Mine Closure 2011 — A.B. Fourie, M. Tibbett and A. Beersing (eds)

doi:10.36487/ACG_rep/1152_31_Sompie

Reclamation and its succession in the used mine site of PT Newmont Minahasa Raya in Ratatotok, southeast Minahasa – a case study

H.N. Pollo *Forestry Sciences Study Programme, Faculty of Agriculture, Sam Ratulangi University, Indonesia*

D. Sompie *PT Newmont Minahasa Raya, Indonesia*

J. Kojansow *PT Newmont Minahasa Raya, Indonesia*

H.I. Mansur *Faculty of Forestry, IPB, Indonesia*

Abstract

Reclamation activities in the "PT Newmont Minahasa Raya (PTNMR)" mined area have been carried out since 1997 and include land reclamation, construction of erosion protection structures, planting and maintenance activities. The reclamation aimed to provide slope stability for geotechnical activity and erosion control, landscape improvement to complement the natural topography, generate the growth of independent vegetation, support the expected future land use, and return native faunas back to the reclaimed areas. Monitoring of reclamation development has been carried out since mine closure in 2004. The five parameters monitored include: plant density and vegetation dynamic, canopy coverage, seed production, return of fauna, and forest productivity. The areas monitored comprise of the entire mined site and the surrounding natural forests. The results of the study indicate that the current ecosystem in the reclaimed areas has changed from a man-made ecosystem to a natural ecosystem. The acceleration of such an ecosystem change occurred because PTNMR has consistently maintained "patches" of natural area around the reclamation area since the beginning of its operations to promote progressive reclamation.

1 Introduction

The gold mining site of PT Newmont Minahasa Raya (PTNMR) is located in Ratatotok Subdistric, southeast Minahasa Regency, North Sulawesi Province on the northern tip of Sulawesi Island in Indonesia (Figure 1). The primary objectives of the reclamation effort as specified in the PTNMR's Environmental Management Plan (1994) were to recover the post project area and develop its productivity.

Reclamation activities have been carried out by PTNMR at its mined area since 1997. The activities include land reclamation, construction of erosion protection structures, plantings and maintenance. To implement its primary objectives, it was developed a reclamation activity framework to provide slope stability for geotechnical activity and erosion control, landscape improvement to complement the natural topography, generate growth of independent vegetation, support the expected future land use and return native faunas back to reclaimed areas.

Figure 1 Gold mining location of PTNMR in Ratatotok, Southeast Minahasa, PTNMR, 1985

2 Methodology

Reclamation monitoring activities in 2004, 2005, 2006, 2007, 2008 and 2010 (referred to as monitoring period I to VI, respectively) were carried out on reclaimed and revegetated areas in 1997, 2000, 2001, 2002, 2003, and 2006. Three locations of natural forests untouched by mined activities (referred to as secondary forests) surrounding the reclaimed areas were also monitored as controls for comparative purposes. Since the reclamation area is located on mountainous areas, the natural forest located on the lower area is referred to as the lower secondary forest (located on the eastern area), the middle area is referred to as the middle secondary forest (located on the southern area), and the upper area is referred to as the upper secondary forest (located on the northern area). In each reclaimed area, three different lines were determined as sampling transects, and considered as replication, with the first line being randomly selected.

Six parameters are monitored: 1) plant density and vegetation dynamic, 2) canopy coverage, 3) seed production, 4) return of fauna, 5) root medium development, and 6) forest productivity. Except for the root medium development parameter, the remainder parameters are discussed in this paper. The third, fourth and the sixth parameters were monitored six times; and the first, second and the fifth parameters were only monitored four times, i.e. during the first four monitoring activities.

In the field, all parameters were monitored at the same sampling transects oriented on top of the ridge. Monitoring activities for the second, third, fifth and the sixth parameter were done on the same quadrilateral sampling plots of 20 x 20 m.

2.1 Plant density and vegetation dynamics

Plant monitoring variants in reclaimed areas include vegetation classification, trees composition and structure, and renewal identification (Yuzammi and Hidayat, 2002). Vegetation data was collected from a quadrilateral plot which was systematically separated and adjusted directly in each transect. The size of each seedling plot was 1 x 1 m, sampling 5 x 5 m, pole 10 x 10 m and trees 20 x 20 m (following Brower and Zar, 1984). Plant species categorised as seedlings were herbaceous, semi-woody, and tree species with diameter ≤ 1 cm and/or height up to 1 m. Sampling diameter was between 1–10 cm; height >1– m. Shrubs and poles diameter was between 10–30 cm and the trees diameter was > 30 cm (following Harlow et al., 1991).

2.2 Canopy coverage

The canopy coverage was measured by tube solarimeters and its integrators for quantitative data gathering. The ratio between radiation that is intercepted on top of a plant canopy and transmitted below its canopy is the value of the canopy coverage. A canopy densiometer was also used to gather qualitative data. The canopy stratification, humidity, soil temperature, and solar radiation were monitored for supporting data.

2.3 Seed production

Data and information on the source of seeds (population, number of fruits per tree and number of seeds per fruit), and seeds deposited on the forest floor were obtained using the census method. Seed viability was determined by the number of seed sprouts.

2.4 Returning native faunas

2.4.1 Vertebrate

Bird monitoring activities were conducted in line with the Indices Ponctuels d'Abondance method (IPA) (Blondel et al., 1970). The distance between each monitoring point was 100 m. Periods of monitoring were between 0530–0800 hrs and 1530–1830 hrs. The duration of each monitoring was 15 minutes (Alikodra, 2002).

The number of birds that were seen and heard within a radius of approximately 50 m at each point was recorded. In addition to birds, other animals found along the strip were also recorded. Bat monitoring activities were done at night time (Suyanto, 2001).

2.4.2 Invertebrate

The insect collecting method was conducted in several ways:

- Direct monitoring and catching of flying insects with a sweep net.
- Catching by hand the swarming insects around the lamps in residential houses at Mesel.
- Insect trapping by a Malaise trap. Malaise traps were placed in strategic places for three days to trap both diurnal and nocturnal flying insects, including crawling insects.

2.5 Forest productivity

The general measurement of forest productivity is wood production per unit area and time (ton/ha/year). Forest productivity is counted by using the biomass approach. Tropical forests contain approximately 40–50% of carbon deposited as terrestrial biomass and productivity (Brown, 1997).

Data collected was analysed using gravimetric and allometric equations. The gravimetric equation for ground litter biomass (1 x 1 m) used simple mathematical equations in the form of ratio calculation. Forest productivity calculation was based on allometric model developed by Adinugroho and Sidiyasa (2006) to predict biomass parts of mahogany tree, and the Dahlan et al. (2005) model was used to predict total biomass in ton/ha or kg/ha.

3 Results and discussion

3.1 Plant density and vegetation dynamics

3.1.1 Plant density

The number of species and individual plants found during monitoring activities in all reclaimed areas is shown in Table 1. Table 1 shows that the number of plant species increases with time. It is clear that the younger the vegetation, the fewer the number of species. On the contrary, the younger the vegetation, the greater the number of individual plants.

There were 28 plant species that invaded the reclaimed areas. As plant invasion is a form of increasing plant diversity in an area, it gives certain advantage for a progressive succession by enriching plant composition and by creating new habitat it provides a chance for a plant species to invade the habitat.

In contrast to the other areas, reclaimed areas in 2000 showed a decrease in the number of species and individual plants. This was probably during the vegetation establishment phase, when strong plants displace the weaker ones.

3.1.2 Vegetation dynamic

Figure 2 shows the relation between the Shannon Index and plant life form in the monitoring areas. The trend in progressive vegetation succession is shown by the increasing plant structure, composition, and plant diversity.

In Figure 2, seedling, sapling, pole and tree show a certain characteristic form of plant diversity. The succession pattern shows that the older the vegetation is, the higher the diversity. This characteristic indicates that succession is progressive, and the area is still in the succession process. The high value of species diversity indicates that the reclaimed areas have created a habitat with a particular ecological niche.

3.2 Canopy coverage

Table 2 shows the average plant canopy coverage in the reclaimed areas. Canopy coverage of the reclaimed areas seems to be similar to the canopy coverage of the secondary forest. It indicates that the vegetation on the reclaimed forest can improve landscape development to complement the natural topography.

Table 1 Number of species and individual plants in all the reclaimed areas

		Monitoring Period				Monitoring Period			
		I	II	III	IV	I	II	III	IV
No	Area	Number of Species				Number of Individual			
1	LSF	49	29	46	64	206	127	205	481
2	MSF		45	73	72		175	338	456
3	USF	60	10	86	80	246	17	323	558
4	Rec. 1997	25	28	37		100	336	339	
5	Rec. 2000	41	45	52	41	1,159	1,192	1,622	938
6	Rec. 2001	32	46	38	42	1,470	1,324	737	972
7	Rec. 2002	34	45	42	47	924	2,062	1,645	2,187
8	Rec. 2003				46				2189
9	Rec. 2006				59				1643
Total		241	248	374	451	4,105	5,233	5,209	9,424

Note: LSF, MSF, USF = Lower, Middle and Upper Secondary Forest, Rec. = Revegetated area in year.

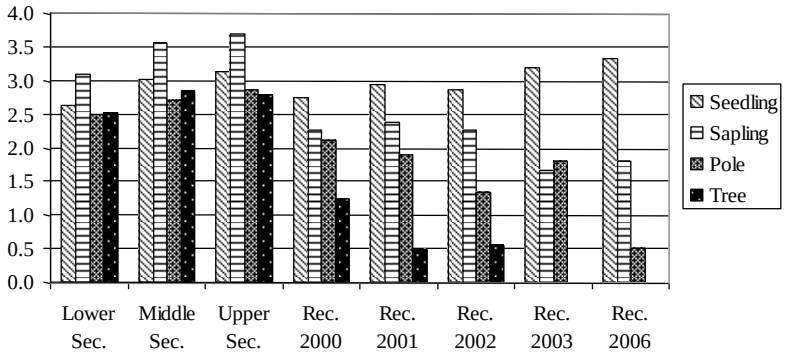

Figure 2 Shannon Index of plant life form in the reclaimed areas

Table 2 Average percentage intercepted and transmitted radiation

Area	Monitoring Period				Remarks
	I	II	III	IV	
	(%)				
MSF	90.0	83	98.87	98.68	Very good
Rec. 2000	79.6	92	96.99	98.31	Very good
Rec. 2001	64.0	92	89.99	69.02	Good
Rec. 2002	72.0	79	89.99	76.49	Good
Rec. 2003	43.0	43	44.99	48.39	Not so good
Rec. 2006			43.99	48.73	Not so good

Note: MSF = Middle Secondary Forest, Rec. = Revegetated area in year.

3.3 Seed production

In the first monitoring period, on the reclaimed areas in 1997, Mimusops elengi were bearing fruits and there were seedlings on each tree floor. On the reclaimed areas in 2001 Tectona grandis were starting to produce fruits and seedlings. During the second monitoring period, on the reclaimed areas in 2002, Tectona grandis were starting to produce fruits and seedlings. In the third monitoring period, on the reclaimed areas in 2000, Pterocarpus indicus were starting to produce fruits and seedlings. For the fourth monitoring period, there were no tree bearing fruit; although the flowers were abundant. In the fifth monitoring period, there were more trees bearing fruits, seeds, and seedlings. In the sixth monitoring period, on the reclaimed area in 1997 (Table 3), Palaquium spp were starting to produce flowers.

Based on the data shown in Table 3 and the above explanations, reclaimed trees on almost all of the reclaimed areas have the capability to produce fruits, seeds, and seedlings. It could be interpreted that the man-made forests on the reclamation areas are healthy enough to generate the growth of independent vegetation.

Table 3 Fruit, seed and seedling production at the sixth monitoring period

No	Reclaimed Year	Plot Number	Trees	Fruits	Fruited Trees	Seeds	Seeded Trees	Seedlings	Seedling Trees
1	Upper rec. 1997	P1	35	22	1	0	0	1,246	35
2	Lower rec. 1997	P1	16	0	0	200	6	98	6
3	Rec. 2000	P1	27	0	0	0	0	127	12
4	Rec. 2000	P2	26	0	0	0	0	0	0
5	Rec. 2000	P3	23	0	0	0	0	0	0
6	Rec. 2001	P1	24	1,850	6	530	6	0	0
7	Rec. 2001	P2	31	5,300	22	1,143	21	0	0
8	Rec. 2001	P3	14	90	2	60	2	0	0
9	Rec. 2002	P1	37	3,710	27	782	27	7	1
10	Rec. 2002	P2	14	1,678	12	683	11	2	1
11	Rec. 2002	P3	15	810	7	150	6	0	0
12	Rec. 2002	P4	30	5,995	25	1,915	25	0	0
13	Rec. 2003	P1	31	1,000	5	170	5	0	0
14	Rec. 2003	P2	29	1,600	5	335	5	0	0
15	Rec. 2003	P3	29	0	0	0	0	0	0
16	Rec. 2003	P4	39	0	0	0	0	0	0
17	Rec. 2003	P5	45	2,150	12	405	12	0	0
18	Rec. 2006	1 P1	34	0	0	0	0	0	0
19	Rec. 2006	1 P2	45	0	0	0	0	0	0
20	Rec. 2006	1 P3	25	0	0	0	0	0	0
21	Rec. 2006	2 P1	25	0	0	0	0	0	0
22	Rec. 2006	3 P1	30	0	0	0	0	0	0
23	Rec. 2006	4 P1	44	0	0	0	0	0	0
Total			668	24,205	124	6,373	126	1,480	55

3.4 Returning native faunas

3.4.1 Vertebrate

3.4.1.1 Avi-fauna structure

Avi-fauna structure is described by its importance value. Structure difference was calculated and converted to the Shannon Index as the diversity index. Figure 3 shows the graphical relationship.

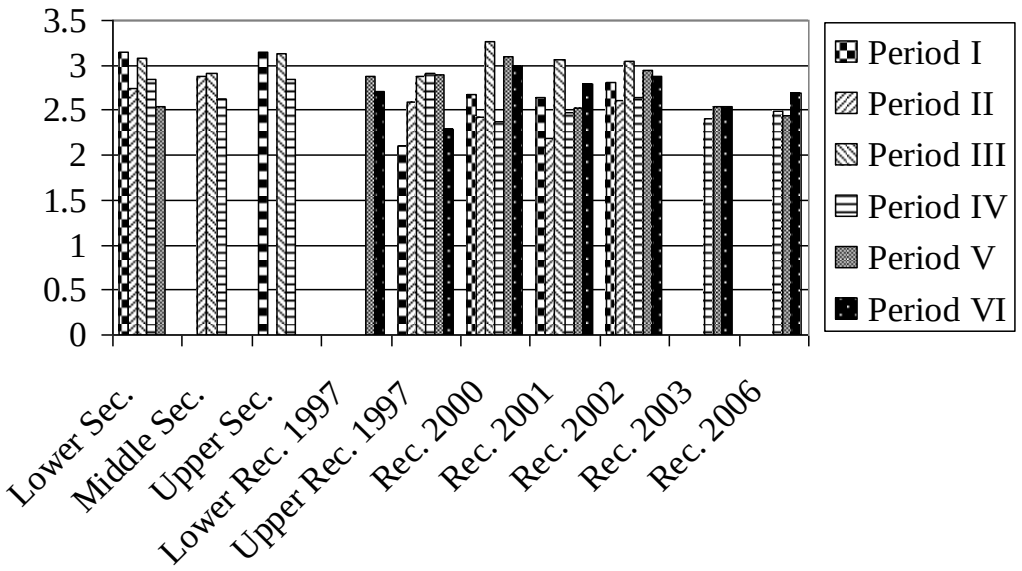

Figure 3 Shannon Index of avi-fauna at all monitoring areas

Based on the data shown in Figure 3, values of the Shannon Index of the reclaimed areas tend to be equal to those of the secondary forests, between 2.5–3.25. The high number of species and individual plants, as indicated by the relative high Shannon Index, suggests that the avi-fauna community on the reclaimed areas is now more stable. This condition indicates that vegetation on the reclaimed areas has created a new habitat to fit with the needs avi-fauna niche, which is functionally similar to that of the secondary forests.

3.4.1.2 Avi-fauna composition

Based on field data gathered, the total number of avi-fauna species found during the six monitoring periods was 109 bird species. Table 4 shows 51 endemic and protected avi-fauna species found during the monitoring activities. Endemic avi-fauna species are listed in the "Field Guide of The Birds of Sulawesi" (Holmes and Phillips, 1999), "A Guide to the Birds of Wallacea" (Coates and Bishop, 2000), and the protected avi-fauna species are listed by the Indonesian Government Regulation (Noerdjito and Maryanto, 2001). Table 5 shows the distribution of vertebrate fauna, other than birds, that were found in the monitoring areas. During the monitoring period, footpaths of the Sulawesian Wild Boar (Sus celebensis) were also found on reclaimed areas in 1997 and 2002, and in the middle secondary forest.

Based on the research findings, it is evident that the creation of an animal habitat and ecological niche by the vegetation has supported the return of fauna to the reclaimed areas, especially for the rare and protected fauna species that require specific habitat and ecological niche. As shown in Table 4, there are 35 rare bird species with 9 bird species among them being protected. The rest are protected, with 25 bird species protected. Based on Table 5, there are 3 rare species and 1 species act as a seed disperser and pollinator.

Table 4 Rare and protected avi-fauna species found in all reclaimed areas

No.	Scientific Name	No.	Scientific Name
1	**Accipiter griseiceps** (Celebes Gostad Goshawk)	27	Haliaetus leucogaster (White-bellied Sea Eagle)
2	**Accipiter trinotatus** (Spot-tailed Sparrowhawk)	28	Haliastus indus (Brahminy Kite)
3	**Aceros cassidix** (Knobbed Hornbill)	29	Ictinaetus malayensis (Black Eagle)
4	**Actenoides monachus** (Celebes Green Kingfisher)	30	**Loricullus exilis** (Small Sulawesi Hanging-Parrot)
5	Aethopyga siparaja (Crimson Sunbird)	31	**Loricullus stigmatus** (Large Sulawesi Hanging-Parrot)
6	Alcedo meninting (Blue-eared Kingfisher)	32	**Meropogon forsteni** (Purple-bearded Bee-eater)
7	Anthreptes malacensis (Brown-throated Sunbird)	33	**Mulleripicus fulvus** (Ashy Woodpecker)
8	**Artamus monachus** (Ivory-backed Wood-swallow)	34	Nectarinia jugularis (Yellow Breasted Sunbird)
9	Bubulcus ibis (Cattle Egret)	35	**Ninox punctulata** (Speckled Boobook)
10	Butastur liventer (Rufous-winged Buzzard)	36	**Otus manadensis** (Sulawesi Scops-Owl)
11	**Centropus celebensis** (Bay Caucal)	37	**Penelopides exarhatus** (Celebes Hornbill)
12	**Ceyx fallax** (Sulawesi Dwarf Kingfisher)	38	**Phaenicophaeus chalyorhyncus** (Yellow Billed Malkoha)
13	**Coracias temminckii** (Purple Winged Roller)	39	Pitta erythrogaster (Red Breasted Pitta)
14	**Coracina bicolor** (Pied Cuckoo-shrike)	40	**Prioniturus flavicans** (Yellow-breasted Racquet-tail)
15	**Coracina morio** (Sulawesi Cicada Bird)	41	**Prioniturus platurus** (Golden-mantled Racquet-tail)
16	**Coracina temminkii** (Caerulean Cuckoo-shrike)	42	**Ptilinopus fischeri** (Red-eared Fruit Dove)
17	**Dicaeum aureolimbatum** (Yellow-sided Flower Pecker)	43	**Scissirostrum dubium** (Finch-billed Myna, Grosbeak Starling)
18	**Dicaeum celebicum** (Grey-sided Flower Pecker)	44	**Spilornis rufipectus** (Celebes Serpent Eagle)
19	Egretta garzetta (Little Egret)	45	**Streptocitta albicollis** (White-necked Myna)
20	Egretta intermedia (Lesser Egret)	46	**Tanygnathus sumatranus** (Blue-backed Parrot, Muller's Parrot)
21	Egretta sacra (Pacific Reef Egret)	47	**Trichastoma celebense** (Sulawesi Babbler)
22	**Eudynamis melanorhyncha** (Black-billed Koel)	48	**Trichoglossus ornatus** (Ornate Lory, Ornate Lorikeet)
23	**Gallicolumba tristigmata** (Sulawesi Ground Dove)	49	**Turacoena manadensis** (Sulawesi Black Pigeon)
24	Gallirallus torquatus (Bared Rail)	50	**Tyto rosenbergii** (Sulawesi Owl)
25	Halcyon coromanda (Red Kingfisher, Ruddy Kingfisher)	51	**Zoothera erythronota** (Red-backed Thrush)
26	Halcyon sancta (Sacred Kingfisher)		

Note: Bold = Rare, Underline = Protected, Bold and Underline = Rare and Protected

Table 5 Vertebrate fauna other than birds found in the monitoring areas

Reptiles		**Bats**		**Snakes**	
1	Mabuia multifasciata	1	Thoopterus nigrescens (rare)	1	Boiga dendrophila
2	Unidentified sp. 7 (Spotted Lizard)	2	Cynopterus brachyotis	2	Unidentified sp. 4
3	Gecko	3	Macroglossus minimus	3	Unidentified sp. 5 (red-tongue)
4	Draco volans	4	Rousettus celebensis	4	Unidentified sp. 6
5	Varanus salvator	5	Megaderma spasma	5	Ahaetulla nasuta
		6	Nyctimene cephalotes		
Mice		**Primates**			
1	Paruromys dominator	1	Macaca nigra (rare and IUCN status: endangered)		
2	Unidentified sp. 1 (black-tailed)	2	Tarsius spectrum (rare)		
3	Unidentified sp. 2 (white-spotted)				
4	Unidentified sp. 3 (prickled-hairs)				

3.4.2 Invertebrate

Figure 4 shows Shannon Index of insects in the monitoring areas.

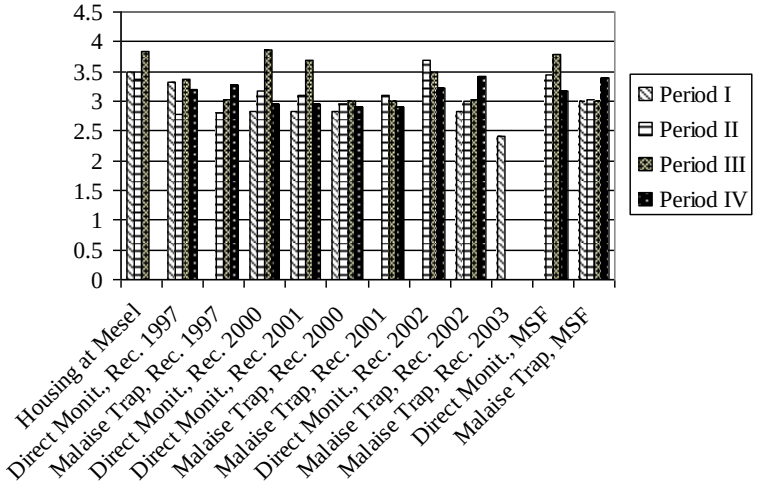

Figure 4 Shannon Index of insects found on reclaimed areas

Based on the research findings, several categories of insects were found in the reclaimed areas. During monitoring activities the most important adult pollinator insects of Lepidoptera and Hymenoptera were found in all monitoring areas. In addition, some moths of Spingidae, Noctuidae, Pyralidae, Notodontidae and Arctidae were found. The presence of pollinator insects will accelerate the progressive succession process. These pollinator insects play an important role in the growth and development of flora and fauna of any particular area or ecosystem. The more diversified the flora, the more diversified the fauna is. Hence, the

food chain will become more and more complex as the insect species increase in the system. An increase in the species of pollinating insects indicates that there is a positive growth of flora in the area.

Insects that have an important role in decomposing organic material were also found. They are Carabidae and Scarabidae in order Coleoptera. Collembolla, Protura and Carabidae are decomposer insects that are most dominant in the reclaimed areas. The crawling insects of Hymenoptera were also found, but they are categorised as being non-effective organic material decomposer. The presence of decomposers on reclaimed areas will support the nutrient availability for plants.

Insects that act as a population controlling agent to other insects called natural enemies, consisting of predators and parasitoid, were found on the reclaimed areas. The predators are Diptera, Orthoptera and Coleoptera and also Hymenoptera that act as a parasitoid.

3.5 Forest productivity

Table 6 shows the average tree crops diameter and height in the six monitoring areas. The total biomass on the soil surface and above ground is shown in Table 7. Ground litter biomass produced by the main vegetation is used to support further forest development.

Table 6 Diameter and height average of tree crops

Area	Diameter (cm)	Height (m)
Rec. 1997	27.96	16.77
Rec. 2000	32.31	16.97
Rec. 2001	15.82	10.79
Rec. 2002	12.68	10.55
Rec. 2003	16.93	11.47
Rec. 2006	9.25	6.91

Table 7 Ground litter, standing biomass, and carbon stock for the six monitoring areas

No	Area	Ground Litter Dry Weight (Kg/Ha)	Standing Biomass (Kg/Ha)	Ground Litter to Standing Biomass (%)	Biomass (Kg/Ha)	Carbon (Kg/Ha)
1	Rec. 1997	9,255.45	694,069.81	1.33	703,325.26	316,496.37
2	Rec. 2000	9,858.07	1,188,332.83	0.83	1,198,190.90	539,185.91
3	Rec. 2001	9,463.27	213,330.63	4.44	222,793.90	100,257.26
4	Rec. 2002	7,125.40	126,470.93	5.63	133,596.33	60,118.35
5	Rec. 2003	8,671.32	480,062.11	1.81	488,733.43	219,930.04
6	Rec. 2006	3,521.48	113,534.25	3.10	117,055.73	52,675.08
Total		47,894.99	2,815,800.56		2,863,695.55	1,288,663.00
Average		7,982	469,300		477,283	214,777

With reference to the carbon content of tropical forest, on average 45%, (Table 10), it seems that the carbon content on the reclaimed areas is now as much as 214,777 kg/ha. As PTNMR had revegetated the reclamation area of 215 ha, it means that the area contains 46,177,091 kg or 46,177 tonnes of carbon stock.

Since the forest productivity calculation was based on allometric equation, it seems that the 477,283 kg/ha biomass is adequate for a newly established forest. Calculation using the graphymetric method on the reclaimed areas to develop an allometric model is also important.

4 Conclusion

Based on the results and discussion, it can be concluded that the reclamation and maintenance activities on the reclaimed areas show a progressive and accelerated succession, and have fully performed as natural vegetation/secondary forest; from a man-made ecosystem to a natural ecosystem.

The acceleration took place because PTNMR had protected and maintained the natural patches (secondary forests) surrounding the reclaimed areas since the beginning of its mining activities in order to allow a consecutive progression for forest succession.

References

Adinugroho, W.C. and Sidiyasa, K. (2006) Model Pendugaan Biomassa Pohon Mahoni (Swietenia macrophyla King) di Atas Permukaan Tanah, Jurnal penelitian Hutan dan Konservasi Alam, Vol. III No.1, pp. 103–117.

Alikodra, S.M. (2002) Teknik Pengelolaan Satwa Liar, Jilid 1, Penerbit: Yayasan Penerbit Fakultas Kehutanan, Institut Pertanian Bogor, xxii + 366 hlm.

Blondel, J., Ferry, C. and Frochot, B. (1970) La méthode des indices ponctuels d'abondance (I.P.A.) ou des relevés d'avifaune par "stations d'écoute", Alauda, Vol. 38, pp. 55–71.

Brady, N.C. (1990) The Nature and Properties of Soils, 10th Edition, Macmillan Publishing Company, New York, 621 p.

Brower. J.E. and Zar, J.A. (1984) Field and Laboratory Methods for General Ecology, 2nd Edition, Wm.C. Brown Pub. Dubuque, Iowa, 226 p.

Brown, S. (1997) Estimating Biomass and Biomass Change of Tropical Forests: A primer, UN-FAO Forestry Paper 134, UN-FAO Forestry Paper 134, Rome, Italy, URL: www.fao.org/docrep/W4095E/ W4095E00.htm.

Coates, B.J. and Bishop, K.D. (2000) Panduan Lapangan Burung-burung di Kawasan Wallacea: Sulawesi, Maluku dan Nusa Tenggara, BirdLife Indonesia-Indonesia Programme & Dove Publications, 246 p.

Dahlan, I., Nengah, S.J. and Istomo (2005) Estimasi Karbon Tegakan Acacia mangium Willd Menggunakan Citra Landsat ETM+ dan SPOT-5: Studi Kasus di BKPH Parung Panjang KPH Bogor, Disampaikan pada Pertemuan Ilmiah Tahunan MAPIN XIV, Institut Teknologi Sepuluh November, 14–15 September 2005, Surabaya, pp. 108–117.

Harlow, W.M., Harrar, E.S., Hardin, J.W. and White, F.M. (1991) Textbook of Dendrology, 7th Edition, Mc.Graw-Hill, Inc, Singapore, 501 p.

Holmes, D. and Phillips, K. (1999) Burung-burung di Sulawesi – Seri Panduan Lapangan, Puslitbang Biologi – LIPI, Bogor, Indonesia, 106 p.

Noerdjito, M. and Maryanto, I. (eds) (2001) Jenis-jenis Hayati yang Dilindungi Perundang-undangan Indonesia, Cetakan ke II, Balitbang Zoologi (Museum Zoological Bogoriense), Puslitbang Biologi-LIPI dan The Nature Conservancy dan USAID, Bogor, Indonesia, 221 p.

Suyanto, A. (2001) Kelelawar di Indonesia, Bogor: Puslitbang Biologi – LIPI.

Yuzammi and Hidayat, S. (eds) (2002) The Unique, Endemic and Rare Flora of Sulawesi, Center for Plant Conservation – Bogor Botanic Garden, Institute of Indonesian Sciences, Bogor, Indonesia, pp. 220.