.6	0.4	0.0	0.0
16	Swamp	438.0	0.3	438.0	0.3	0.0	0.0
	Total	128,738.3	100.0	128,738.3	100.0	0.0	0.0

In terms of area, land cover which has the widest area in Rote and surrounding small islands, including nDana Island is shrub, which, in 2000, had an area of 40,647.80 ha (31.57%); in 2014, it had an area of 46,146.89 ha (35.85%). Some of the other main land uses that had sufficiently wide areas in 2014 were respectively dry land secondary forest (15.96%), savannah (14.43%), mixed dry land agriculture (12.07%), and primary dry land forest (11.85%). In terms of land use and land cover changes, significant changes occurred only in some types of land use and land cover. Land cover that increased in its extent was shrub (by 4.27%), from 40,647.80 ha in 2000 to 46,146.89 ha in 2014. Other land uses and covers had relatively small changes (less than 1%), including shrub/swamps, secondary dry land forests and settlements. Meanwhile, the types of land cover and land use that were reduced by a substantial amount were mixed dry land agriculture, which suffered an extensive decrease from 18,729.59 ha in 2000 to 15,535.06 ha in 2014 (2.48%) and dry land agriculture farming, which decreased from 6,083.35 ha in 2000 to 4,519.51 ha in 2014 (1.21%). Decreases in the other land uses and land covers occurred evenly, but in small quantities, such as the primary dry land forest, primary mangrove forest, primary swamp forest, savannah and bare land.

The station of observation, plotted against the result of interpretation of the land use/land cover analysis of Landsat imagery from 2014 is presented in Figure 4. These sites were selected according to several criteria: (i) if a mangrove area existed, (ii) if it was accessible and possible to obtain measurements, and (iii) if it was representative of the entire island. Results of the vegetation analysis of all stations of observation are given in Table 2.

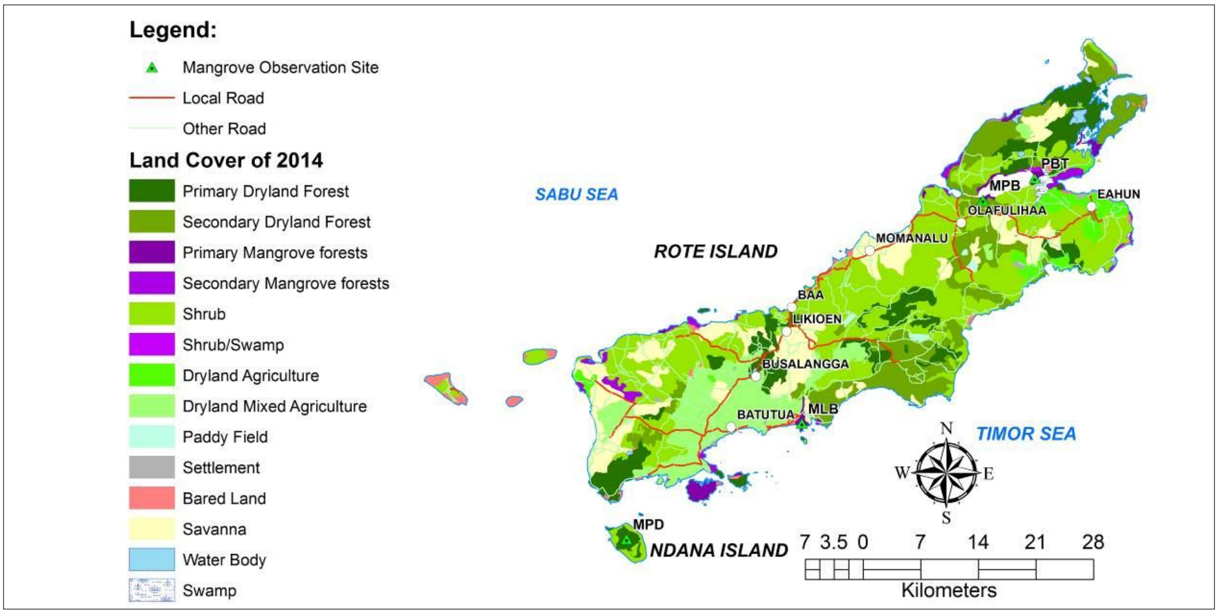

Figure 4. Mangrove observation site on Rote and nDana Islands.

Table 2

Plant vegetation analysis results in the mangrove ecosystem on Rote and nDana islands

Mangrove species	*Family*	*D*	*Dr*	*Fr*	*Br*	*IV*
		tree ha^{-1}	*%*	*%*	*%*	*%*
		Transect of MPB				
Seedling strata						
1. *Ceriops* sp.	Rhizophoraceae	-	7.14	14.29	4.71	26.14
2. *Rhizophora apiculata*	Rhizophoraceae	-	21.43	28.57	7.89	57.89
3. *Rhizophora mucronata*	Rhizophoraceae	-	71.43	57.14	87.40	215.97
Sapling strata						
Rhizopora mucronata	Rhizophoraceae	-	100.00	100.00	100.00	300.00
Tree strata						
1. *Rhizophora mucronata*	Rhizophoraceae	-	96.30	66.67	-	162.96

		D	Dr	Fr	Br	IV
2. *Ceriops* sp.	Rhizophoraceae	-	3.70	33.33	-	37.04
		Transect of PBT				
Seedling strata						
1. *Sonneratia alba*	Lythraceae	264.44	29.17	44.59	-	73.76
2. *Rhizophora stylosa*	Rhizophoraceae	297.78	32.84	32.43	-	65.27
3. *Camptostemon schultzii*	Bombacaceae	11.11	1.23	2.70	-	3.93
4. *Bruguiera parviflora*	Rhizophoraceae	44.44	4.90	2.70	-	7.60
5. *Rhizophora mucronata*	Rhizophoraceae	44.44	4.90	2.70	-	7.60
6. *Ceriops tagal*	Rhizophoraceae	177.78	19.61	9.48	-	29.09
7. *Pemphis acidula*	Lythraceae	-	-	-	-	-
8. *Ceriops decandra*	Rhizophoraceae	66.67	7.35	5.40	-	12.75
9. *Intsia bijuga*	Fabaceae	-	-	-	-	-
Sapling strata						
1. *Sonneratia alba*	Lythraceae	720	48.94	50.0	73.47	172.41
2. *Rhizophora stylosa*	Rhizophoraceae	431.11	29.30	28.17	22.64	80.11
3. *Camptostemon schultzii*	Bombacaceae	28.89	1.96	1.41	0.20	3.57
4. *Bruguiera parviflora*	Rhizophoraceae	33.33	2.27	1.41	0.15	3.83
5. *Rhizophora mucronata*	Rhizophoraceae	46.67	3.17	2.82	0.35	6.34
6. *Ceriops tagal*	Rhizophoraceae	117.78	8.01	6.35	2.78	17.14
7. *Pempis acidula*	Lythraceae	33.33	2.27	4.92	0.11	7.30
8. *Ceriops decandra*	Rhizophoraceae	60.00	4.08	4.92	0.30	9.30
9. *Intsia bijuga*	Fabaceae	-	-	-	-	-
Tree strata						
1. *Sonneratia alba*	Lythraceae	677.78	71.60	56.93	96.44	224.97
2. *Rhizophora stylosa*	Rhizophoraceae	146.67	15.49	21.16	3.31	39.96
3. *Camptostemon schultzii*	Bombacaceae	2.22	0.23	1.46	0.00	1.69
4. *Bruguiera parviflora*	Rhizophoraceae	8.89	0.94	2.92	0.00	3.86
5. *Rhizophora mucronata*	Rhizophoraceae	22.22	2.35	2.92	0.04	5.31
6. *Ceriops tagal*	Rhizophoraceae	44.44	4.70	6.57	0.07	11.34
7. *Pemphis acidula*	Lythraceae	35.56	3.76	5.12	0.14	9.02
8. *Ceriops decandra*	Rhizophoraceae	6.67	0.70	1.46	0.00	2.16
9. *Intsia bijuga*	Fabaceae	2.22	0.23	1.46	0.00	1.69
		Transect of MLB				
Seedling strata						
1. *Rhizophora stylosa*	Rhizophoraceae	1359.26	24.35	56.91	-	81.26
2. *Ceriops tagal*	Rhizophoraceae	4046.30	72.49	34.96	-	107.45
3. *Bruguiera parviflora*	Rhizophoraceae	92.59	1.67	3.25	-	4.92
4. *Bruguiera gymnnorhiza*	Rhizophoraceae	46.30	0.83	3.25	-	4.08
5. *Sonneratia alba*	Lythraceae	-	-	-	-	-
6. *Ceriops decandra*	Rhizophoraceae	37.04	0.66	1.38	-	1.96
7. *Pemphis acidula*	Lythraceae	-	-	-	-	-
Sapling strata						
1. *Rhizophora stylosa*	Rhizophoraceae	1179.63	37.06	53.85	29.17	120.08
2. *Ceriops tagal*	Rhizophoraceae	1898.15	59.63	33.08	70.72	163.43
3. *Bruguiera parviflora*	Rhizophoraceae	61.11	1.93	5.38	0.10	7.41
4. *Bruguiera gymnnorhiza*	Rhizophoraceae	12.96	0.41	3.08	0.003	3.49
5. *Sonneratia alba*	Lythraceae	-	-	-	-	-
6. *Ceriops decandra*	Rhizophoraceae	9.26	0.29	1.53	0.002	1.822
7. *Pemphis acidula*	Lythraceae	22.22	0.68	0.04	0.005	3.765
Tree strata						
1. *Rhizophora stylosa*	Rhizophoraceae	462.96	57.21	52.78	81.55	191.54
2. *Ceriops tagal*	Rhizophoraceae	224.07	27.69	27.01	15.26	69.99
3. *Bruguiera parviflora*	Rhizophoraceae	83.33	10.30	9.04	2.80	22.14
4. *Bruguiera gymnnorhiza*	Rhizophoraceae	9.26	1.14	4.17	0.04	5.35
5. *Sonneratia alba*	Lythraceae	3.70	0.46	1.49	0.06	2.01
6. *Ceriops decandra*	Rhizophoraceae	3.70	0.46	1.49	0.01	1.96
7. *Pemphis acidula*	Lythraceae	22.22	2.74	4.17	0.28	7.19
		Transect of MPD				
Tree strata						
1. *Avicennia alba*	Avicenniaceae		59.46	40	77.83	177.29
2. *Heritiera littoralis*	Sterculiaceae		21.62	20	8.84	50.46
3. *Rhizophora apiculata*	Rhizophoraceae		13.51	20	8.22	41.73
4. *Rhizophora mucronata*	Rhizophoraceae		5.41	20	5.11	30.51

Note: D = Density; Dr = Relative Density; Fr = Relative Frequency; Br = Relative Dominancy; IV = Important Value Index.

From both the results of the analysis and the results of the field observation at the mangrove station of MPB transects, it can be seen that the area of mangroves in this site remains only in the form of thin belt (less than 50 metres). The species composition consists of only three types, namely *R. mucronata*, *R. apiculata* and *Ceriops* sp. Based on the structure of the vegetation, it is conceivable that in the future, mangrove vegetation here will be dominated by *R. mucronata*. This species has the highest score on the Important Value (IV) index in all strata of mangrove vegetation at this site. It seems that such dominancy relates to the substrate of sandy muds, which is dominant at this site.

In PBT Transect, the mangrove species of *S. alba* has the highest IV in the strata of seedling, sapling and tree, where the IVs were, successively, 73.76%, 172.41% and 224.97%. *R. stylosa* has an IV high enough in the strata of seedling and sapling, with IVs of 65.27% and 80.11% respectively. At the tree level, *R. stylosa* has a low IV of 39.96%. *C. tagal* at the strata of seedling, sapling and tree, has low IVs: 29.09%, 17.14% and 11.34% respectively. The other six types, *C. schultzii, B. parviflora, R. mucronata, P. acidula, C. decandra* and *I. bijuga*, have very low IVs for seedlings, saplings and tree strata.

The conditions for regeneration in PBT transect can be seen from seedling and sapling availability of mangrove vegetation. For *S. alba*, the level of regeneration is not good; the availability of seedlings is low (seedling density of 264.44) and the availability saplings is high (sapling density of 720). For *R. stylosa*, the level of regeneration is not good; the availability of seedlings is low (seedling density of 297.78) and the availability of saplings is high (sapling density of 431.11). For *C. schultzii*, the level of regeneration is very bad; the availability of seedlings and saplings is very low (seedling density of 11.11 and sapling density of 28.89).

At this PBT transect, *B. parviflora* has poor regeneration conditions due to the low availability of seedlings and saplings (seedling density of 44.44 and sapling density of 33.33). *R. mucronata* has a poor level of regeneration due to the low availability of seedlings and saplings (seedling density of 44.44 and sapling density of 46.67). *C. tagal* has a high level of regeneration because the availability of seedlings and saplings (seedling density of 177.78 and sapling density of 117.78). *P. acidula* has a low level of regeneration because of very low density in the sapling strata (sapling density of 33.33). *I. bijuga* has no regeneration conditions because there are no seedlings or saplings. Overall, in this location, *S. alba* seems to be the most dominant species, followed by *R. stylosa*.

In MLB transect, the data in the Table 2 show that *C. tagal* has the high IV in the seedling and sapling strata (107.45% and 163.43%, respectively), followed by *R. stylosa* with an IV of seedling and sapling strata at 81.26% and 120.08%, respectively. At the tree strata, *R. stylosa* has the high IV (191.54%), followed by *C. tagal* (69.99%). The other species have relatively low IVs for seedling, sapling and tree strata.

For *R. stylosa*, levels of regeneration are very good; the availability of seedlings and saplings is very high (seedling density of 1359.26 and sapling density of 1,179.63), with the availability of seedlings being higher than saplings.

C. tagal has a very high level of regeneration; the availability of seedlings and saplings is very high (seedling density of 4,046.30 and sapling density of 1,889.15), with the availability of seedlings being higher than saplings. For *B. parviflora*, the level of regeneration is not good; the availability of seedlings and saplings is low (seedling density of 92.59 and sapling density of 61.11). For *B. gymnnorhiza*, the level of regeneration is not good; the availability of seedlings and saplings is low (seedling density of 46.30 and sapling density of 12.96). *S. alba* does not have a level of regeneration because the vegetation in seedling and sapling strata was not found. *C. decandra* has a poor level of regeneration due to the very low availability of seedlings and saplings (seedling density of 37.04 and sapling density of 9.26). *P. acidula* has a poor level of regeneration, no seedlings were found, while the availability of saplings was low (sapling density of 22.22). Overall, *C. tagal* and *R. stylosa* are the most dominant in the mangrove.

In MPD transect on nDana island, mangrove vegetation is found only around the lake and wetlands in the centre of the island, which is the highest place of the island.

There is no mangrove vegetation growing directly on the beaches. There are two lakes on the island, one of which is called the Red Lake. Here, *Avicennia* dominates the mangrove species found. *Heritiera* was also found due to the relatively dry soil conditions. The fact that on nDana Island mangroves are present at the top of the island and not on the coastal plain may indicate that geological lifting has occurred (Head et al 2001).

Results of land use and land cover analysis indicate that it seems, since the island is remote, land use and land cover has not significantly changed over one decade. In this remote location, there is only minimum pressure from population growth, which is characterised among others, by the increase of settlement, which is not as pronounced as on the other densely populated islands. The low pressure from population growth is reflected in the relatively low population density. Based on statistical data (Rote Ndao Statistics 2014), the population of Rote Ndao is 127,911 inhabitants. The population density is relatively low, only 100 people km^{-2}. There is even a district (Central Rote) with the low population density of 51 people km^{-2}.

However, attention needs to be paid to the decreasing mangrove area. Mangrove land cover, both primary and secondary have declined. Decreasing mangrove area reached 145.87 ha for the primary mangrove forest and 43.96 ha for the mangrove secondary forest. As a percentage of island area as a whole, the percentage of this decrease is small, only 0.11% and 0.03% respectively. However in terms of percentage of the mangrove forest itself, it is sufficiently high: 7.05% and 2.17% for the primary and secondary mangrove forests respectively. This amount was equivalent to a total conversion of 9.2%, or in absolute terms, 190 ha of mangrove. Given the increasingly importance of mangrove in Indonesia (Kusmana 2005, 2011) and the importance of mangrove forests for small island protection (Vannucci 2002; Vermaat & Thampanya 2006; Mukherjee et al 2010; Kathiresan 2012; Lee et al 2014), this phenomena is of concern.

The results of mangrove diversity measurement showed that there was a sufficiently high diversity of mangrove species in the islands. There was quite a diverse species found dominating the area; it seems that this is influenced by the diversity of natural resources where mangroves grow. There are many factors that influence the types of mangrove species. A research conducted by Mendez-Alonzo et al (2008) found that there is a relation between the high diversity of plants, in term of average dbh, to rainfall variability. Salinity plays also an influence, as discovered by Lugo et al (2007), proving that with the increase of salinity, some *Rhizophora* species have smaller stem and leaves. Inundation seems to affect also mangrove species (Watson 1928; Krauss et al 2006). Temperature factors also have an effect on mangrove species (Lugo & Patterson-Zucca 1977; Lugo & Medina 2014) as well as hydroperiod (Watson 1928; Pezeshki et al 1990), nutrient availability (Feller et al 2007) and substratum redox gradient (McKee 1993; Alongi 2009). In terms of mangrove diversity, the results presented in this study could be considered as an original result of mangrove. This is due to the fact that the location of this was in a relatively remote area with only minimal human activity disturbance

Conclusions. The research was done in Rote and nDana Islands, two of the outermost islands in Indonesia. Land use and land cover changes on these outermost and remote islands were generally static. Changes in land use and land cover appeared minimally affected by the population, which is still miniscule. Nevertheless, mangrove destruction has begun and these areas require protection

Distribution in all categories (seedlings, saplings and trees) on Rote and nDana islands was not spread evenly (uniform), but was different at each station measured. At a station where the substrate was sandy muds *R. mucronata* was the dominant species. In the area where the substrate was dominantly muddy, *A. alba* and *C. tagal* were dominant. On nDana island, where the mangrove was found on the plateau of the island, *Avicennia* spp. and *Heritiera* spp. were the dominant species.

This research described the diversity of mangroves in different locations at different strata. This description should become part of the database on the mangrove ecosystem. One of the findings that should be underlined is that we found the mangrove ecosystem at the top of nDana island. There are geological processes that affect such phenomena, and research that is more detailed on this subject is suggested.

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