Land-use Changes in Mount Papandayan: Its Associated Impacts on Biodiversity and Carbon Stock

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ABSTRACT
Given the fact that most lowland forests in the highly populated island of Java have been converted to other uses, the mountain forests play a critical role in providing key ecosystem services such as biodiversity maintenance and partial stabilization of climate through carbon sequestration. This paper assesses the extent to which land-use changes in Mount Papandayan happening during 1994 – 2001 has resulted in loss of forest habitats and carbon sequestered in vegetation. The assessment was done by analyzing the data derived from biodiversity survey for plants and birds, field-measurement of carbon stocks, remote sensing, and interview. The remote sensing method (using Landsat) was used to quantify the extent of deforestation. In order to estimate carbon stock and its changes in the landscape, we have developed a statistical model based on the correlation between the spectral characteristics and field-measurement of carbon stocks. The results indicated that the mixed-forest of Mount Papandayan had high diversity of plants and birds. Deforestation mainly due to conversion to agricultural fields has been instrumental in causing the loss of such diverse habitat. During 1994-2001, around 2,700 hectares of forest have disappeared with the associated loss of carbon of more than 800,000 tons. This paper will also highlight the implication of this finding to the ecosystem management in order to conserve the remaining and restoring the forest.

Keywords: Biodiversity, carbon stock, land-use change.

1. INTRODUCTION

Conversion of natural forests into to agriculture fields has been one major source of deforestation in Indonesia, which leads to decreasing the ecological role of forests in providing key ecosystem services such as biodiversity maintenance and partial stabilization of climate through carbon sequestration. Both species diversity and ecosystem diversity are important component of life supporting system providing water, clean air, and preventing erosion as well as floods. Forest also plays an important role in the global carbon cycle because it stores a large amount of carbon in biomass and soil (Falkowski *et al*., 2000).

In highly populated island of Java, most lowland forests have been converted to other uses (Adi *et al*., 2004), therefore mountain forests play a critical role in providing those key ecosystem services. Despite their critical role, however, the mountain forests in many parts of Java are currently facing serious threats leading to forest degradation and deforestation. Mount Papandayan in West Java is one of the mountain forest ecosystems experiencing that problem.

This paper aimed to assess the extent to which land-use change happening in Mount Papandayan region during 1994-2001 has resulted in loss of forest habitats and carbon sequestered in vegetation. It presents the summary of findings from three studies conducted in the region, i.e. biodiversity assessment (Sulistyawati *et al*., 2005), carbon stock assessment (Ulumuddin *et al*., 2005), and management assessment (Zuhri, 2007).

Study Site

This study covered the forested area and a small extent of grassland in Mount Papandayan region and three villages in the neighbouring areas. Mount Papandayan is an active volcano located in the southern part of West Java Province, Indonesia. The last major eruption occurred in 2002. Its peak is located at 07^{o}19’42’’S and 107^{o}44’00’’E with the elevation of 2,675 m asl. Administratively, it belongs to the Garut Regency (eastern part) and Bandung Regency (western part). Almost all forested areas in Mount Papandayan have been designated as Nature Reserve in which the major type of vegetation is mixed forest. In the outskirt of the Nature Reserve there is production forests planted with pines, *Altingia exelsa* (rasamala) and *Agathis damara* (dammar) as well as tea plantation.

2. MATERIALS AND METHODS

Biodiversity Assessment

The biodiversity assessment was conducted for plants and birds. The measurement for plants was conducted in three vegetation types, i.e. crater vegetation, mixed forest, and grassland. The sampling plots for plants were nested; size of the outermost plot was 20 x 20 m2 (for trees with DBH >= 10 cm) enclosing four 5 x 5 m2 plots (for trees with DBH < 10 cm, shrubs and climbers). A 1 x 1 m2 plots in each 5 x 5 m2 plots was set for measuring herbs. The data was analyzed to calculate species richness and diversity.

Bird survey was conducted in the crater vegetation, the mixed forests and forest areas near the edge of the Nature Reserve bordering with agricultural fields. Bird diversity assessment was conducted using a modified transect method. In this survey, the distance along transect was ignored; instead, the counting of the bird was recorded on 2 hours interval. The total length of observation time was (± 38 hours). This paper only presents the qualitative result, i.e. the number of species and conservation status according Birdlife Red Data Book.

Carbon Stock Assessment

The carbon stock in this study refers to the organic carbon held in the biomass of trees, shrubs, litters as well as in the soil. To estimate carbon stock and its changes in the landscape, we have developed a statistical model based on the correlation between the spectral characteristics and field-measurement of carbon stocks. The remote sensing data used to build the model is Landsat ETM year 2001 with spatial resolution of 30x30 m. Field carbon stocks was estimated using allometric method based on measurements on twenty 30x100 m^2 plots located in mixed forest, forest plantations and grasslands. In each plot in which the coordinate has been identified, a number of spectral characteristics from the Landsat image were extracted and then the model was constructed using stepwise multiple regressions (see Ulumuddin *et al*., 2005 and Sulistyawati *et al*., 2006 for fuller explanation). The best equation for estimating carbon stock at pixel level acquired was

$$C = 29.531\ TM57 - 2.569\ RAT\_7\_B1 + 104.607 \quad (1)$$

C refers to carbon stock (Mg/900 m^2); **TM57** refers to the value of vegetation index calculated as the ratio of band 5 to band 7, whereas **RAT_7_B1** refers to the value of texture measure calculated for band 1 using 7x7 pixel windows. The correlation coefficient for this equation is 0.802. This model was then applied for calculating the landscape level carbon stock in the Mount Papandayan region in 1994 and 2001.

Management Assessment

Deforestation happening in this area can be taken as a sign of the failure of management in protecting the forests. In order to reveal the causes of that problem, a management assessment has been conducted. Data were collected through semi structure interview, direct observation, and literature study. The respondents selected using purposive sampling method and they represented all stakeholders, i.e. neighbouring village community (69 persons), the Nature Reserve officials (10 persons) and other stakeholders (5 persons). The data was subsequently analyzed by qualitative descriptive analysis.

3. RESULTS AND DISCUSSIONS

Plant Diversity

This research found 42 species of trees, 14 species of shrubs, 106 species of herbs and 23 species of climbers (See Sulistyawati *et al*. (2005) for the complete list of species). The plant diversity as measured by both the species richness and diversity varies among the sites (Table 1). For almost all life forms, the plant diversity of the mixed forest was higher than that of the crater vegetations and grassland. Importance of Mount Papandayan for biodiversity conservation can be judged by its high plant diversity compared with other mountain forests in Java of comparable altitude, e.g. in Mount Pangrago and Mount Tangkubanparahu (See Sulistyawati *et al*. (2005).

Table 1
Plant diversity in three-ecosystem types in Mount Papandayan

Ecosystem Type	Trees (d ≥ 10 cm)		Trees (d < 10 cm)		Shrubs		Herbs		Climbers	
	S	H’	S	H’	S	H’	S	H’	S	H’
Crater vegetation	-	-	8	1.54	6	1.2	13	2.13	3	0.6
Mixed forest	35	2.93	28	3	12	1.15	53	2.32	15	2.19
Grassland	-	-	-	-	-	-	26	1.97	-	-

S: species richness; H’: species diversity (Shannon Diversity Index)

Bird Diversity

The number of species found during observation was 73 species from 26 families (see Sulistyawati *et al.* (2005) for the complete list of species) some of them have specific conservation status (Table 2). The number of species found in the mixed forest (41) was higher than in the crater vegetation (16 species). The high diversity of plants and the structural complexity certainly contributes to the high bird diversity in the mixed forest. Mount Papandayan is an Important Bird Area (IBA) as judged by the presence of two endangered species, i.e. Javan hawk-eagle (*Spizaetus bartelsi*) and Blue-tailed trogon (*Harpactes reinwardtii*). Comparison with old record shows that 64 species reported by Hoogerwerf (1948) was not re-found in this study. Conversion of forests into agricultural fields and poaching were likely to play a role in the disappearance of such large number of species.

Table 2
Birds with specific conservation status found in Mount Papandayan

Status	Number of Species
Restricted range	16
Protected by regulations	15
Endangered	2
Near threatened	2

Carbon stocks

Field measurements show that in general the carbon stock in the mixed forest was far higher than in the tree plantations and grasslands (Table 3). The average of carbon stock in the mixed forest was 270.96 Mg/ha, which is quite high compared with that found in forest at Sumber Jaya, West Lampung, Indonesia i.e. 262.82 Mg/ha (van Noordwijk *et al*., 2002).

Table 3
Carbon stocks in different vegetation types

Vegetation Type	Number of Samplings	Average of Carbon Stock (Mg/ha)	Standard Deviation
Grassland	3	63.59	9.79
Mixed forest	10	270.96	80.51
Plantation forest	7	170.43	67.39

Land-use Change in Mount Papandayan Region during 1994-2001

Remote sensing analysis shows that the forested area decreased from 10,283 ha (1994) to 7,581 ha (2001), which is equal to deforestation rate of around 2,700 hectares per year. Our analysis indicated that most forested area have been converted into agricultural fields. The shape of the forested area has also changed. It became more convoluted (Figure 1) as the middle part became narrower. Considering the shape change, there was a real threat that the forested area will be fragmented, if this trend continues.

When the model for estimating carbon stock at the pixel level (equation 1) was applied, it showed that the magnitude of carbon stock at landscape level was around 2,772,575 Mg in 1994. However, this number decreased to around 1,944,151 Mg in 2001 due to forest conversion into agricultural fields. Therefore the carbon stock decrease was 30% in seven years or 118,346 Mg/year.

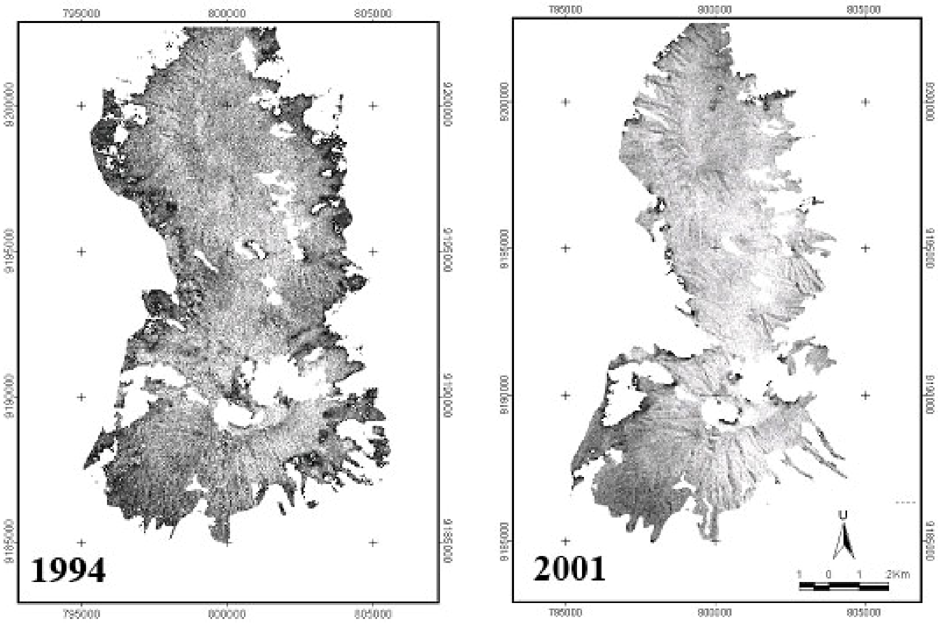

Figure 1 Changes in the forested area in the Mount Papandayan region during 1994-2001

Management Problems in Mount Papandayan Nature Reserve

In general, the main activity contributing to the deforestation in Mount Papandayan was conversion of forest into agricultural fields. Poverty and land scarcity were identified as the among key factors driving the forest conversion. Meanwhile, the Reserve has also been subjected to several forms of forest resource exploitation resulting in forest degradation in some parts of the Reserve, such as poaching, channelling water resource for irrigating the fields, collecting honey, fuel woods, mushrooms, and livestock feeds. The presence of activities inside the Reserve boundary was a clear indication of failure of the management to protect the Reserve. Inadequacy of the number and quality of the staffs, limited equipments and lack of law enforcement to punish the actors seemed to make the occurrence of destructive activities in the Nature Reserve hard to control.

Given the limitation on resources provided by the management, it is unlikely that protection of Reserve can succeed without a form of community involvement. “Collaborative management” is one approach that can be used as a framework for building an effective management of the Reserve by involving relevant stakeholders including the local community. This management approach has bseen adopted in several national parks in Indonesia, e.g. Bunaken, Komodo, and Bali Barat National Park.

The fundamental issue of poverty and land-scarcity in the local community also has to be addressed promptly. We have identified several potential alternative economic incomes, which are less land demanding, that can be developed further for improving the livelihood the local people. These include cultivation of honey bees and mushroom.

4. CONCLUSION

The forested area of Mount Papandayan represents an important mountain habitat harbouring a large number of plants and birds including those with specific conservation status. However, the extent of this habitat has been reduced due to conversion into mainly agricultural fields amounting at 2,702 ha over the period 1994-2001. This land-use change also resulted in decrease on landscape level carbon stock, i.e. from 2,772,575 Mg to 1,944,151 Mg (30% reduction). Such large extent of deforestation prompts to a need for conducting reforestation and establishing a new management approach to restore and maintain the ecological functions of Mount Papandayan forest.

5. ACKNOWLEDGMENTS

We would like to express a sincerely gratitude to Osaka Gas and Rufford Foundation for financing this study and to the Natural Resource Conservation Bureau of West Java Province (BKSDA JABAR II) and PT PERHUTANI for facilitating this study. Sincerely thanks were also conveyed to those who help us a lot in the fields and to Center for Remote Sensing ITB for facilitating the preparation of this manuscript.

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