Global Environment Research Account for National Institute

Evaluation and Forecast of CDM Plantation Influences on Biodiversity（Abstract of the Final Report）

Contact person Kenji Fukuyama
Principle Research Coordinator, (Biodiversity and Forest Health)
Forestry and Forest Products Research Institute
Matsunosato 1, Tsukuba, Ibaraki, 305 Japan
Tel:+81-29-829-8212 Fax:+81-29-873-3799 -
E-mail: fukuchan@affrc.go.jp

Total Budget for FY2004-FY2008 106,018,000Yen (**FY2008**; 18,854,000Yen)

Key Words: Remote sensing, GIS, Acacia mangium, secondary forest, biodiversity, distance

1. Introduction

The Clean Development Mechanism (CDM) was proposed at the third meeting of the Conference of the Parties to the Convention on Biological Diversity (COP3) held in December 1997 as a means to meet reduction targets for greenhouse gas emissions, with the rules set at the subsequently held COP9 meeting. However, there is a possibility that unique organisms, vegetation and ecosystems may exist in the non-forest areas targeted by new CDM afforestation projects. Because CDM afforestation often targets a single, large area, there has been concern about its impact on local biodiversity; Japan, as an executor of CDM afforestation projects, needs to develop scientific evaluation methods for biodiversity and other methodologies to evaluate and predict the impact of CDM afforestation on biodiversity. It is also important in CDM projects to develop silvicultural methods that aid in recovering biodiversity as a measure of restoring deteriorated rainforests, in addition to acting as a measure for combating global warming.

2. Research Objectives

a) Vegetation Survey, GIS and Satellite Data

The objective of this research was to clarify the influence that distance from natural forest had on the biodiversity of surrounding secondary understory vegetation by producing forest cover maps using ground truthing data and satellite image analysis in order to evaluate differences in distance from primary forest which acts as a source of seed.

b) Insects

In this study, the diversity of butterflies (that interact with plant diversity), the diversity of dung and carrion scarabaeid beetles (that interact with mammals and provide various ecological services (Nichols et al., 2007)) were investigated and compared in CDM afforestation model study sites, including Imperata cylindrica grasslands, plantations of *Acacia mangium* (hereinafter referred to as *Acacia* plantations), and natural forests. Based on the results, the impact of afforestation was evaluated.

c) Parasitoid Wasps

To understand the impacts of forest fires and the effects of Acacia plantations on forest ecosystems and biodiversity, assemblages of parasitoid wasps as an indicator group of the diversity of forest vegetation and arthropods (Hilszczański et. al. 2005, Sääksjärvi et. al. 2006) were compared among Imperata grasslands, Acacia plantations, secondary forests, and natural forests.

To understand the impact of landscape and vegetation factors on the function of secondary forests in supplying endemic species to plantation forests, we investigated the spatial changes in the assemblage of parasitoid wasps along a gradient from unburnt to severely burnt forest areas, using SPOT satellite images for analyzing landscape structures.

d) Mammals and birds

Whether plantations in the course of the CDM project can play a key role in conservation and restoration of species diversity may be highly dependent on plantation design at the landscape level. For example, we could establish ecological corridors which connect remaining forests as stepping stones for wildlife. Such corridors would affect tree species distributions by influencing the travel of seed-dispersing wildlife species, and thus CDM plantations could play an important role in the conservation of biodiversity. We attempted to assess species diversity both of the targeted areas and the surrounding areas to select suitable places for CDM plantations, and to develop effective monitoring methods.

3. Methods

a) Vegetation Survey, GIS and Satellite Data

1) To make a base map for evaluating the landscape level biodiversity, we gathered Satellite images taken in 2003 and 2005 and made a land use/cover map. A Spot 5 image taken on Feb. 27 2003 was used to make a ground survey map, which was classified by the unsupervised classification method. We conducted a ground survey in Dec. 2007 and collected ground truth data, including photo images with position information.

2) A transect (length 1800m) was established from unburnt remnant logged forest at the edge of Sungai Wain protection forest to heavily burnt forest. These forests had been burnt several times since 1997. The line plot started from S1.04.00, E116.53.18 and stretched southeast. Thirty-eight subplots (10 x 10 m) were set every 50 meters. Distance from the starting point was used to designate each plot.

b) Insects

1) Study sites: For butterflies and for dung and carrion scarabaeid beetles, several study sites located 10-30 km north of Balikpapan, East Kalimantan, Indonesia, were selected in grasslands, *Acacia* plantations, burnt natural forests, and intact natural forests of the Sungai Wain Reserve Forest (SWRF) and Bukit Bangkilai Reserve Forest (BBRF). Surveys were also conducted in one cattle pasture for dung and carrion scarabaeid beetles. We also conducted a study using a transect starting from an intact remnant forest free from fire to an *Acacia* plantation through burnt natural forests (called Remnant-Transect (RT)), to evaluate the function of the burnt natural forest as a corridor between the intact natural forest and the plantation.

2) Butterflies: In 2004 and 2005 we collected butterflies several times with insect nets along a transect set inside and on the edge of an intact natural forest in the SWRF, in three Acacia plantations, and two grasslands, over a period of 2 hours using two persons as collectors. In 2006 and 2007 we also collected butterflies along RT and totalled butterflies collected every 100 m.

3) Dung and carrion scarabaeid beetles: A crush-board trap was set up by driving a plastic cup in the ground so that its opening was level with the ground. Then, two B4-size transparent plastic sheets crossing over each other were mounted on the cup, upon which a top was placed. Each cup contained a glass bottle with a perforated lid (6 holes, each 5 mm in diameter) containing propylene glycol. Human excrement (10 g) or raw fish (30 g) was used as bait. Captured insects were collected five days after trap installation. Traps were distributed along a 90 m transect at an interval of 10 m, alternating human excrement and raw fish as baits. We collected the dung and carrion scarabaeid beetles at each site over different years between 2004-2008 and at RT in 2007 and 2008.

c) Parasitoid Wasps

Research plots were set up in Imperata grasslands (5 plots) formed following forest fires, Acacia plantations established in grasslands (5 plots), burnt secondary forests (2 plots), and unburnt natural forests (2 plots), in or near the Sungai Wain Forest Reserve, 10-30 km north of Balikpapan, East Kalimantan, Indonesia. We sampled braconid parasitoids (Yu et. al. 2004) by sweep netting at each plot. Abundance, species richness, and species composition of braconids were analyzed using EstimateS and PC-ORD.

We placed plots at 100 m intervals in naturally regenerating secondary forests along the 1.1km census line located from an unburnt forest into an area intensively burnt in 1997/98. Landscape structure around the census line was analyzed with a SPOT satellite image taken in 2003. We sampled braconid parasitoids in December 2006 and 2007. Abundance, species richness, and species composition (NMS scores) were analyzed in relation to distance from the unburned forest and vegetation parameters with GLM.

d) Mammals and birds
As a complementary index of avian species diversity and abundance, we trapped birds in secondary forest patches using mist nets in July (non-breeding season) and December (breeding season). To clarify the relationship between forest type and habitat stability, we compared the recapture rate among plantation, secondary forests, and grassland. For mammals, we surveyed fauna using a passive infrared camera and traps in *Acacia* plantations, Macaranga forest patches, and open land in the Bukit Soeharto Education Forest, and compared biodiversity using new statistical methods that consider ecological, phylogenetic characteristics, and rarity of species.

4. Results and Discussion

a) Vegetation Survey, GIS and Satellite Data
1) We found that the 2003 Spot 5 image was not an appropriate way to classify artificial plantations, because at that time, some of the plantation forests were only just planted or were at a very young stage and were difficult to identify. We used another SPOT 5 image taken on June 19 2005 which was able to detect most young artificial stands and made a base map for biodiversity evaluation using a supervised classification method. Mature forests covered less than 10% of our target area (about 40km square) with 30% being secondary forests affected by fire in 1998. Artificial forests, agricultural lands, and grass lands covered 5%, 15% and 25% of the area, respectively. If we consider grasslands as candidate sites for CDM plantation, its area can be estimated as 5 times that of existing plantation forests.
Aerial photos taken in 1981, LANDSAT images taken in 1992 and 1998 and a SPOT5 image from 2005 were used to analyze the transformation of land use/forest cover around Sungai Wain Reserved Forest (SW) and Bukit Bangkirai Forest (BB). In 1981, mature forests widely occupied the area and SW and BB were united as a single large forest. Due to rapid development/cutting activities during the 1980's, mature forests decreased and SW and BB became connected only by a narrow corridor. A very large forest fire in 1998 affected most of these forests. Mature forest was limited to the core of SW and BB forests by 1998, with remnant forests found around the core of SW and BB by 2005. Rapid changes in the history of the target area are an important basis on which to understand the biodiversity of these areas.

2) Species richness per 16 square meters of each forest type was highest in low-level damaged secondary forest (61.92), followed by Sungai Wain Forest Reserve (50.0), grassland (31.25), high-level damaged secondary forests (26.98), and lowest in plantation forests (19.58).
Number of species per ha that re-colonized within three years totalled only 6 species, consisting of two herbs (*Axonophus compressus* and *Scleria levis*), two ferns (*Blechnum orientale* and *Lygodium flexuosum*), one shrub (*Ficus glandulifera*), and one tree, *Macaranga hypoleuca*. The results of NMDS ordination showed plantations were still high in disturbance level and far different in composition to natural forests. Vegetation distance between plots and the distance between plots were significantly correlated. Three tree species (*Cotylelobium lanceolatum*, *Pternandra coerulescens*, and *Syzygium urceolatum*) were biased to plots near natural forests, while in contrast, many ruderal species were biased to plots distant from the natural forests. Consequently, it may take a very long time to recover natural forest species by planting only *Acacia mangium* in degraded lands.

b) Insects
1) Butterflies: Species richness was highest in the intact natural forests followed by the Acacia plantations, and abundance was highest in the Acacia plantations followed by the intact natural forests. Butterfly diversity was highest in the intact natural forests. The plantations contained a large number of forest species, while the grassland had only a few of these. However, the communities

differed greatly between the intact natural forests and plantations. Based on these results, it is suggested that afforestation increases the number of species of insects and contributes to the restoration of forest species that do not inhabit the inner areas of intact natural forests. Collection along RT showed that many species in the intact natural forest also inhabited the burnt natural forest. This result suggested that, next to plantations, burnt natural forest was important as a source of supply of forest species.

2) Dung and carrion scarabaeid beetles: The number of species was highest in the intact or burnt natural forests and did not differ between plantations and grasslands. However, species common in natural forests were also present in plantations, but not in grasslands. Abundance was highest in cattle pasture, followed by natural forests, but did not differ between plantations and grasslands. A community structure analysis using NMS allocated plantations as intermediate between natural forests and grasslands. Based on these results it is suggested that while afforestation does not increase the number of species of insects, it contributes to the restoration of the community structure of natural forests. Collection along RT showed that both species richness and abundance declined in accordance with the distance from the intact natural forest. Both species richness and abundance were lower in the valley than on the ridge.

Findings in this study suggest that afforestation increases the local diversity of insects when compared with grasslands left as they are, and that CDM afforestation contributes to the increase of biodiversity. Our results are consistent with a study reporting that afforestation promoted the restoration of native tree species (Otsamo, 2000) and studies reporting that the diversity of moths and dung beetles were high in plantations (Nummelin and Hanski, 1989; Holloway et al., 1992; Chey et al., 1997; Estrada et al., 1998; Harvey et al., 2006). However, it is still considered difficult to use afforestation to restore rare forest species that are decreasing due to the loss of natural forests, since community structure was very different between natural forests and plantations.

c) Parasitoid Wasps

Both abundance and species richness of braconid parasitoids markedly declined in Imperata grasslands, but increased somewhat in mature Acacia plantations, indicating that Acacia plantations in grasslands promote the recovery of arthropod diversity. DCA ordination also showed that species composition of parasitoids in Acacia plantations was intermediate between natural forests and grasslands, verifying that Acacia plantations drive the insect assemblages of grasslands to native natural forests to some degree. Recovery after plantation establishment as well as declines after forest fires were both more distinctive in parasitoids of wood borers than for those of herbivores.

Abundance and species richness of braconid parasitoids decreased exponentially with distance from unburnt forest stands in both 2006 and 2007, and species composition analyzed with NMS ordination changed along the same gradient. Parsitoids were also highly affected by species richness of canopy trees, which increased in forest remnants remaining along streams that were probably unburnt. For conservation and promotion of regional biodiversity in degraded forests areas after fires it is important to make appropriate landscape designs for CDM plantations, especially considering the location of large and small unburnt remnants and their connections, and which can be rather easily identified using satellite images.

d) Wildlife and birds

Avian diversity was poorest in grasslands, medium in plantations and richest in the secondary forests according to the complexity of forest structure. In May-July, the number of captured bird species were 7, 8, 11, 19, 21, 21 and 18 species in grasslands, immature and mature plantations, small, medium, large-size, and lightly burnt secondary forests, respectively. The diversity indices were similar among small, medium and large-size burnt secondary forests, and lightly burnt secondary forests, but species compositions were very different among these four forest types. The dominant species in secondary forests was *Arachnothera longirostra*. However, *Pycnonotus goiavier* was dominant in the grasslands and plantations. It was not captured so frequently in secondary forests and never caught in the large-size and lightly burnt secondary forests. On the other hand, the other bulbul species were caught only in large and lightly-burnt secondary forests. Bulbuls are a likely good indicator of avian diversity. The recapture rates were more than 10% in middle- and large-size burnt and lightly-burnt secondary forests, but less than 5% in small secondary forests, which were more similar to plantations and grasslands. In the middle and large size burnt and lightly-burnt secondary forests, there may be more resident individuals probably because of abundant food availability. This suggests that small secondary forests and plantations cannot be the source of this diversity alone, although they were better than grasslands. Such habitats can contribute to maintaining avian diversity in combination with larger secondary forests. In the secondary forest, we caught 91 individuals (21 species) in the non-breeding season and 40 individuals (14 species) in the breeding season. The relationship between forest structure and avian diversity showed that the complexity of structure in the mid-layer appeared to relate to the diversity index.

Our passive infrared cameras and traps caught 23 and 8 mammalian species, respectively. The results showed that mammalian diversity was low in open land, and the primary and secondary forests showed a relatively high diversity compared to that in plantation forests. Compared to the fauna in the non-burnt forest, there was no difference in the number of middle and large mammalian species. However, 2 small species *(Lariscus insignis* and *Trichys fasciculata*) were not caught in the burnt forest, indicating these 2 species were vulnerable to forest fires. We also found that mammals functioning as seed dispersers still remained even after forest fire. Further, more than 78% of local people were able to distinguish 3 species of primates, and the results of the questionnaire showed a geographical gradient in the distribution of these species. These results assured us that information from local people was useful for monitoring mammalian fauna.

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