ISSN 1341-562X

JOURNAL OF FOREST PLANNING

Vol. 10 No. 1
April, 2004

Japan Society of Forest Planning

JOURNAL OF FOREST PLANNING

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Manuscripts should be submitted to following Editorial Office.

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Subscription Information

JOURNAL OF FOREST PLANNING is pubished halfyearly. The subscription for 2003 is 5,000 yen and the single issue price is 2,500 yen. Subscription orders can be sent to following office.

Toho Shoten
343 Yamabuki-cho
Shinjuku-ku, Tokyo 162-0801, Japan
Phone: +81-3-3269-2131, Fax: +81-3-3269-8655
http://www.toho-shoten.co.jp

JOURNAL OF FOREST PLANNING **is published by**
Japan Society of Forest Planning
Tokyo University Forest in Chichibu
1-1-49 Hinoda-cho, Chichibu, Saitama 368-0034, Japan

JOURNAL OF

FOREST PLANNING

Vol.10, No.1 April, 2004

Japan Society of Forest Planning

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Articles

Article

Community Forestry and Its Impact on Rural Livelihood - A Case of Chaubas-Bhumlu Community Forest, Kavrepalanchok District, Nepal -

Subash Gurung[*1], Takashi Iguchi[*2] and Katsuhisa Ito[*3]

ABSTRACT

More than two decades have been passed since the introduction of the people participatory community forestry in Nepal. This paper explores changes in rural livelihoods with changed circumstances that have been largely brought by the community forestry. Chaubas-Bhumlu community forest of Middle Mountain was taken as a case study for the analysis. Based on the case study, the situation before community forestry intervention and the present situation after Community forestry have been analyzed at the household level. Households as units of analysis were chosen based on the systematic random sampling and were interviewed with structured questionnaire. Two key informant groups, one consisting of ten village elites and other ten elders, were formed and were discussed to access the community level information. The result indicates that community forestry is successfully achieving its objectives from resources demand fulfillment to increased economic benefits. However, economic improvement has been visible at the community level but not at the household level. It means only the access to resources use is not enough for the household economic development. On the other hand, the farm activities are gradually declining with increasing off-farm activities. This situation has led the "complex" farming system from a stable state, though stagnant, to a vulnerable state. This paper concludes (1) the present community forestry model lacks mechanism to utilize the income from the forest to households' economic benefits; (2) the farming system which has a major role in household economy has not been integrated to and supported by community forest; (3) the socio-economic development activities should go simultaneously with the development of community forest to multiply the total benefit from forest.

Keywords: Community development, Community forestry, Forest products market, Off-farm income, Rural livelihood

INTRODUCTION

Rural people's livelihood strategy is primarily based on their accessibility to the natural resources. The land and the forest resources are the determinant factors for the quality of rural livelihoods, which possesses ethical, economic and environmental value to the rural people leading to food security. The forest products provide diversity to the rural economic activities and security when times are difficult (SOUSSAN, 1995). These importances of diversification have not been realized by the market based commercial forestry as well as by the government controlled forestry policy. Instead, the market based enclave commercial forestry model has mere concentrated on demand and supply for market. This has enhanced the development of man-made forest. The enclave commercial forestry development model has not been found to use forest's multiple benefits in the welfare of rural households; instead, it has widened the gap between poor and rich people (WESTOBY, 1987). The state led forestry policy was substantially practiced by state control mechanism to increase state revenue, e.g. the Private Forest Nationalization Act, 1957 in Nepal. As consequences, people were forbidden to access the natural resources and most of the people managed indigenous techniques of forest management were vanished

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(Gurung, 2003). This has resulted the open access condition leading to reckless deforestation and destruction.

However, the realization of these facts during 1970s led to a paradigm shift from enclave commercial or state controlled forestry development model to people managed participatory forestry. As a first attempt, Food and Agriculture Organization (FAO) crystallized the concept with the release of the landmark FAO publication *Forestry for Local Community Development* in 1978, which defines community forestry as "Any situation, which intimately involves local people in a forestry activity" (Gillmour *et al.*, 1991). This has become the concrete and operational definition for social or community forestry. Since then, forestry objectives has gradually shifted to the over all socio-economic development of the communities beyond mere daily forest resources demand fulfillment of the communities. Now a days, Community forestry refers to a wide range of activities, which links rural people with forests and trees, and the products and benefits derived from them. Recently, organizations such as World Bank and FAO have been debating on the policy reform to bring public forest resources to mainstream market economy by investment, privatization, taxation, and other market oriented mechanisms.

The community forestry policy has been adopted since 1978 in Nepal with broader objectives on reduction of poverty and environmental degradation. Economical and environmental sustainability of the natural resources use is possible through local people participation, as a common property natural resources management, is the main thrust of the community forestry model. By 2001, the government had handed over a total of about 847,000ha of state-owned forests to over 10,969 community forestry users groups (MIS, 2002). People based forest resource management institutions have sufficiently undertaken the forest management at the grassroots level. The forest policies have been taking account of peoples' abilities and then, easing the rules and regulation of community forestry.

Almost two and half decades have past since the introduction of community forestry in Nepal. To this regard, community forestry should have impact on people's livelihood. Even if it has less direct impact on household, the resources use pattern has been changed due to its intervention, which makes differences in the household's livelihood.

The community forestry intervention has brought some changes at different levels. Production surplus in forest products indicates that communities are not likely to absorb potential supply from forests. This can be considered as an achievement. Unfortunately, there is a lack of simultaneous socio-economic development. Communities are still struggling due to declining agriculture production characterized by traditional production techniques and subsistence orientations. Consequently, the communities are still giving importance to basic subsistence forest needs like firewood, fodder, litters, etc. These scenarios have been illustrated below from the available facts collected from the field.

METHODOLOGY

Research Hypothesis

The research attempts to explore the impact of community forestry on the livelihoods of the rural people. The main hypothesis is that the changes in means of production lead to the changes in household livelihood, where people adopt significantly different living strategies. Community forestry functions as a means of production to provide easy access to natural resources. This leads to socio-economic changes resulting in changed household welfare. To see the significance of the project, the two situations before project "Previous situation" and after project "Present situation" has been compared with the different livelihood activities.

Research Area

Chaubas-Bhumlu is a middle mountain located in Kavrepalanchok district (30 km NE from the capital city Kathmandu), and has altitudinal range from 1,700 m to 2,600 m above mean sea level. Latitude ranges from 27°35'-27°39' North and longitude ranges from 85°47'-86°02' East. The community forestry has been operating under Nepal- Australia Community Forestry Project (NACFP) since 1978 and is considered as a pioneer project in Nepal.

The community forestry policy has been adopted mainly in middle mountain of Nepal. Since forest possesses long economic cycle, i.e. from investment to production, its impact on rural livelihood still needs more time than its actual economic cycle. The research area has been chosen based on the two main characteristics, 1) the area representative of the middle mountain where most of the community forestry lies, and, 2) the community forestry has been undergoing annual sustainable harvest.

Research Method

The area was purposely chosen, as it is a pioneer community forestry area in Nepal. The household was taken as the unit of analysis. The household heads were the primary source of information. Of the total number of households (N = 298) in this site, sample households were selected using *Systematic Random Sampling* based on the Forest Users Group's (FUG's) members list. All members' serial numbers divided by two (interval = 2) were taken as the sample (n = 149). Household heads of sampled households were interviewed with structured questionnaire. Eight households who were excluded from random sampling but were playing important role in the FUG were also interviewed.

Two key informant groups, one consisting of village elderly people, and the other of village elites, with 10 members each, were formed to conduct discussion and data were collected regarding the history of the area and other related information. The elites were three school teachers, two village leaders, two local level government forest officials, and three social workers. The elders' people were chosen voluntarily who were old aged mostly above 70 years old and have historical knowledge of village. In absence of primary data regarding the previous situation i.e. before the establishment of community forest, secondary information has been utilized to make comparison.

PREVIOUS SITUATION

The dense natural forest that had been used by the local people for their basic subsistence needs was cleared by the state during 1950's and had gradually changed to pasture land. Since then, the pastureland, cultivated land, and private forest were the main sources for their livelihood. Both private and national forest were used for forest resources. The nearest national forest was about 5 km away from the village. One had to devote around six hours to 8 hours for collection of a head load of firewood or fodder. Additionally, access to national forest was illegal and villagers had to acquire permission from government officials whose field visits were very rare.

Agriculture was subsistence that constituted difficult and less rewarding farm practices such as cultivation of steep and unproductive land and ranching of large numbers of animals, almost the double than in the recent past (Collett, *et. al*, 1996). Rain-fed maize was the major crop grown, as most of the land was non-irrigated. However, few households who possessed both non-irrigated as well as irrigated land had better quality of living with varieties of farm products. Livestock, besides its direct household's benefit i.e. meat, milk and milk products, were used to maintain farm productivity, where *in-situ* manuring in crops field was widely practiced.

The village economy was characterized by agro-livestock based contemporary economy limited to the village and was much less dependent on markets. Livestock had greater value than crops. Exchange of labor, goods, etc, among farm households was of a typical practice. Market was functioning only for their needs that could not be met on the farm. Farmers sell some of their products so that they can buy off-farm products. Fig. 1 shows the household livelihood and resources flow. On-farm activities were the main sources of the village livelihood. Off-farm activities were not in practice. Scarcity of forest resources was high. The households seemed to value their forest resources same as the food crops.

The village had less infrastructural development like road, school, etc. They had only one primary school in Bhumlu area. Villagers usually did not send their children to school. There was only one foot trail linking to capital city and was made to link Everest base camp.

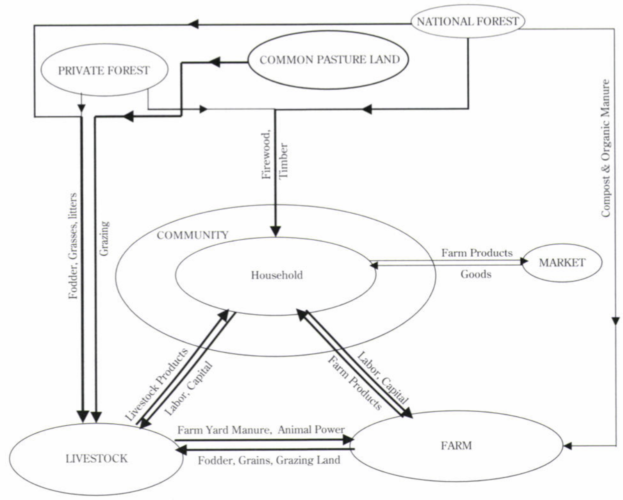

Fig. 1 Flow of Resources in a Household in the past
Note: Relative thinness and thickness of the arrow indicates low and high resources flows respectively Source: Field Survey, 2001

PRESENT SITUATION

This situation gradually changed due to the intervention of the community forestry since 1978. The pastureland has changed to community forestry and the national forest has changed to protection forest. Four community forests have established by FUGs. The management of the forest has been done by the active participation[*4] of the group members.

The total forest area (222.9ha) has been divided into many management blocks. Around 80% of the forest is pine and rest is locally available broad leaf. The average age of pine is 20 years and about 1,400 stems per ha have been stocked. The timber harvesting is being done periodically since 1996. About 38,226 cu. ft of timber have been harvested within last five years. These activities are based on the operational plan prepared by the FUGs. However, the government banded tree felling in 1999 disrupted the harvest.

Socio-economic situation of the village has also been changing over time. The community forestry has started to pay back to some extent both in cash and in kind. The production of forest resources has largely exceeded the basic household demand of the community. The income of the village has substantially increased whenever they used marketing opportunities. As a result, FUGs have established a sawmill with the income from their own forest. This can be

[*4] FUG will decide the time to care and harvest of forest. Each member household participates in the activities for which they will receive wage. The care and management are being done with the proper silvicultural advice from the technician provided by the government.

Table 1 Dependency over forest resources

Type/Sources	PF		CF		PF+CF		NR		Total
	HH	%	HH	%	HH	%	HH	%	
Timber	32	20.4	51	32.5	32	20.4	42	26.8	157
Fodder	94	59.9	12	7.6	40	25.5	11	7.0	157
Firewood	7	4.5	35	22.3	112	71.3	3	1.9	157
Bedding material	31	19.7	68	43.3	51	32.5	7	4.5	157

(Note: PF= Private Source, CF= Community Forest, NR= No Response, HH= Household),
Source: Field survey, 2001

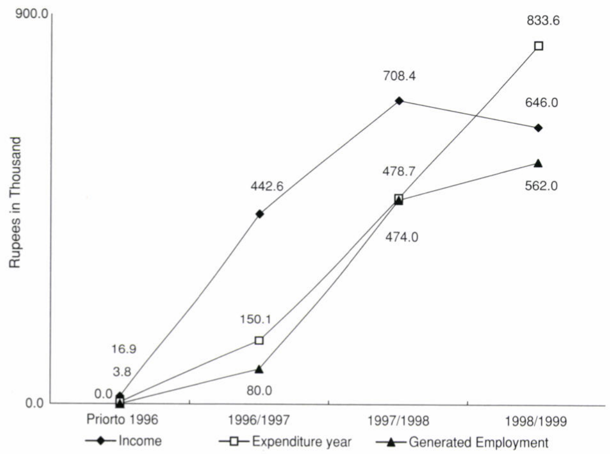

Fig. 2 Income, Expenditure, and Employment by FUG
Source: NACRMP, Discussion Paper, 2001

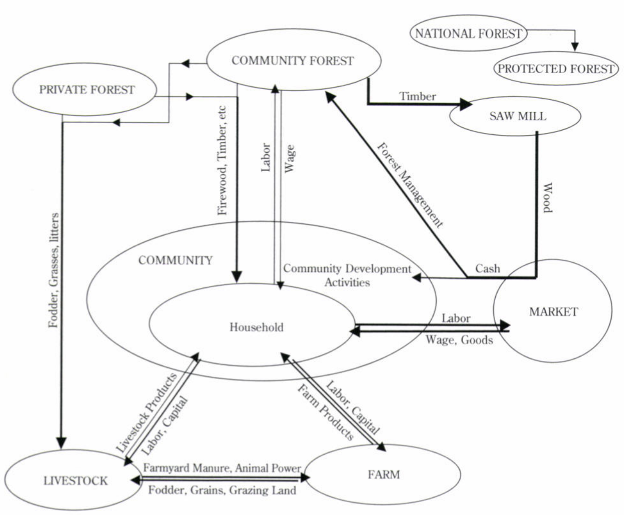

Fig. 3 Flow of Resources in a Household at Present
Note: Relative thinness and thickness of the arrow shows low and high resources flow respectively
Source: Field Survey, 2001

considered as a significant achievement. The village economy is going through a substantial economic transition. Fig. 2 shows that about NRs[*5] 1,813,900 have been transacted in the last four years due to the forest harvest by FUGs. The expenditures shown in the Fig. 2 includes investment on forest management, sawmill establishment, and infrastructure development of the villages like school building, sawmill construction, and road construction. These activities have also generated employment in the village. The local level generation of employment opportunities has reduced the seasonal labor migration to some extent. The Fig. 3 shows the present situation of flow of resources in a household.

DEPENDENCIES ON FOREST RESOURCES

Community and private forest are the main sources of forest resources for most of the household, where firewood, fodder and bedding material are the most commonly harvested non-timber forest products followed by timber.

Timber

Timber is the most accessible forest product for the sample households. Of the total households, 32.5% are depended solely on community forestry, 20.4% on community forestry as well as private forest, followed by 20.4% solely on private forest (Table 1). However, the timber requirement is relatively low (per capita 0.40 cu. ft as per NO-FRILLS, 2000). Due to this, 26.8% of the sampled households have not responded.

Fodder

The community forestry has been providing fodder to only 7.6% of households (Table 1). About 60% of the households harvest fodder from private forest only, while the rest (25.5%) depend both on private as well as community forest. The result is consistent with other studies (MALLA, 1993) that show households' high dependency on private

[*5] Nepalese Rupees

forest for fodder. A large number of household (45% for tree fodder and 36% for grasses) spend 2 to 3 hours, only 2% of households spend more than 3 hours and 11% spend below an hour to collect a head load of fodder (Table 2).

Firewood

About 97% of the household energy comes from forest in the study area where a household harvests 138 head load (20kg/head load) of firewood on an average annually (KAYASTHA, *et. al.*, 2002). Of the sample household, 71.3% depend on community forest and private forest for firewood, 22.3% depend solely on community forestry and only 4.5% depend solely on private forests (Table 1). Similar results were found by Malla, (19923 where the dependency on private forests was 70% about a decade ago. The data shows, 57% of the sample households spend 1 to 2 hours, 18% spend more than 2 hours, and only 21% households spend less than an hour to collect a head load of firewood (Table 2).

Bedding Material

The tree leaf, grasses, etc. are used as a bedding material for livestock. The bedding material is finally used in the farm as compost mixed with animal dung. Over 43% households collect bedding materials from community forestry, 32.5% household collect from private sources as well as community forestry, and 19.7% of households depend solely on private forests. Prior to the introduction of community forests, households solely depended on private sources for the bedding material.

The above statistics show a gradual shift in households' dependency for different purposes from private sources to community forestry. Firewood and bedding materials are relatively easily accessible resources than fodder. This is partly due to lack of fodder in community forests. About 78% of the household identified fodder as the most scarce forest resource followed by bedding material by 12% (field survey, 2001). The lack of fodder in community forests has to do with the nature of plantation dominated by pine trees. However, to cope with alarming problem of fodder, people have started to plant fodder trees on their private land.

SOCIO-ECONOMIC CHANGE

Social Change

Users group approach appears to be restructuring the socially stratified community to a more rational and collective action oriented institution i.e. common property natural resource users and management groups. Ethnically community is divided into Tamang, Brahmin/Chetri, Pahari, Kami/Damai/Sarki, and Newar, which are represented 47%, 22%, 22%, 7% and 2% respectively in the FUGs. This has been an honor to the socially deprived and different believers bringing them a sense of equality and decision-making authority for use of local resources. However, the representation of socially deprived ethnic groups is still low in different level of decision-making bodies and other activities. This shows that the society is still ingrained in the traditional social structure.

Economic Change

The previous farm based subsistence economy is gradually changing and off-farm income is playing the central role in the household economy. 53% of the total household income is derived from off-farm activities (Malla, 1994). Labor is the main off-farm activity whereas businesses have been reported to some extent in the city. The labor migration has increased by 10-12% in 2000, while compared to 1995 (Eijnatten, *et al.*, 2001). One member from each household on an average has been migrating to city for some kinds of job. Of the total farm income that accounts 47% of total household income, about 20% is governed by forest-related income and rest 80% is by agriculture, livestock, local labor, and other sectors. Livestock items are the major goods marketed for cash but no agriculture products are being exported (Kayastha, 2002). Regarding the direct economic benefit of community forestry to the household, about 43% households have earning about Rs.1500 annually from forest-related employment opportunities (Field survey, 2001). This trend has

Table 2 Time needed to collect a head load of fodder and grass

Resources type/Hrs		Below one hrs		1-2 hours		2-3 hrs		Above 3 hrs		NR		Total
		HH	%	HH	%	HH	%	HH	%	HH	%	
Fodder	Tree	18	11.5	56	35.67	71	45.22	3	1.91	9	5.7	157
	Grasses	16	10.2	47	29.93	56	35.67	33	21	5	3.2	157
Firewood	Leaf Twigs	33	21	90	57.32	24	15.29	4	2.5	6	3.8	157
	Main stem	2	1.3	49	31.21	7	4.46	–	–	99	63	157

Note: HH= Household, Hrs= Hours, NR= No Response, Source: Field survey, 2001 been reducing seasonal migration to some extent. However, this has still been only an occasional source of income. In other words, households could not take it as a stable source of income.

Educational Change

The changing scenario of the study area has also been observed in education status. In the last five-year period, 44% and 12% increase has been observed in male and female literacy respectively. Male literacy increased to 73% in 2000 from 44% in 1995 (EIJNATTEN, *et. al.*, 2001). Similarly, female literacy in 2000 reached 40% from 28% in 1995. The school enrollment of the children has also increased by 31% during this time. This shows a rapid progress in literacy in the village in the last five years. However, this recent progress has yet to be impacted the household economy.

DISCUSSION

The village has changed not only with respect to the forest sector but also with respect to other sectors. In other words, people livelihoods have been influenced substantially by forestry activities. Easy access to some of the forest resources has positive impact on household welfare. The upgrading literacy rate might be an effect of changed in household welfare. People who spent most of their time in grazing and forest resources collection have leisure time thereafter. It appears that they have used their surplus time in education and in activities in other sectors.

Institutional development activity such as FUG is also one of the factors influencing the social change. This has forced socially and ethnically divided community to mainstream development interest group. This aspect of community forestry appears to have lessened the value of traditional social boundaries.

Timber is the major exported items from the village. Due to this, the economic transactions have increased which shows the positive impact of community forestry on the village economy. However, the exports from farm products have not been observed (KAYASTHA, *et. al.*, 2002). In addition, only 47% household income is from farm activities (MALLA, 1993). It means that farm activities have been declined compared to the previous situation, which was characterized by agro-pastoral based subsistence farming and was not dependent on off-farm. This indicates that the household level of production is still at subsistence level unlike the community level of production, which has a commercial component. As NAIR (1989) points out that economic progress in agro-livestock based economy is largely dependent on the production of surpluses over and above consumption, and their transformation into other goods and services through either trade or investment. So the economic progress in terms of production at household level in the study area is meager. This might be due to (1) pine tree plantations that do not directly support livestock or agriculture activities (2) households' reluctance to upgrade their agriculture as their off-farm income increased substantially, and (3) supportive activities for agriculture or community development that do not synchronize with supportive activities in community forestry in the past i.e. an enclave development of community forestry. In response to the less supportive role of the community forestry to agriculture and livestock due to pine plantation, COLLET, *et. al.*, (1996) in a similar study found that trees on private forest have increase with the introduction of community forestry which has fulfilling the needs of the livestock fodder. However, it must also be noted that marginal landholders' are not able to plant tree in their private land.

The off-farm income is largely characterized by unskilled labor migration to city (MALLA, 1993). However, the community forestry activities mainly forest management and sawmill activities have prominent role on decreasing the seasonal migration. But on the other hand, growth in permanent labor migration is still continuing. According to MALLA (1999), this is largely caused by the rural-urban labor wage differential and also might be due to less secured employment in forest activities in the village. Besides, the low productive agro-livestock system and decreasing farm activities are also important factors in permanent labor migration. Most of the labor migrated are unskilled daily wage labor (78% of the total migrated labor) that is consistent with limited availability of skilled human resources. Recent literacy increase has not impacted much on the skill level of labor as a whole.

With the changed circumstances from different perspectives, the livelihood patterns of the community have also changed widely. Influence of the community forestry is the major factor accelerating the change. Agro-pastoral based livelihood has changed to dependency on market, agriculture, livestock, and to some extent forest. In the main component of the farming system, previous pastureland has replaced by community forestry, which yielded to structural changes in agriculture and livestock patterns. Agriculture has changed to more intensify however decreasing farm activities, and free grazing livestock pattern has changed to stall feed. The decreasing farm activities and surplus working hours made community to divert themselves to off-farm activities. Off-farm income has become an important source of household economy. The growing attractions to out migration as off-farm activities finally resulted to labor scarcity in the village, which again became accelerating factor for lower agriculture production.

These arguments suggest that the earlier developed model of community forestry, which has primarily focused on people's basic forest needs, is not enough to curb the broader socio-economic development of the community. Excess resources for community in one hand and income for community development in other hand seems satisfaction of the objectives sketched by the model. However, the model could not deal about how income from forest trickles to household level, so that socio-economic improvement of household can be achieved.

CONCLUSIONS

With the introduction of community forestry various changes have been observed. With the devolution and decentralization of the right to access forest resources to the community, people seem to have enough resources to meet their basic needs of forestry products. Consequently, households seem to have a tendency to spend more time on education and other social activities. For instance, the school enrollment has been increasing rapidly within last five years. The social differences have markedly reduced due mainly to empowerment of the socially deprived groups.

Substantial economic gain is observed at the community level due to the production from community forestry. However, such an economic impact has less observed at the household level. The lower impact at the household level might be due to (1) weak linkage of investment on community forestry to household level production, and (2) the overall or non-forestry sectors' development are not in tune with the development activities in the forestry sector. It is likely that underdevelopment of non-forestry sectors made communities less responsive to opportunities given by forest development.

Households seem to have been inadequately rewarded for their sacrifice of the pastureland to community forestry. This might have forced them to migrate to city seeking to earn the balance in their household budget. Locally generated employment is the direct economic benefit to households from community forest. However, new employment opportunity happens to be occasional and unstable and therefore, less dependent income sources. The employment generation from community forestry did not impact the permanent labor migration that has been going for at least a few decades. Instead, being less response of community forestry in the farming activities might have adverse effect on farm income. This adverse effect divert household to be more dependent on off-farm income by accelerating the labor migration.

There is a need of FUG's income to be invested in programs, so that people could benefit from market opportunities in other sectors-agriculture, livestock, craft making, etc. Such an investment may help in lowering households' dependency on subsistence agriculture system and may lessen the out migration.

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(Received 3 September 2003)
(Accepted 7 January 2004)

Article

The Analysis of Stand Structure and Growth Characteristics of Natural Forest in Papua New Guinea

Mex Memisang. Peki*[1] and Seiji Ishibashi*[2]

ABSTRACT

This paper discusses the stand structure and growth characteristics of twenty one-hectare plots in selectively cut natural forests in Papua New Guinea. The research sites are Ari, Hawain, Iva Inika, Serra, Sogeram, Manus, Gumi and Vudal. These plots were re - measured to analyze changes in stand structure and growth. Tree species were grouped according to their regenerative characteristics into three species groups, (I) Primary species (P), (II) Secondary species (S) and (III) Primary/Secondary species (P/S). It was found that total diameter distribution showed an exponential decrease pattern from a lower DBH class to a higher DBH class. This pattern is true for P and P/S species, however S species showed high growth in the lower DBH class (P>P/S>S). Recruitment was mostly from P and S species and was high in Vudal plots, while mortality was mostly from P and P/S species. Fire and logging damage was the main cause of mortality. BA gain in Vudal 2 and Serra 2 had the highest increase of 2.34 and 2.09m^2/ha respectively. Gumi 3 and 4 had a high lost of 7.32 and 15.15m^2/ha respectively. Generally high diameter growth for P and P/S species was found to be at a DBH class of 20 to 50cm, high growth for S species was encountered to be at a 10 to 15cm DBH class in most of the plots studied. P/S and S species showed slightly higher growth than P species. Three types of natural forests were proposed from this study based mostly from the diameter transition pattern after selective cutting system. Type I showed an increasing trend from a lower DBH class to upper classes in stands at Ari, Hawain, Serra, Gumi and Manus. Type II showed a decreasing trend from a lower DBH class to an upper class at stands in Iva Inika and Sogeram. Type III showed the highest increase in the lower DBH class with mostly S species going from low to upper classes in stands at Vudal.

Keywords: diameter distributions, species composition, diameter increment, basal area distribution, mortality and recruitment.

INTRODUCTION

The tropical rainforest of Papua New Guinea (PNG) comprising an area of 39.3 million hectares, predominantly covers PNG's 46.4 million hectares. Only 11.9 million hectares are identified as production forests. Natural forests in PNG are decreasing at a rate of 120,000ha per annum through logging, agricultural activities, mining and other land uses (PNGFA, 1998).

Harvesting in the natural forests of PNG is selective. Only merchantable species with diameter breast height (DBH)≥50 cm are felled. Currently, PNG harvests about 4.71 million m^3 per annum of timber from the natural forest. About 2.4 million m^3 of round logs are exported each year. The taxes and tariffs are a very important source of revenue generated to assist the National Government to fund the social services and infrastructure development in PNG. Due to reduction in the resource base, log output within the next ten years may be expected to drop in volume for both log export and local processing (PNGFA, 1998).

Stand dynamics of tropical forest in PNG is very little known in any detail, as is quantitative analysis of stand structure and growth of natural forests. The most important

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point's essential for ecologically based management for sustainable harvest requires knowledge of the following three points;

i . Understanding the characteristics of natural regeneration, density and species composition
ii . Dynamics of natural forest stand structure before and after selective cutting
iii . Effects of selective cutting on the residual trees

Sustainable management of these natural forests for timber production has been somewhat difficult. There are several reasons for this. Firstly, little is known about the ecological requirements of the main commercial species. Secondly, little information is available on the growth and yield of natural forests. There have been very few studies on structure of residual trees after selective logging in PNG (e.g. ALDER, 1999; ABE *et al.*, 2000). Often the structure of primary forest is characterized by a large amount of small trees, i.e. it represents an inversed J-shaped diameter distribution. Growth of natural forest is difficult to predict, because its structure is complicated. However, growth prediction is very important for natural forest management in PNG.

The purpose of this paper is to evaluate the stand structure and growth characteristics of natural forests. The species composition, basal area, diameter distribution, diameter increment, mortality and recruitment are some of the characteristics to be analyzed.

STUDY SITES AND METHODOLOGY

The research sites are located in PNG (Fig. 1). Tables 1 and 2 presents the summary of plot site details and other background information. A total of 20 one-hectare plots in

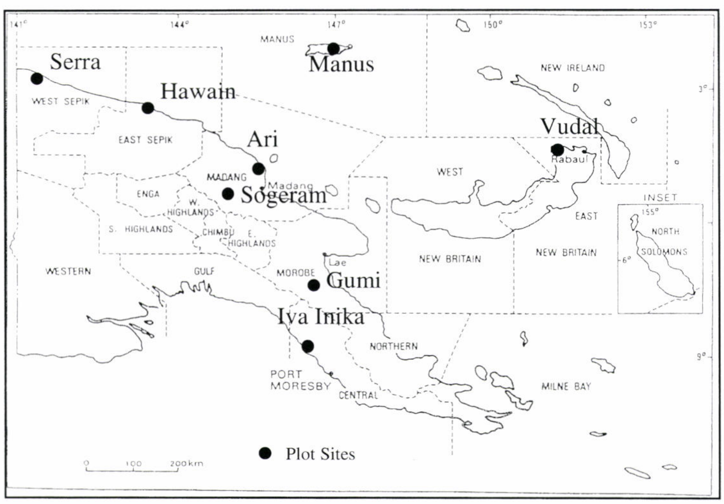

Fig. 1 Location of research sites in PNG

Table 1 Summary of research site location and descriptions

Research sites	Total number of plots	Location GPS reading	Major soil types (Source: BLEEKER, 1983)	Altitude (m) a.s.l
Ari	2	145° 43′ E, 05° 01 - 02′ S	Alluvial soils	122
Sogeram	2	145° 20 - 21′ E, 05° 13 -14′ S	Humic brown Clay soils	30 - 61
Serra	2	141° 30′ E, 03° 07 - 08′ S	Alluvial soils	61
Hawain	2	143° 29 - 30′ E, 03° 32′ S	Young Alluvial soils	30
Iva Inika	2	146° 49′ E, 08° 47 - 48′ S	Alluvial soils	61
Vudal	2	151° 55 - 56′ E, 04° 55 - 56′ S	Humic brown Clay soil (Volcanic ash)	61
Manus	4	146° 44 - 48′ E, 01 - 02° 01 - 59′ S	Humic brown Clay and Alluvial black soils	30 - 21
Gumi	4	146° 55 - 58′ E, 07° 29 - 30′ S	Clay loam and Calcareous soils	700 - 750
Total	20			

Note:
Average minimum and maximum temperatures for all the sites ranged from 22 - 33℃, except for Gumi plots ranged from 15 - 26℃
Average annual rainfall for all sites ranged from 2219 - 3533mm, only Iva Inika with 1193mm (MCALPINE *et al*, 1983)

Table 2 Plot establishment and re-measurement descriptions

Plot name	Selective cut date (month & year)	Initial establishment and measurement date (day.month.year)	Last observation and re-measurement date (day.month.year)
Ari 1	January-1995	19.02.1996	03.03.2000
Ari 2	January-1995	26.02.1996	07.03.2000
Gumi 1	August-1994	09.08.1995	16.03.2001
Gumi 2	August-1994	25.08.1995	16.03.2001
Gumi 3	January 1999*	12.03.1997	16.03.2001
Gumi 4	January 1999*	27.03.1997	28.03.1999
Hawain 1	July-95	24.06.1996	29.08.2000
Hawain 2	June-1995	01.07.1996	01.09.2000
Iva Inika 1	January-1995	27.03.1996	14.04.1998
Iva Inika 2	January-1995	03.04.1996	20.04.1998
Manus 1	August-1995	28.08.1996	28.06.2001
Manus 2	September-1995	05.09.1996	29.06.2001
Manus 3	Not cut	01.12.1998	30.06.2001
Manus 4	Not cut	09.12.1998	01.07.2001
Serra 1	January-1995	01.07.1996	15.08.2000
Serra 2	January-1995	08.07.1996	17.08.2000
Sogeram 1	February-1995	02.02.1996	22.02.1998
Sogeram 2	February-1995	09.02.1996	23.02.1998
Vudal 1	August-1996	08.05.1997	17.08.1999
Vudal 2	August-1996	13.05.1997	19.08.1999

Note:
* The selective cut dates for Gumi 3 and 4 are after the initial measurements in the uncut stands

PNG were summarized for this discussion. All plots are one hectare in size, 100m x 100m with the plot sides running along the cardinal bearings. For all the trees with a DBH (diameter breast height)≥10cm, tree position, species identification and tree height and DBH are enumerated and measured.

Re-measurement Interval

Plots are re-measured at two-year intervals for first and second re-measurements; third and subsequent re-measurements are scheduled at five-year intervals. More detail regarding plots establishment and re-measurement procedures can be found in ROMIJN (1994).

Species Grouping

The tree species were grouped according to their regenerative characteristics, various individuals (BROKAW, 1985; SWAINE and WHITMORE, 1988; 1989) have described in detail about shade-intolerant and shade tolerant species regeneration. They recognized and classified tree species into primary and pioneer species or climaxed and pioneer species. Primary or climaxed species are species with a regeneration mode the same as advanced regeneration (regenerated in climaxed forest or shade-tolerant species). Pioneer species are those species that regenerate in gaps. Based on this idea, a species grouping proposed by DAMAS (1999) for logged-over natural forests in PNG, placed species into three main groups.

Group (I) consists of Primary species (P) and, by implication, includes trees regenerated in gaps from saplings recruited before gap formation but which die without reaching the canopy layer or are species that regenerate in shade and reach canopy layer.

Group (II) consists of Secondary Species (S) a group which, by implication, includes species without advanced regeneration and seedling which can not be established under a closed canopy but can only be established and grow in gaps.

Group (III) consists of Primary/Secondary Species (P/S) and, by implication, includes tree species occurring in all regeneration categories such as canopy tree, gap maker, advanced regeneration and gap successor categories, or tree species which can regenerate in the shade but need gap to grow to canopy and are also known as helophytic species.

Diameter Distribution Patterns

Once the tree species were grouped into three species groups, they were again grouped into diameter classes (5cm intervals) to see the distribution of stand density in each diameter class by species group.

Periodic Mean Annual Diameter Increment (PMAI)

Based on species group and diameter class, the PMAI for each DBH class and group was calculated: PMAI is the change in diameter between two ages divided by the number of years between those ages

$$PMAI_a = \frac{Y_{a+n} - Y_a}{n}$$

Where

$PMAI_a$ =Periodic mean annual diameter increment at age a
Y_a =Yield at age a
n = Number of years between observations

Mortality

This was defined as the total number of trees which died in a year as expressed as a percentage of the total number of trees in each plot.

Recruitment and Regeneration.

Recruitment is the total number of trees included in the lower limit DBH class (10cm). It is expressed as the number of trees per year or can be expressed as a percentage too. Regeneration is the renewal of forest stands by natural (self sown seed, coppice, suckers, and lignotubers) or artificial means (sowing and planting). However, in this paper it refers to natural regeneration.

RESULTS AND DISCUSSION

Change of Diameter Distribution

When comparing the diameter distributions in the initial and the current remeasurements, the change in stand density from one DBH class to the next showed some differences. Generally, three types of distribution trends were identified from the twenty plots studied. With regards to Type (I), the distribution showed an incremental trend from a lower DBH class to the next higher classes. Plots at Ari, Hawain, Serra, Gumi and Manus showed this increasing trend. However, it was also noted that the increments in the number of trees differ in each DBH class and plot. The reasons for these kinds of differences may be due to the number of years after logging, the number of trees in each DBH class before and after logging, the species composition before logging, topography, damage and mortality to residual trees, and logging intensity with the amount of gap created at each site. All of these factors may account for increment trend differs at each plot site. Fig. 2a shows an example of the diameter distribution trend and Fig. 2b shows a relationship between diameter and height respectively in this type.

Regarding Type (II), DBH distribution in Iva Inika and Sogeram plots showed a decreasing trend from lower DBH class to upper classes mostly up to 50cm. The reason why these sites showed this kind of trend was because the plots were burned in 1997 due to the effect of a prolonged dry season (PEKI and ISHIBASHI, 2000b). Fig. 3a shows the type of diameter distribution found and Fig. 3b shows diameter height relationship respectively for this type.

Finally, regarding Type (III), the distribution showed an increasing trend mostly in the lower DBH class and was mostly from the plots at Vudal. It was observed that approximately 50% increments in the number of trees were in the 10cm DBH class (mostly recruits). The reason for this kind of increment trend is because the Vudal sites were probably selectively cut more than once in the past prior to current studies (PEKI and ISHIBASHI, 2000a; PEKI, 2000). Hence, the number of trees in the lower DBH class is high compared to a larger DBH class of above 30cm DBH. Fig. 4a shows an example of the diameter distribution trend and Fig. 4b shows the relationship between diameter and height in this type.

Generally for all the plots, P and P/S species groups showed that the diameter distribution of stands followed well the negative exponential decrease pattern from lower diameter

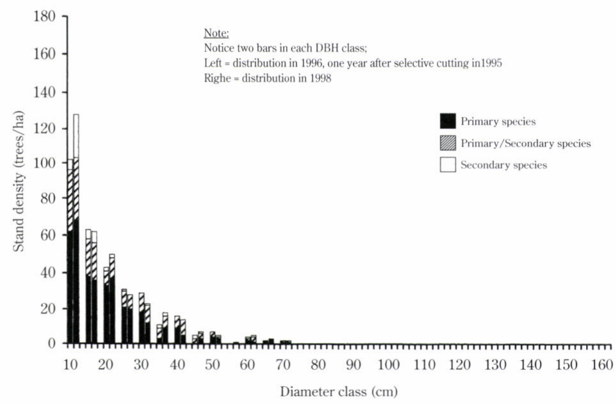

Fig. 2a Diameter frequency distribution in Hawain 1

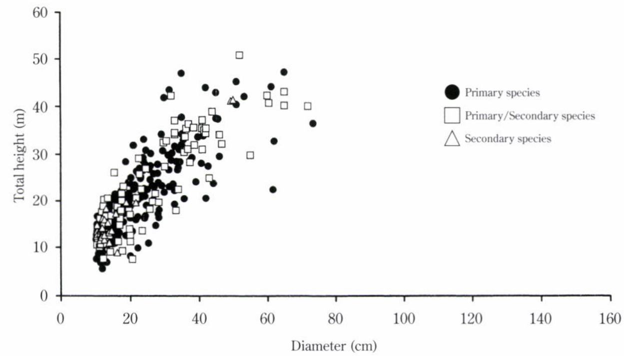

Fig. 2b Relationship between diameter and height in Hawain 1

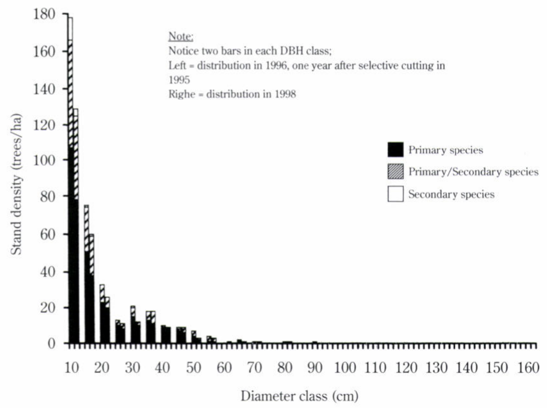

Fig. 3a Diameter frequency distribution in Iva Inika 2

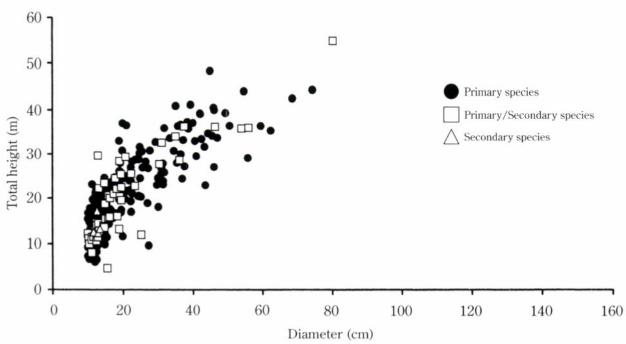

Fig. 3b Relationship between diameter and height in Iva Inika 2

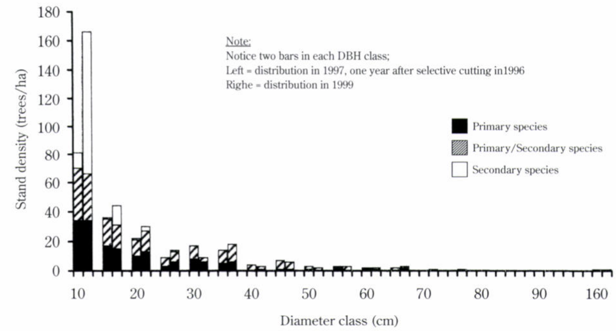

Fig. 4a Diameter frequency distribution in Vudal 2

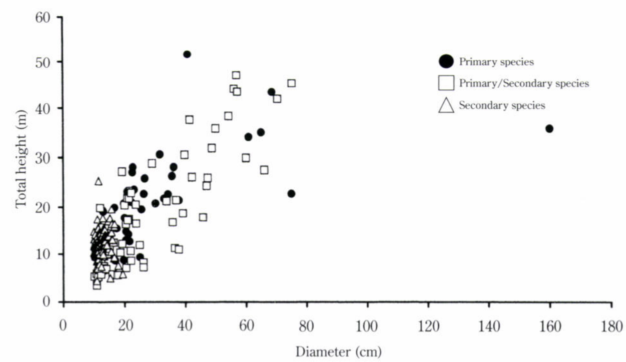

Fig. 4b Relationship between diameter and height in Vudal 2

class to the higher diameter class. S species showed generally more trees in a lower DBH class of 10 to 15cm. In some cases, few S species were found in the upper DBH classes maybe from earlier regenerations in gaps created naturally.

Species Composition and Stand Density

A total of 344 and 330 species were encountered in the initial and the last observations respectively. Of which, 30 species were commonly found in between 45 to 95% of the total plots studied. The nine species that have the highest population of trees in all 20 plots studied include *Syzygium* spp (303), *Cryptocarya* spp (260), *Pometia pinnata* (193), *Myristica* spp (157), *Macaranga tanarius* (134), *Pouteria chartacea* (127), *Microcos argentata* (102), *Pimeleodendron amboinicum* (102) and *Celtis latifolia* (66) (Table 3).

In almost all the plots sites studied, P and P/S species dominate most of the stands being followed by S species. Table 4 shows the number of species and number of trees in each species group in the initial and the last observations. From the mean figures, one could generally see that the total number of species and trees per plot has slightly decreased from the initial observations.

The highest number of species increment was found in Gumi 1 and Vudal 2 with 11 and 10 species respectively. Highest species recruitment was mostly from the P and S species, because initially there were abundant seedlings, saplings and poles of P species in the forest floor and high frequencies of fast growth S species that were regenerating after selective cutting (PEKI, 2002). The highest number of species lost was found in Iva Inika 2 and Sogeram 2 with 13 and 16 species respectively. Most of the species lost were from the P and P/S species as most of them have a population of one or two trees per plot. The high loss in the Iva Inika and Sogeram plots was mostly induced by fire as a result of the prolonged El Nino effect in 1997 (PEKI and ISHIBASHI, 2000b). The total number of trees, including all species groups, ranged from 129 trees in Vudal 1 to 593 trees in Gumi 3. The difference in the number of trees per hectare in each plot depends on the initial condition of the individual plots studied such as being from a logged over area or not a logged area. The availability of commercial harvestable size trees in a site being determined by the number of trees to be harvested and other factors such as topography and logging intensity or the amount of damage inflicted in relation to the initial number of

Table 3 Common species encountered in plots studied

No	Genus and species	Family	Species group	No. of plots encountered	Total number of trees in plots encountered
1	*Syzygium* spp	Myrtaceae	P	19	303
2	*Cryptocarya* spp	Lauraceae	P	18	260
3	*Ficus* spp	Moraceae	P/S	17	116
4	*Pometia pinnata* J.R. Forster & J.G.Forster.	Sapindaceae	P/S	16	193
5	*Myristica* spp	Myristicaceae	P	14	157
6	*Gnetum gnemon* L.	Gnetaceae	P	14	58
7	*Canarium indicum* L.	Burseraceae	P	14	50
8	*Pouteria chartacea* (F.v. Mueller) Baehni.	Sapotaceae	P	13	127
9	*Microcos argentata* Burret.	Tiliaceae	P/S	13	102
10	*Dysoxylum gaudichaudianum* (A. Juss.) Miq.	Meliaceae	P	13	58
11	*Pimeleodendron amboinicum* Hassk.	Euphorbiaceae	P/S	12	101
12	*Chisocheton erythrocarpus* Hiern.	Meliaceae	P	12	57
13	*Macaranga tanarius* (L.) Muell.Arg.	Euphorbiaceae	S	11	134
14	*Cerbera floribunda* K.Schumann.	Apocynaceae	P/S	11	43
15	*Sterculia ampla* Bakh.f.	Sterculiaceae	P/S	11	36
16	*Dracontomelon dao* (Blanco) Merr. & Rolfe.	Anacardiaceae	P/S	11	27
17	*Tristiropsis acutangula* Radlk.	Sapindaceae	P	11	18
18	*Polyalthia oblongifolia* Burck.	Annonaceae	P/S	10	10
19	*Gymnacranthera paniculata* Miq.	Myristicaceae	P	10	60
20	*Horsfieldia* spp	Myristicaceae	P	10	32
21	*Maniltoa psylogne* Harms.	Caesalpiniaceae	P	10	30
22	*Gynotroches axillaris* Blume.	Rhizophoraceae	P	10	29
23	*Pterocymbium beccarii* K.Schumann	Sterculiceae	P	10	21
24	*Celtis latifolia* (Blume) Planch.	Ulmaceae	P	9	66
25	*Aglaia sapindina* (F.v.Mueller) Harms.	Meliaceae	P	9	39
26	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	P/S	9	36
27	*Artocarpus altilis* (Parkinson) Fosberg.	Moraceae	P/S	9	28
28	*Prunus gazellepeninsulae* (Kaneh. & Hatus.) Kalkman.	Rosaceae	P	9	20
29	*Xylopia papuana* Diels.	Annoniaceae	P	9	18
30	*Galearia celebica* Koord.	Pandaceae	P	9	17

trees. In a forest area, if the initial numbers of merchantable tree species are in abundance with topography more accessible, one could experienced high density logging removing most of the merchantable species without much regard for future crop trees. This type of logging was most apparent in Manus 1, because these areas were initially dominated by *Calophyllum* spp (P species) and mostly by merchantable trees with accessible topography, showed most of the trees being removed with few residual trees left. As a result of high intensity logging with more clearings, it was obvious to see high recruitment of S species. On the other hand, if less number of merchantable trees or with most rugged topography, the number of trees removed, damaged and disturbance done will be minimal (Peki, 2001a; 2001b). The reason for highest number of tree lost being in Gumi plots 3 and 4 is because these plots were initially established in uncut forests and later these plots were selectively cut removing timber species from the marked trees from the initial observation. In the process, the smaller size trees (<50cm DBH) were destroyed during logging operations (Table 4).

In this study, species composition of trees above 10cm DBH is generally diverse which is true in any moist tropical rainforest. Only six species and three genera in this study can attain a relatively large population density when compared to the total number of tree species encountered in 20 plots, which were summed up and shown in Table 3 above. Usually these species occupy or could be found in all strata. Though the species composition here involved only trees, there are other plant species which have been also included in other studies, e.g. as those by Richards (1952) and Whitmore (1991) who state that the general floristic composition always remains very diverse and rich, containing an immense multitude of species in any one part of the tropical natural forests.

Basal Area (BA) Distribution

A total BA for all the plots including P, P/S and S species

Table 4 Species composition and stand density per plot

Plot	Initial observations (1)								Last observations (2)								Integral
	P		P/S		S		Total		P		P/S		S		Total		(1) & (2)
	Spp.	Trees	Spp.	Trees	Spp.	Trees	SPP.	TREES	Spp.	Trees	Spp.	Trees	Spp.	Trees	SPP.	TREES	
Ari 1	51	181	18	103	3	9	72	293	50	193	20	90	4	19	74	299	2
Ari 2	43	143	19	61	5	18	67	222	41	128	16	38	4	56	61	222	-6
Gumi 1	34	379	9	32	2	15	45	426	38	357	12	51	6	34	56	442	11
Gumi 2	45	449	7	36	2	34	54	517	42	423	10	41	3	46	55	510	1
Gumi 3	36	684	5	35	3	29	44	748	31	543	4	26	3	24	38	593	-6
Gumi 4	45	540	11	114	5	76	61	730	42	414	9	90	5	58	56	562	-5
Hawain 1	55	193	14	104	3	19	72	316	61	206	14	105	5	36	80	347	8
Hawain 2	38	107	16	78	2	21	56	206	39	117	16	71	3	47	58	234	2
Iva Inika 1	57	233	13	109	2	12	72	354	51	234	13	50	2	10	66	294	-6
Iva Inika 2	50	204	22	101	4	7	76	312	44	214	17	64	2	5	63	274	-13
Manus 1	29	205	7	14	3	22	39	241	28	197	5	12	4	76	37	285	-2
Manus 2	31	170	1	11	3	36	35	217	31	145	3	15	4	46	38	206	3
Manus 3	38	382	10	70	2	11	50	463	37	373	10	68	2	10	49	451	-1
Manus 4	42	426	10	40	2	6	54	472	42	420	8	40	3	6	53	466	-1
Serra 1	80	263	18	134	4	47	102	444	81	314	18	89	4	19	103	422	1
Serra 2	62	192	20	134	3	3	85	329	62	201	21	139	6	27	89	367	4
Sogeram 1	58	215	18	95	2	11	78	321	52	158	11	65	3	8	66	231	-12
Sogeram 2	52	185	15	107	2	9	69	301	38	99	12	54	3	7	53	160	-16
Vudal 1	33	86	10	43	2	0	45	129	34	96	9	56	6	95	49	247	4
Vudal 2	31	84	10	104	0	2	41	190	34	87	11	99	6	128	51	314	10
Mean	46	266	13	76.3	2.7	19.4	61	361.6	44	246	12	63.2	3.9	37.9	59.8	346	

Note:
Spp = number of species per group/ha, Trees = number of trees per group/ha.
SPP & TREES = Total number of species and trees per hectare respectively

Table 5 Summary of total basal area distribution in plots studied

Plot	Initial observations				Last observations				Basal area gains and losses			
	P	P/S	S	Total	P	P/S	S	Total	P	P/S	S	Total
	ba	ba	ba	BA	ba	ba	ba	BA	ba	ba	ba	BA
Ari 1	6.62	4.95	0.39	11.96	6.91	5.55	0.49	12.95	0.29	0.60	0.10	0.99
Ari 2	6.68	2.82	1.76	11.26	5.71	1.88	2.80	10.39	-0.97	-0.94	1.04	-0.87
Gumi 1	16.20	1.43	0.54	18.17	15.84	2.12	0.88	18.84	-0.36	0.69	0.34	0.67
Gumi 2	25.63	1.81	0.84	28.28	24.57	2.11	1.12	27.80	-1.06	0.30	0.28	-0.48
Gumi 3	29.94	1.83	1.09	32.86	23.18	1.42	0.94	25.54	-6.76	-0.41	-0.15	-7.32
Gumi 4	30.00	10.22	3.76	43.98	18.73	7.77	2.33	28.83	-11.27	-2.45	-1.43	-15.15
Hawain 1	9.51	5.83	1.17	16.51	9.80	6.84	1.48	18.12	0.29	1.01	0.31	1.61
Hawain 2	6.88	6.13	1.16	14.17	6.81	6.13	1.51	14.45	-0.07	0.00	0.35	0.28
Iva Inika 1	9.30	3.56	0.14	13.00	7.78	2.78	0.14	10.70	-1.52	-0.78	0.00	-2.30
Iva Inika 2	11.82	4.94	0.38	17.14	9.15	3.94	0.23	13.32	-2.67	-1.00	-0.15	-3.82
Manus 1	14.44	0.82	0.29	15.55	15.12	0.62	1.64	17.38	0.68	-0.20	1.35	1.83
Manus 2	9.51	0.21	0.68	10.40	7.85	0.27	1.07	9.19	-1.66	0.06	0.39	-1.21
Manus 3	30.13	3.28	0.30	33.71	30.43	3.37	0.28	34.08	0.30	0.09	-0.02	0.37
Manus 4	30.13	1.23	0.09	31.45	31.35	1.33	0.09	32.77	1.22	0.10	0.00	1.32
Serra 1	15.40	6.70	1.31	23.41	14.10	4.90	1.10	20.10	-1.30	-1.80	-0.21	-3.31
Serra 2	9.48	7.06	0.06	16.60	10.66	7.66	0.37	18.69	1.18	0.60	0.31	2.09
Sogeram 1	11.98	3.62	0.40	16.00	8.45	2.49	0.37	11.31	-3.53	-1.13	-0.03	-4.69
Sogeram 2	7.96	4.42	0.20	12.58	4.05	2.36	0.15	6.56	-3.91	-2.06	-0.05	-6.02
Vudal 1	3.98	3.84	0.00	7.82	1.05	0.78	7.79	9.62	-2.93	-3.06	7.79	1.80
Vudal 2	6.11	6.23	0.06	12.40	6.47	6.64	1.63	14.74	0.36	0.41	1.57	2.34

Note:
ba = total basal area per species group/ha (m^2/ha), BA = Total basal area per hectare all species (m^2/ha)

Table 6 Types of mortality or losses encountered after the last observations

Plot	Types of mortality and losses														Total	
	NLD		HUM		TIM		FUN		IN		WT		FIRE		N	BA
	n	ba	n	ba	n	ba	n	ba	n	ba	n	ba	n	ba		
Ari 1	12	0.42	7	0.43	_	_	_	_	_	_	_	_	_	_	19	0.85
Ari 2	41	2.15	_	_	_	_	_	_	_	_	_	_	_	_	41	2.15
Gumi 1	82	3.35	_	_	_	_	_	_	_	_	_	_	_	_	82	3.35
Gumi 2	92	5.19	_	_	_	_	_	_	_	_	_	_	_	_	92	5.19
Gumi 3	172	5.21	_	_	14	4.95	_	_	_	_	_	_	_	_	186	10.16
Gumi 4	142	5.16	_	_	32	10.49	_	_	_	_	_	_	_	_	178	15.65
Hawain 1	5	0.16	_	_	_	_	_	_	1	0.20	7	0.85	_	_	13	1.21
Hawain 2	4	0.42	2	0.05	_	_	1	0.03	4	0.11	9	0.56	_	_	20	1.17
Iva Inika 1	28	1.48	_	_	_	_	_	_	_	_	_	_	55	3.36	83	3.50
Iva Inika 2	3	0.07	_	_	_	_	_	_	_	_	_	_	97	3.80	100	4.38
Manus 1	41	2.15	_	_	_	_	_	_	_	_	_	_	_	_	41	2.15
Manus 2	40	4.05	_	_	_	_	_	_	_	_	_	_	_	_	40	4.05
Manus 3	_	_	_	_	_	_	_	_	_	_	13	1.13	_	_	13	1.13
Manus 4	_	_	_	_	_	_	_	_	_	_	2	0.81	_	_	2	0.81
Serra 1	33	1.96	_	_	_	_	_	_	_	_	_	_	_	_	33	1.96
Serra 2	29	1.12	_	_	_	_	_	_	_	_	_	_	_	_	29	1.12
Sogeram 1	29	1.28	7	0.11	_	_	_	_	4	0.10	4	0.06	70	3.06	114	4.78
Sogeram 2	33	1.78	15	0.49	_	_	_	_	_	_	_	_	101	2.80	149	6.44
Vudal 1	13	0.70	1	0.03	_	_	_	_	_	_	_	_	_	_	14	0.73
Vudal 2	13	0.83	_	_	_	_	_	_	_	_	_	_	_	_	13	0.83
Total	812	37.48	32	1.11	46	15.44	1	0.03	9	0.41	35	3.41	323	13.72	1262	71.61

Note:
Refer to text for the meanings of the abbreviations on the types of mortality above (n & N) = number of trees/ha., (ba & BA)=m^2/ha. TIM is not a mortality but harvested as timber

was calculated to see if there are any gains or loss. The highest total basal area gain from the initial observations were observed in Vudal 2 and Serra 2 with 2.34m^2/ha and 2.09m^2/ha respectively, while the lowest increment was observed in Hawain 2 and Manus 3 with 0.28 and 0.37m^2/ha respectively. Gumi 3 (7.32m^2/ha) and 4 (15.15m^2/ha) showed the highest BA lost from initial observations, due to selective cutting, including trees being removed as a timber (48.7% as TIM in Gumi 3 and 67.0% in Gumi 4 respectively) and other losses inflicted by selective cutting. On the other hand, Gumi 2 showed the lowest loss of 0.48m^2/ha from the initial observations. High BA loss in Iva Inika 1, 2, Sogeram 1 and 2 plots were mostly caused by fire (the ratio per total mortality are 57.9, 98.2, 67.6 and 64.8% respectively (Tabel 6)) in 1997 and in Serra 1, Ari 2 and Manus 2 were mostly from damaged trees or natural loss. All species groups had a negative growth in fire-affected plots at Sogeram and Iva Inika. While in areas not affected by fire, all species groups generally showed positive growth. Decrease in BA at Ari 2, Manus 2, Serra 1 was mostly from P and P/S species. However, high BA gain in Vudal plots was from S species. Generally, high BA gain was from P and P/S species, while high BA loss was also from P and P/S species groups with less in S species (Table 5). The BA increases from the lower diameter class to the upper diameter classes, whereby diameter distribution decreases from lower classes to upper classes.

Mortality and Recruitment.

Mortality is measured in terms of numbers of trees dying annually as a percentage of the total population. There are six types of mortality considered in this study: (i) Mortality occurring from undamaged and damaged by logging trees (NLD); (ii) Mortality directly influence by humans (HUM); (iii) Mortality occurring due to fungal attack (FUN); (iv) Mortality occurring due to insect attack (INS); (v) Mortality occurring due to wind throw (WT); (vi) Mortality occurring because of fire (FIRE) and (vii) Harvesting loss as a result of trees being removed as timber (TIM) and not mortality. However we discussed here about both mortality that includes all types mentioned above and TIM as losses. Mortality was lowest in Manus plots 3 and 4 (0.7 and 0.1% respectively) and highest in Sogeram plots 1 and 2 (17.7 and 24.8% respectively). It is also observed that there was high mortality in Iva Inika plots. Generally, mortality in P and P/S species is greater than S species (Tables 6, 7 and Fig. 5). One reason for higher mortality of P and P/S species was because these species groups had a high frequency of individuals present initially (Fig. 2a, 3a and 4a). The other reason that we estimated was shown below. The most of P and P/S species trees stayed at logging time and some of them get damage by

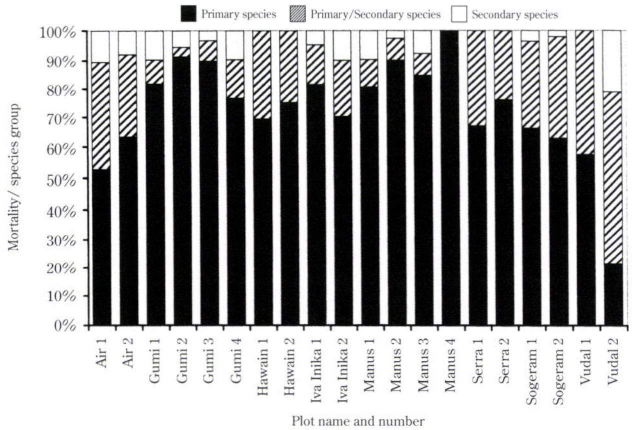

Fig. 5 Showing percentage of mortality by species groups

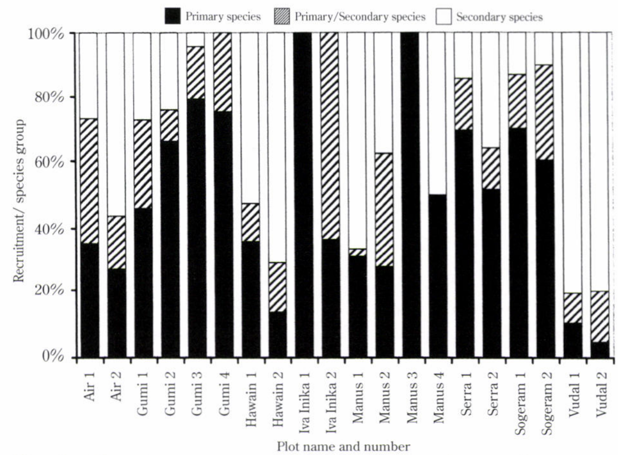

Fig. 6 Showing percentage of recruitment by species groups

Table 7 Annual rate and number of recruitment and mortality after last observations

Research Sites	Recruitment								Intial no. of stems	Growth period (yrs)	Mortality							
	P		P/S		S		Total				P		P/S		S		Total	
	stems	(%)	stems	(%)	stems	(%)	stems	(%)			stems	(%)	stems	(%)	stems	(%)	stems	(%)
Ari 1	18	3.2	11	2.0	11	2.0	40	7.2	278	2	9	1.6	8	1.4	2	0.4	19	3.4
Ari 2	10	2.3	7	1.6	23	5.2	40	3.0	222	2	30	6.8	7	1.6	3	0.7	40	9.0
Gumi 1	48	1.9	15	0.6	21	0.8	84	3.3	426	6	68	2.7	2	0.1	5	0.2	75	2.9
Gumi 2	41	1.3	12	0.4	16	0.5	69	3.3	518	6	72	2.3	2	0.1	3	0.1	77	2.5
Gumi 3	5	0.2	3	0.1	1	0.0	9	0.6	763	4	147	4.8	1	0.0	6	0.2	154	5.0
Gumi 4	6	0.4	2	0.1	0	0.0	8	0.5	729	2	111	7.6	20	1.4	13	0.9	144	9.9
Hawain 1	13	2.0	7	1.1	22	3.5	42	6.6	318	2	9	1.4	4	0.6	0	0.0	13	2.0
Hawain 2	5	1.2	6	1.4	27	6.3	38	8.8	216	2	15	3.5	3	0.7	2	0.5	20	4.6
Iva Inika 1	12	1.7	3	0.4	0	0.0	15	2.1	355	2	56	7.9	18	2.5	1	0.1	75	10.6
Iva Inika 2	3	0.4	8	1.1	0	0.0	11	0.6	373	2	72	9.7	21	2.8	7	0.9	100	13.4
Manus 1	26	2.2	2	0.2	58	4.8	86	7.1	241	5	33	2.7	4	0.3	4	0.3	41	3.4
Manus 2	26	2.4	8	0.7	21	1.9	55	8.4	217	5	51	4.7	4	0.4	9	0.8	64	5.9
Manus 3	2	0.1	0	0.0	0	0.0	2	0.1	463	3	11	0.8	2	0.1	1	0.1	14	1.0
Manus 4	2	0.1	0	0.0	2	0.1	4	0.4	472	3	8	0.6	0	0.0	2	0.1	10	0.7
Serra 1	25	3.0	8	1.0	9	1.1	42	5.1	414	2	23	2.8	11	1.3	0	0.0	34	4.1
Serra 2	33	5.0	9	1.4	25	3.8	67	10.2	329	2	22	3.3	7	1.1	0	0.0	29	4.4
Sogeram 1	16	2.5	4	0.6	3	0.5	23	3.6	317	2	74	11.7	33	5.2	6	0.9	113	17.8
Sogeram 2	6	1.0	2	0.3	2	0.3	10	1.7	301	2	100	16.6	55	9.1	4	0.7	151	25.1
Vudal 1	34	13.2	14	5.4	85	32.9	133	51.6	129	2	13	5.0	2	0.8	0	0.0	15	5.8
Vudal 2	23	6.1	4	1.1	110	28.9	137	36.1	190	2	3	0.8	10	2.6	0	0.0	13	3.4

Note:
stems = total trees per species group/ha and total trees/ha respectively
(%) = annual rate per species group/ha and total annual rate/ha respectively

logging (Table 6), and some of them died in a few years after selective cutting. However, most of S species grew up after selective cutting, then they didn't have damage.

Recruitment is usually defined as the rate at which trees reach the minimum measurement size in terms of numbers per year. It is an expression of the natural re-generation occurring in the forest. In these study plots, the minimum size of trees to be included as recruitment for measurement is when trees reach 10cm in DBH. The recruitment rate is lowest in Manus uncut plots 3 and 4 with 0.1 and 0.2% respectively. While the highest was observed at Vudal plots 1 and 2 with 50.8 and 36.1% respectively. Generally, recruitment of P with P/S was high compared to S species. It was also seen that in sites with high intensity logging, S species seems to have high rate of recruitment after two to three years after logging, e.g. Manus 1 & 2 and Vudal plots (Table 7 and Fig. 6).

Periodic Mean Annual Diameter Increment

Table 8 shows the summary of the highest periodic mean annual growth in diameter class for each plot studied. Generally, P species in all the plots analyzed, showed highest increment at diameter class ranged from 20 to 55cm. However, in Ari plot 2, it was observed that the highest growth rate was at 15cm DBH class. This similar growth trend in P species was also observed in P/S species, except in Manus plot 2 where high growth was at 15cm DBH class. The exception of P and P/S growth in Ari 2 and Manus 2 respectively is due to few larger trees above 15cm DBH class for competition. The S species showed quite different growth trend, with most of the plots having high growth at 10-15cm DBH class. In Gumi 2, highest growth was observed at 25cm DBH classes, because these plot sites are older in terms of years after logging (ca. 7yrs) than the other plots sites that saw most of the S species grown into upper diameter classes. In the other plots, as seen in Gumi 3, 4 and Manus 2, 35-40cm DBH class had highest increments. S species in these diameter classes were thought to be from the earlier regenerations after natural disturbance and were not from the result of recent selective cutting.

Diameter growth increments in P and P/S species showed a somewhat similar trend. Increment was high in diameter class range 20 to 55cm. The S species showed higher growth in the lower DBH class of 10 to 15cm DBH. S species

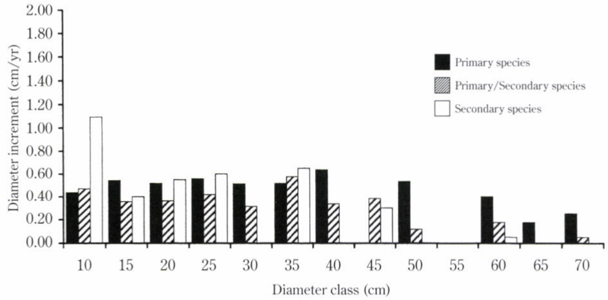

Fig. 7 Periodic mean annual DBH increment in Hawain 1

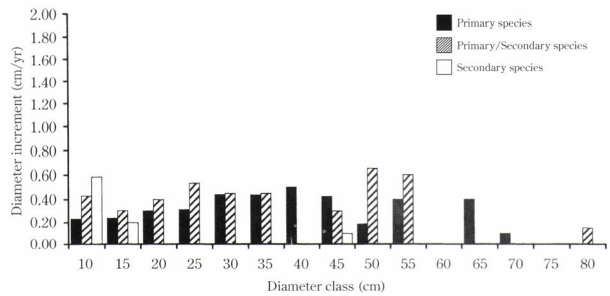

Fig. 8 Periodic mean annual DBH increment in Iva Inika 2

Table 8 Summary of the highest value of diameter increments in plots studied

Research Sites	P species		P/S species		S species	
	DBH class (cm)	DBH increment (cm/yr)	DBH class (cm)	DBH increment (cm/yr)	DBH class (cm)	DBH increment (cm/yr)
Ari 1	35	0.70	35	0.82	15	0.60
Ari 2	15	0.80	20	1.60	15	1.10
Gumi 1	40	0.45	20	0.48	15	0.41
Gumi 2	50	1.00	25	0.45	25	0.80
Gumi 3	55	0.50	40	0.50	35	0.55
Gumi 4	20	0.35	35	0.45	40	0.30
Hawain 1	40	0.60	40	0.60	10	1.10
Hawain 2	40	0.85	20	0.80	10	0.88
Iva Inika 1	40	0.60	30	0.45	10	0.81
Iva Inika 2	40	0.50	50	0.65	10	0.58
Manus 1	35	0.80	15	0.50	10	0.45
Manus 2	55	1.10	20	0.30	40	1.20
Manus 3	50	0.90	55	0.80	15	0.61
Manus 4	50	1.30	35	0.60	10	0.30
Serra 1	30	0.42	30	0.50	20	0.75
Serra 2	45	0.65	35	0.45	10	0.81
Sogeram 1	50	0.90	35	1.70	15	1.50
Sogeram 2	20	0.55	45	1.00	15	0.75
Vudal 1	20	0.80	45	2.50	-	-
Vudal 2	45	0.70	45	1.80	15	1.80

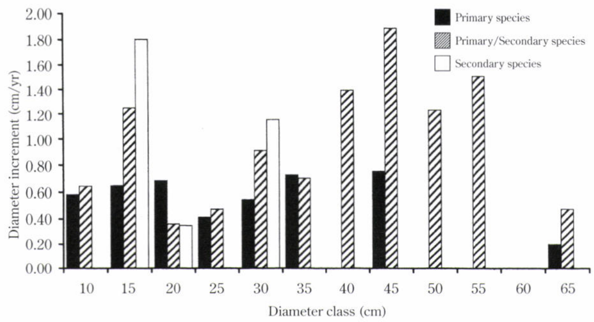

Fig. 9 Periodic mean annual DBH increment in Vadal 2

are mostly found in disturbed or selectively cut areas. Hence, this species group loves gaps or openings to grow in. Therefore, after-effects of logging or disturbance (as in this case) proved conducive for this species group to flourish. On the other hand, the growth trend shown for P and P/S was probably because there were many trees in these species groups and so competition for growth below 20cm DBH class is higher for growing space and light. Hence, the trees in the 20 to 50cm DBH class have high increment because most of the trees in the 50cm DBH class and above were harvested during selective cutting, therefore creating optimum space and light for them to grow vigorously. Figs. 7, 8 and 9, shows examples of the kinds of growth trends in the three types of forests classified by DBH distribution after selectively cutting. Most types seem to have a similar growth trend with slightly different rates. It is also true to say that change in the number of trees from a lower DBH class to the next higher classes is due to increment in PMAI (PEKI, 2001a).

The growth pattern in this study generally showed steep growth rates in the beginning, ranging between 20 and 50cm DBH classes, and than decreasing gradually. This kind of trend suggests that most species break into the main canopy level, thus receiving better light conditions to promote growth when they reach 20 to 50cm DBH. It is also seen that S species are clearly faster growing in their infant stage than P and P/S species (PEKI and ISHIBASHI, 2001; PEKI, 2001a). ONG and KLEINE (1995) studied growth of Dipterocarps in Sabah, and KANAZAKI *et al.* (1995) studies in Thailand found similar diameter growth patterns of trees and by species groups with variations around the means of each diameter class. Mean growth rate peaked around 20cm to 40cm DBH classes and decreased in both directions. It can said that the reasons for decreased growth were caused by two factors with shading probably causing reduced growth rate for smaller trees, while reduced growth rate of larger trees being caused by senescence.

CONCLUSION

The results obtained from this study can be summarized as follows:

Ⅰ. Generally, total diameter distribution in all the plots showed an exponential decrease pattern from a lower DBH class to a higher DBH class, suggesting that the inverse J-shape distribution pattern covers much of the tree population. P and P/S species closely followed the above pattern, while S species showed a rising growth rate in the lower DBH class and little to none in the mid and upper DBH classes.

Ⅱ. For all the plots, the number of P species is greater than P/S, which, in turn is also greater than S species. A total of 344 and 330 species were encountered in the initial and the last observations respectively for all the plots sites studied. The most common species were *Syzygium* spp, *Cryptocarya* spp, *Pometia pinnata*, *Myristica* spp, *Macaranga tanarius*, *Pouteria chartacea*, *Microcos argentata*, *Pimeleodendron amboinicum* and *Celtis latifolia*. Generally high diameter growth increment for P and P/S species was found to be in the 20 to 50cm DBH class. The highest for S species was found to be in the 10 to 15cm DBH class.

Ⅲ. Based on the results analyzed, especially from diameter distribution patterns and its transition from one class to the next, about three forest types were tentatively proposed for the twenty plots in PNG:

Type Ⅰ. Stands at Ari, Hawain, Serra, Gumi and Manus showed a diameter transition increase from lower DBH class to upper classes.

Type Ⅱ. Stands at Iva Inika and Sogeram showed diameter transition not normal, decreasing from lower DBH classes to upper classes due to mortality mainly caused by fire and logging damaged inflicted during selective cutting.

Type Ⅲ. Stands at Vudal showed high increase in the lower DBH class and only S species revealed an increasing trend from a lower DBH class to upper classes.

Natural catastrophic events like the El Nino drought in 1997, appears to have influence on the structural and growth characteristics of the plots, complicating future predictions.

ACKNOWLEDGEMENTS

This study was supported by the PNG Forest Authority as part of a project in Natural Forest Management Program at the PNG Forest Research Institute (PNGFRI). We are grateful to the respective landowners for allowing us to conduct this study on their land and their field assistance in the initial plot establishment. The authors also thank the anonymous reviewers for valuable comments on the earlier version of the manuscript and Professor Kitabayashi, Chair, Department of

English of Daito Bunka University for editing of our English.

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(Received 10 September 2003)
(Accepted 22 January 2004)

Article

Logging Ban in Kenya: Convergence or Divergence from the Forest Law and Policy and Impacts on Plantation Forestry

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ABSTRACT

Logging bans as means of trying to control deforestation and other wrong forestry practices has been in use for along time in many parts of the world. It is evinced by command and control regulation. Recent cases of interest are in Asia Pacific countries. This mainly involved logging bans in natural forests. In the case of Kenya, cutting in natural forests was banned many years back. What is of interest lately is the near total ban, which includes a cutting moratorium on plantations. Kenya's case is unique in the sense that the ban is a presidential decree. The aim of this paper is to explain the relationship between the ban and law and policy, and to show that imposition of a logging ban without due consideration of existing forest law and forest policy does not enhance the well-being of the forest plantation. This research was conducted through an examination of the Forests Act and Forest Policy and interviews with forestry officers and saw millers. Other forms of secondary data were also examined. Results indicated that there is lack of convergence to the law and policy, as the President does not derive his powers from the forest law and policy. There are associated impacts on plantation forestry. These are both positive and negative. Long term unintended effects are negative and this is a lesson that we can learn from this form of command and control in forestry when applied to plantations. Stakeholders should learn that adverse political solutions do not sit well with good plantation forest management.

Keywords: Kenya, Logging ban, Law and policy, Impacts, Plantations

INTRODUCTION

To this day, many parts of Africa are still inhabited by forest dwelling communities. These communities have rules governing the usage of flora and fauna found in these forests. Among the rules are certain prohibitions, which are seasonal bans. Following colonial rule, these traditional systems have given way to new forms of regulation as forests have been brought under central government management. Kenya is no exception. After Kenya attained independence from British Colonial rule, this continued but also challenges have arisen. Faced with various problems associated with forests, governments have reacted in many ways.

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Since the early 1970s, governments throughout the industrialized world have responded to the rise of environmental degradation and industrial pollution with a myriad of environmental policies. The dominant government response however has been the application of 'direct' or 'command and control' regulation designed to prohibit or restrict environmentally harmful activities. (GUNNINGHAM *et al*, 1998). This statement is largely true based on the way in which most states formulate laws to govern natural resources. For along time, there has been very little consultation with other stakeholders. Although other aspects may be considered such as extension, incentives, and education, it is largely a government affair. This therefore creates a leeway for command and control by the government or responsible Forestry Department (FD).

Felling bans as a direct means of controlling forest degradation are used in many countries, both developed and less developed. Bans are a form of command and control. Recent cases of interest have been seen in Asian countries where bans have been imposed on felling of natural forests. Countries with logging bans include New Zealand, Peoples

Republic of China, Philippines, Sri Lanka, Thailand and Vietnam. FAO in 2001 has prepared reports on each of the countries and we shall briefly look at the findings.

In New Zealand before 1987, logging was prohibited in some 300,000ha of state owned natural forests, including 80,000ha that were previously classified as production forests. Policy changes initiated in 1987 resulted in 4.9 million ha of state owned natural forests being transferred to permanent conservation status under separate administration including an estimated 1 million ha of state owned natural forests with a potential for harvesting under sustainable forest management.

In the Peoples Republic of China, estimates show that some 49.6 million ha of natural forest are in need of greater protection. Responding to natural disasters, China established a priority for natural forest conservation and protection, shifting timber production to forest plantations. Reflecting concern for deterioration of the forest environment, and stimulated by the severe flooding in 1998, China imposed a logging ban in state owned forests to include upper reaches of the Yangtze River and the middle and upper reaches of the Yellow River. In addition, the Natural Forest Conservation Program (NFCP) stressed the need for afforestation and greening of wastelands, increasing forest cover, rehabilitating forest stand qualities, and expanding forest eco-functions.

In the Philippines, logging bans have been selectively imposed since the early 1970s on a case-by-case basis. General bans were initiated in 1983 covering much of the Philippines, with additional specific bans in 1986 and 1989. More than 70% of the provinces are now under logging bans or harvesting moratoria. At present (2001) two proposed bills are under consideration. The first senate bill S.No 1067, "An Act to protect the Forest by banning all Commercial logging operations, Providing Mechanisms for its effective enforcement and Implementation and for Other Purposes" would prohibit all commercial logging operations in all types of forest for a period of 20 to 30 years. The second, "An Act providing for the Sustainable Management of Forest Resources and for Other Purposes" (Senate S.B 1311) allows for logging in some residual forests and would constitute partial ban (fragile areas, steep slopes protected areas) and provide for sustainable management.

In Sri Lanka, in 1989 a "temporary ban" on logging in natural forests was imposed on highly degraded areas to allow them to recover and to develop sustainable management plans, primarily in the wet zone in the south west of the Island. This was extended to a total ban in 1990 at which time another 31 areas covering 61,300ha were added to the protected area system. Overall, the ban affects about 1 million ha of production forests. In 1995, a large proportion of the natural forests were given protected area status, and residual natural forests outside the protected areas were set a side for sustainable multiple-use management.

The logging ban in Thailand was imposed on 17^{th} January 1989 in response to devastating floods in Nokorn Srithammarat Province in Southern Thailand the previous November. Logging contracts and concessions were canceled, and applications for new concessions were dismissed. In 1991, the Government reoriented its forest policies to emphasize management of some 27.5% of the land areas as conservation and protected areas.

In the case of Vietnam, in June 1997, the Government imposed the logging ban in natural forests on 4.8 million ha. It prohibited harvesting in special use forests, and declared a 30-year moratorium on logging in critical watershed protection forests. Logging in the remaining natural forests is restricted to less critical natural forests in 19 provinces. The number of enterprises permitted to log was reduced from 241 in 1996 to 105 by 2000.

The goals for timber harvesting bans in Asia Pacific are seldom well articulated. Most bans are the response of policy "failures". The undesirable outcomes from conventional forest practices and utilization is presented in arguing for swift and decisive actions to correct past problems and abuses (FAO, 2001). This argument by FAO carries weight viewed from the point that the bans have been imposed after cases of unsustainable usage were noted. However, in cases like China where there were natural disasters prompting action, its not easy to completely state that this was policy failure. Looking at the cases mentioned above, one could not fail to notice that they all relate to some form of disaster that may be natural. Another thing that emerges is that all are to a large extent within some legal framework and plans exist on how to proceed with the ban.

The use and management of forests is certainly influenced by the actions of the government. The latter in its quest to enhance social and economic well-being of the citizens makes decisions which ultimately lead to a variety of programs including the imposition of regulating actions deemed necessary to force private actions on behalf of forestry; IUFRO (1984). It is correct to assume that this should be the case under representative government. However, under undemocratic states, certain action can be undertaken to settle economic scores. For example if there are not set criteria for which companies should continue logging and which ones should not, then personal economic gain rather than national interests may prevail. Special characteristics of each ban necessitate the need for separate studies on each.

This research was conducted through an examination of the Forests Act and Forest Policy and interviews with forestry officers and saw millers. Other forms of secondary data were also examined. Special emphasis in data collection was given to three districts, Nyeri, Nakuru, and Kakamega, which jointly produce more that 80% of Kenya's soft wood.

Kenya is situated on the equator in East Africa, between Lake Victoria and the Indian Ocean, and has a total land area of 220,000 square miles. The country rises gradually from the sea to about 6,000ft, 300 miles inland where the Great Rift

Valley divides it from North to South. Broadly speaking, the country has mountain forests (5,500ft and above), Semi-tropical Rain Forests of the highlands (4,000-6,000ft approximately) lowland forests (below 4,000ft approximately) and Edaphic forests (Mangroves) (LOGIE and DYSON 1962).

Kenya's gazetted forest area is about 1,600,000ha. Of the gazetted area, about 165,000 ha is plantation forest covered mainly by Cypress, 45%, and Pines, 31%. The plantation area currently under forest is estimated at 120,000ha as areas that have been cleared have not planted and some areas have been under consideration for excision. Estimates published in 1994 by the Kenya Forestry Master Plan show that 54% of the area in the establishment phase is under stocked, 96% of the area in the maintenance phase has backlogs in silvicultural treatments, while 21% of the total plantation area is occupied by over mature stands. Concerning wood extraction on an annual basis, the following figures emerge, Sawmilling industry: 545,000m^3, plywood mills, 105,000m^3, transmission poles 75,000m^3 and pulp and paper 345,000m^3. After the logging ban, saw millers have no access to government forests hence the consumption should be nil. Whatever they extract is from the farms and this has resulted in a total closure of at least 50% of the mills as at the time of the survey. Currently the forest estate is estimated to cover only 1.7% of the land area. This is almost half, what it was a decade ago. Before the logging ban, there have been almost annual excisions since the early 1980s. This is a bigger threat to forestry than anything else is. Available examples of excisions are as follows: In 1999, an approval was given for excision of 34,800ha, off East and Southern Mau forests. This was later extended to 42,400ha. By September 2000, 146 excisions taking 355,650ha had been made. In 2001, the Mau forest again lost 50,000ha. In 2002, a total of 167,000 ha were proposed for excision but have been subject of litigation by human rights and environmental groups. All the excisions have been made by the same government that brought in the logging ban with the full knowledge of the president.

The first stage of Kenya's logging ban began in on October 12th 1999. The government (Forestry Department) through a circular to all forest officers suspended allocations of forest plantations. This was followed by a legal notice No 171 of 17th November 1999 (Kenya Gazette supplement No 65 pages 3,505-3,506 of November 26th 1999) which suspended for 90 days, harvesting of forest plantations in all forest areas including quarrying in Ololua forest. The objective was to enable stocktaking of the plantation status with a view to establishing a mechanism for sustainable harvesting as well to enhance the management of indigenous forests. From the exercise, a deplorable state of Kenya's forest was noted. Inappropriate forest practices were realized including backlogs in establishment, maintenance and treatments, lack of silvicultural treatments, unplanned harvesting leading to revenue leakages, lack of professionalism and high levels of corruption.

Based on the findings, the Forestry Department (FD) outlined procedures and rules to be followed at all levels of forest management in an effort to revert to sustainable forest management. Thus, the moratorium on harvesting was lifted through Kenya gazette supplement No 8 of 11th February 2000, in legal notice No 18 pages 28-29. However, after the FD had stuck to the law and put in place plans for better forest management, an indefinite Presidential logging ban was imposed in March 2000. The presidential ban covered all forests and trees in the Republic of Kenya. Since the ban was made through a public radio pronouncement, we can only assume that the objectives were the same as the earlier ban that had just been lifted. In addition, since the President is senior to the Minister of Environment or Chief Conservator of Forests, it can only be assumed through what followed that the presidential ban was meant to go a step beyond what the FD had in mind. It was meant to protect and better manage both public and private resources. The ban has been in operation even during the period of the survey. This will form the basis of our study. In the case of the Presidential ban, there is no prescribed way of doing it. According to Kenyan law, the president is above the law. In the case of the ban therefore, a presidential announcement is made over the national radio. What follows next is that the senior civil servants are supposed to interpret what the president has said and issue circulars or verbal directives to junior officers on what should be done. In so doing they disregard all other normal procedures of banning. Whether this way of banning leads to better plantation forest management is an issue, we seek to investigate.

Kenya has very limited private forests. Private forest, forests on farms, and other forests outside the Forestry Departments jurisdiction were all affected by the logging ban. This means that even for those privately owned trees on farms, cutting was prohibited. If a farmer wanted to cut a tree for his or her own use, permission was required from the local District Forestry Officer (DFO).

The objective of the study is to explain the relationship (convergence or divergence) between Kenyan forestry laws, policy and the logging ban the impact on the plantation forestry estate, and show that imposition of a ban in disregard of the law and policy does not lead to better forest management. In forestry, a well planned law and policy should be the guide in all matters of forest management. The imposition of a logging ban, if need arises should be well thought out and planned. The introduction of bans in a command and control fashion will lead to operating in a legal vacuum and this will not augur well for forest management. Furthermore, if the law and policy are well planned, there will not arise a situation where logging bans in plantation forests become necessary. In the Asia Pacific case, the ban was in natural forests. Kenya has had a ban on logging of natural forests since 1982. The recent ban included plantations hence the need to look at this special case.

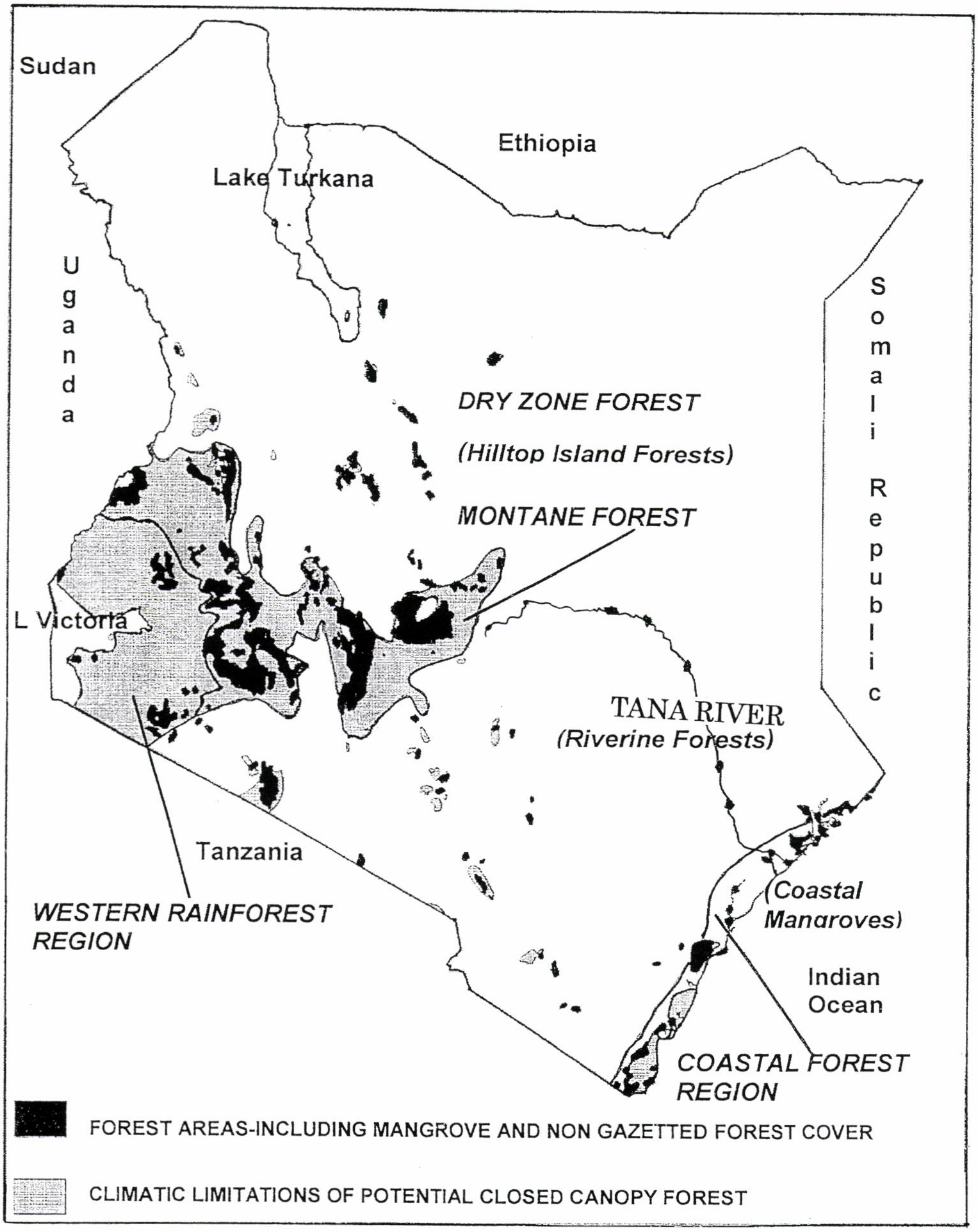

Fig. 1 Location of forest areas in Kenya
Source: Wass, Peter (Ed). (1995) IUCN

RESULTS AND DISCUSSION

Forests Act, Forest Policy and Relation to the Presidential Ban

Kenya has a forests act. referred to as the Forests Act Chapter 385 of the laws of Kenya. It commenced on 1st March 1942. It is an Act of Parliament to provide for the establishment, control, and regulation of Central forests, forests, and forest areas in the Nairobi area and on un-alienated Government land. The Forests Act, being one of a number of Acts in the laws of Kenya is made and given consent by parliament. This means that any future amendments must also have parliamentary approval. In case of amendments, the minister in charge of forests prepares a bill and presents it to parliament. After debate, the amendment may or may not be done. The current act was last revised in 1992.

Kenya also has a national forest policy, referred to as the Kenya Forest Policy. The general aim of the policy is to provide continuous guidance to all citizens, from elected national leaders and administrators to those whose livelihoods and future depend on sustainably managed forests and forestlands. There are seven policy objectives listed in the policy. These are: i). Increase the forest and tree cover of the country in order to ensure an increasing supply of forest products and services for meeting the basic needs of present and future generations, for enhancing the role of forestry in socio-economic development. ii). Conserve the remaining natural habitats and the wildlife therein, rehabilitate them and conserve their biodiversity. iii). Contribute to sustainable agriculture by conserving the soil and water resources by tree planting and appropriate forest management. iv) Support the government policy of alleviating poverty and promoting rural development, by income based on forest and tree resources, by providing employment, and by promoting equity and participation by local communities. v). Fulfill the agreed national obligations under international environmental and other forest related conventions and principles. vi). Manage the forest resource assigned for productive use efficiently for the maximum benefit, taking into account all direct and indirect economic and environmental impacts; also review ways in which forests and trees are valued, in order to facilitate management decisions. vii) Recognize and maximize the benefits of a viable and efficient forest industry for the national economy and development.

Formulation of the Forest policy involves senior civil servants concerned with forestry. Drafts of the policy are prepared, and then passed to the Minister in charge of forests. The Minister then decides whether the required changes are necessary or not. Parliamentary approval is required to effect the policy. The forest policy has gone through several changes culminating in the current one of 1994. The Forests Act and the Forest policy are the two vital documents that should supersede all other documents in matters of forestry. Forests should be run based on these two.

Bearing the above in mind, we would like to introduce the main findings in this study. We shall explain relevant aspects of the Forests Act, followed by and then later those of the forest policy. It would be prudent to deal with only those aspects that are pertinent to this study. At the end, we shall establish the presence or absence of a linkage to the Presidential decree banning logging.

The Forests Act Cap 385 of the Laws of Kenya

The Forest Act section 15 concerning rules is of relevance here. The relevant parts are a (parts i, ii, iii, iv and vi), c and d. Under the mentioned parts, the following are stated. The minister may make rules-

a) either of general application or in respect of particular Central Forest, forest area or any un alienated government land for all or any of the following purposes
   i) regulating the sale of and the disposal of forest produce and the felling, working and removal thereof;
   ii) Regulating the use and occupation of land in a Central Forest or forest area, for the purposes of residence cultivation, commercial or industrial purposes, or for camping or picnicking or for grazing cattle;
   iii) Regulating and controlling the manner and circumstances in which licenses may be granted and the manner in which a person to whom a license is granted shall exercise a right or privilege conferred upon him by the license and providing for an appeal to the minister and any rule made under this subparagraph may empower the Director of Forestry*3 to require a licensee, as a term or condition of his license, to provide assistance in the prevention and fighting of any fire in the Central Forest or forest area, and to take such measures as the Director of Forestry may require to report, control and eradicate such noxious insects or fungi as may, from time to time, be specified by the Director of Forestry by notice in the gazette*4;
   iv) Controlling the entry of persons into a Central Forest or forest area, and regulating the period during which persons may remain there and the conditions under which they may do so;
   v) Closing paths and roads in a Central Forest or forest area either to persons and traffic or to both
   vi) Closing a Central Forest or forest area
   vii) Controlling and regulating the entry into and the use of a Central Forest or forest area declared to be nature reserve
   viii) Prescribing fees and royalties

b) Deleted L N 246 1964

c) For the protection and management of indigenous forests on alienated Government land; and

d) generally for the better carrying out of provisions of this Act

Parts i, ii, iii, iv, and vi of (a) are the ones that point to some form of logging ban. c and d are also apposite for purposes of our study. Clearly, section 15 gives powers to the minister to make rules. These rules may lead to stoppage of cutting of trees in government forests.

*3 Director of Forestry is currently called the Chief Conservator of Forests

*4 Gazette: Official Kenya government document that validates certain measures taken from time to time to proclaim ministerial or government activities.

Table 1 Plantation allocations 1998/99

	1998	1999
Licensed operators (ha)	2,150.4	1,719.9
Unlicensed operators (ha)	4,420.2	5,130.3
Pan African Paper mills (PPM) (ha)	6,510.5	6,710.5
Recommended annual planting program (ha)	3,000.0	3,000.0

Source: Field survey/ FD reports
Note: In both years, the unlicensed operators got more allocations
PPM is treated separately as it has a 25-year license

Up to 1985, the Forest Department (FD) allocated plantation materials for harvesting strictly on the approved felling plans whose preparation was professionally done taking into consideration materials available, rotation age, appropriate silvicultural treatments, mill capacity, and allowable annual cut. This system slowly started to disintegrate and by 1997, allocations of materials to non-licensees had increased drastically in total disregard of the approved felling and management plans. Table 1 shows forest allocations for 1998 and 1999 compared to the annual planting program.

The allocations exceed annual planting and this is unsustainable because without corresponding increase in planting. Hence, the resources will not be enough especially over along period.In the same period, total annual revenue declined from Kenya shillings 240 million annually to about 135 million. Moreover, outstanding forest debt by November 1999 was Kenya shillings 92 million and backlogs in planting of 40,000ha as at the end of 1999. This was indeed worrying and shocked the FD.

It is conceivable that under these conditions, the first phase of the logging ban was imposed in 1999. Clearly, the aim of the ban was to correct the mistakes that had been done. It was meant to have a positive impact on the forest as a whole. The significance of this ban is that it had taken into account necessary steps that may justify its imposition. The law was followed to the latter in imposing this logging ban.

The logical steps involved in imposing a logging ban by the minister are hereby explained. The Minister in consultation with senior civil servants would initiate an intention of closing the forests. A notice of the same would be published in the Kenya gazette. The period in which there should be any objections is set as 28 days. If there is no objection after 28 days, the Minister will automatically impose the logging ban. If there is opposition, then the matter has to go to court for arbitration. Although the entire above are logical in imposing the ban, a qualitative analysis of the Forests Act reveals that only inferences are made. There is no explicit explanation concerning how and when a logging ban should be imposed.

Almost immediately after lifting the FD ban, the Presidential ban came into effect. The minister may not have directed the president to issue the directive, as the chain of command does not allow for this. Although not clearly mentioned as to what the meaning and significance of the presidential ban are, inferences can be made. Given that the president went ahead to involve three army officers in management of Kenya's forest, it can only be assumed that the meaning of the ban was to enhance better management of the forestry resources. The ban is significant in the sense that it has stopped all felling activities and covered all forest areas, public and private.

Kenya's Forest Policy

As earlier mentioned, Kenya has had a forest policy since colonial times with the earliest recorded policy statements around 1902. The 1957 forest policy states that the object of the Governments Forest Policy is therefore to lay down the basic principles, which shall guide the development and control of forestry in Kenya for the greatest good of all. These basic principles are contained under 10 main heads.

(i) Reservation of land for Forest Purposes;

Reserve in perpetuity the existing forests and, wherever possible add to them so as to provide sufficient land in order to maintain and improve climatic and physical conditions of the country, conserve and regulate water supplies, conserve the soil, and to supply both timber and non-timber forest products.

(ii) Protection of the Forest estate;

Protect the forest estate by all means at the government's disposal for the purposes mentioned above.

(iii) Management of the Forest Estate,

Manage this forest estate on the principle of sustained yield so as to obtain the best returns on its capital value and on the expenses of management.

(iv) Relations with Timber utilization industries

Foster the conception of a mutually interdependent forest industry and ensure close coordination between all interests concerned.

(v) Finance

Provide adequate funds, within the limits of finance available from time to time, for the realization of the policy objectives.

(vi) Employment

Pay full regard to the possibilities of using the Forest

Estate for the provision of employment, food production (through shamba system) and to administer the forest labor in consultation with local authority.

(vii) Relations with African Local Authorities

Encourage and assist African Local authorities to carry out afforestation works and maintain forests in African areas in accordance with the plan approved by the minister.

(viii) Private Forests and other Forest not under state ownership

Encourage and assist in the management of existing private forests and the establishment of new ones, not only for productive but also protective purposes.

(ix) Public Amenities

Foster the value of forests as areas of natural beauty or special interest, develop recreation facilities and preserve wild life, both flora and fauna, in so far as is consistent with sound forest management.

(x) Research and Education

Promote research and education in all branches of forestry and forest products and to foster by education and propaganda a greater understanding among the people of Kenya of the value of forests to them and their descendants.

The 1968 policy followed the one created in 1957. This policy is for the most part the same as the predecessor. The only slight difference is that under each of the ten aspects, details have been included pinpointing exactly what the government intends to do. This was independent Kenya's first forest policy and appears to have been written not for better management of forest resources but as a necessary change from colonial to African majority rule.

The forest policy was revised once more in 1994. This policy borrows largely from the 1957 and 1968 policies. There were policy statements added concerning multipurpose management of forests, social forestry, wood energy in urban and rural areas and international conventions to which Kenya is or should be a signatory. Most forestry activities after 1994 are based on this policy.

In 1999, it was felt necessary to review the forest policy again. This policy takes into account other policies related to land use, environment, agriculture, energy, and industry among others. However, the ten basic principles are the same as in the previous policies. One policy statement that has been added that was not in the other policies talks about the need to increase the forest and tree cover of the country in order to ensure an increasing supply of forest products and services for meeting the basic needs of present and future generations and for enhancing the role of forestry in socio-economic development.

The forest policy, right from the very first one in colonial era, does not mention logging ban. Therefore, the logging ban policy is deviating from the policy that has always been in use. Three different perspectives that show the need for a forest policy are - forest policy as a result of demand of the members of society, forest policy as a result of the competition between political parties, and forest policy as a result of existing forestry bureaucrats' production of demand for their services (Olsen 1978). However, in the case of Kenya, the logging ban does not seem to fit in any of the three. Could there be a fourth aspect of policy? Could it be that the logging ban was meant to hurt particular groups and appease others? This question may remain unanswered unless if the issuer of the ban is closely evaluated vis-à-vis the forest policy and the relationship to·the saw millers.

From the foregoing, it is not easy to imagine how the Presidential ban came into being. First, the Forests Act does not mention the role of the President in forestry. The policy also does not give him/her any powers over the forest. May be these powers are vested in him under the constitution but this is not clear and is not the subject of this discussion. Bearing this in mind, we realize that the ban is not related to the Forests Act and Forest Policy. It therefore diverges rather than converges to the two.

Logging bans are not normally the end objective of policies, but rather represent one of many choices to achieve something else (FAO, 2001). This being the case, would it be prudent to argue that the logging ban had other values or agendas that were hidden.

Conservation and protection policy goals must be more explicit and translated into measurable realistic and operational terms. Without effective monitoring and assessment, it is difficult or impossible to know whether conservation and protection goals of logging bans are being accomplished or not. (FAO, 2001). We concur with these observations. As noted in the Kenyan case, lack of specificity could cause untold negative impacts on the forestry estate. In addition, our research found out that the Kenya government had not instituted any research to find out the impacts of the logging ban. With this in mind, we would like to cap the examination of the Kenyan logging ban with an examination of the impacts on the plantation estate. This will show us what happens where the law and policy is set a side and decrees

IMPACTS OF THE LOGGING BAN ON THE FOREST PLANTATION ESTATE

Logging bans have both negative and positive impacts on the forest estate. The extent of the impacts may depend on how well the ban is planned and implemented. In the Kenyan case, the Presidential logging ban was very abrupt. It appears that there was no planning involved and mechanisms have not been set in place for proper implementation of the ban to achieve net positive impacts. The identified impacts are confusion in forestry management, continued depletion of forest resources, loss of jobs in saw mills, establishment, forest fires and pests are now prevalent, theft of forest products, undermining of silvicultural operations, reduction in planting back log, un-harvested mature plantations, pruning back logs and thinning back logs. We shall now turn to each of the above and shed more light to it.

Confusion in Management of Forest Resources

Before the onset of the logging ban and way back in 1991, the FD and Kenya Wildlife Service (KWS) signed a memorandum of understanding covering Aberdare, Mt Kenya, Namanga Hill, Nguruman/Loita, Ngong hills, Mau Forest, Mathews Range, Mount Nyiro, Kakamega, Arabuko Sokoke and Shimba hills. The MoU was signed in December 1991 with a duration of 25 years. The objective was for biological conservation and maintenance of ecological processes. After the entry of the ban this may not be the case hence the reference to the confusion.

There has been confusion in the management of forest resources especially after the logging ban. Three bodies, the Forestry Department (FD), the Kenya Wildlife Service (KWS) and the provincial administration have had roles to play. As earlier mentioned, there are no proper guidelines in the case a presidential ban. Each department therefore tries its level best to adhere to the Presidential directive. This actually leads to confusion in management of forest resources. The role of each body is not clearly defined under such circumstances. Examples of the confusion caused include the transfer of management of Mount Kenya forest to the management of Kenya Wildlife Service without corresponding increase in resources to KWS or formalizing the transfer as per the Forests Act. This was not legally done and hence had to be revoked at a later stage. In addition, three retired army generals were appointed by the president to help run forestry activities in Kenya. One was stationed at the FD headquarters in Nairobi while one was posted to Nakuru (Western Region) and the other to Nyeri (Eastern region). This created a lot of tension between professional foresters in the Forestry Department and the army officers. The army officers have no training background in forestry. Their understanding of technical silvicultural operations is inadequate and this has had implications for plantations. It has been argued that they are the ones behind the lack of thinning in the forests. The Director of Forestry and his officers are helpless as the officers derive their powers from the head of state. No one wants to antagonize the officers who report directly to the office of the president.

Exploitation of Forest Resources

Although the ban was intended to stop legal and illegal extraction of trees, this is not the case. Interviews showed that cases of illegal extraction are on the rise. Penalties have not changed to reflect the governments' seriousness in combating illegal extractions. As wood shortage bites, the price of sawn timber has risen hence creating a major incentive for illegal extraction. Different areas reported different changes in the price of timber. The lowest recorded price change was an increase of about one third. The highest was ten times. On average, the price is 4 times higher than before the ban. This means that the earnings if one is not apprehended have quadrupled, thus an even greater incentive for exploitation.

Looking at Kakamega forest as an example, the cases of arrest (offences against forestry) are presented in Table 2.

Investigation revealed that there are explanations for some of the years in which arrests have been low. In 1992, which was an election year in Kenya, there were few arrests. During such times, there is general reluctance in arresting offenders as politicians influence whatever happens around forest areas. The same can be seen in 1997, which was an election year. It can be safely assumed that at such times the law and policy are unofficially suspended. However, in the year of the initial ban, 1999, the number of arrests was highest. In the following year, the numbers were still high. This may give an indication that extraction continues despite the ban. This will definitely have a negative impact on the forest estate.

Table 2 Number of arrested offenders in Kakamega forest-1992-2001

Year	No of arrests
1992	124
1993	216
1994	322
1995	300
1996	276
1997	155
1998	135
1999	457
2000	335
2001	274

Source: Annual reports. Kakamega Forest. Note. 1992 and 1997 were election years and are significant in Kenyan forestry.

Loss of Jobs

The Kenya Forestry Master Plan (KFMP) indicates that "the saw milling industry reportedly employs 14,000 people" KFMP (1994). However the study we conducted revealed that before the logging ban, the employees were as follows: Permanent: 25,875 Casual: 18,360 Totaling 44,235 persons. After the imposition of the ban, the numbers dropped as follows: Permanent 1,395 Casual: 1,116, giving a total of 2,511 employees. This clearly shows that there has been loss of jobs. Our aim however is to find out how this relates to the forest estate. In many areas surrounding the forests, residents who depended on sawmills for jobs found themselves without jobs after the Presidential ban. However, this had another impact on the forest estate that is worth noting. There has been the Taungya or Shamba system or recently called Non Resident Cultivators (NRC) system in Kenya. When the local people lost jobs, most turned to the NRC system for survival. They are allocated areas to cultivate and raise seedlings for planting in the forest. The system is the same as the shamba system. The positive side of this is that more seedlings are raised by groups of former sawmill workers. These seedlings are then planted in the plots allocated by FD. According to Forestry officers in Nakuru, the demand for plots far outstrips the supply. It is therefore easier to carry out tree planting in the gazetted forest. If survival is guaranteed through additional measures, backlogs in planting will be a thing of the past.

Establishment, Forest Fires and Pests

Saw millers have in the past contributed a great deal to reforestation activities. These they do by raising seedlings, providing transport and even paying some of the workers wages to carry out planting activities. The reasons why millers have contributed to afforestation activities are varied. One, the law requires them to provide help. Two, some millers do it for the sake of maintaining "good relations" with FD. This means that even in lean times, they are assured of being allocated some area to operate. Three, some millers do activities out of their own conviction that for the future of their businesses, trees will be required. It could be called forward planning on the part of the millers.

The presence of saw millers in the forest has also played a major role in that their workers act as guards for Forestry Department. In their absence, certain aspects of establishment do not flow smoothly. FD may be generating enough revenue but treasury allocation is not adequate for development expenses, hence saw millers have been of great assistance as far as establishment and other forestry activities are concerned.

In accordance with the Forest law, licensees may be called upon to take part in firefighting and control of pests. This, they have done in the past willingly or under coercion due to the law. Now, they are not obliged to help in any of these activities. As such, this has become a problem for the Forestry Department. This has an impact on the forest estate. Fire prevention and fighting and pest control have become the sole responsibility of the FD and this has really stretched their meager resources.

Theft of Forest Products

Theft of forest products cannot be easily quantified. However, through interviews with forest managers, we established that cases of theft have increased. 16 out of 29 forest stations or 55% reported cases of skyrocketed thefts. The main item stolen is timber. Fifteen out of twenty nine reported spending a lot of time in courts than on official office/field work. This they attributed to the fact that since other parties are involved in management of the forests, cases which they originally compounded at the office now ends up in courts. Court prosecutors press charges against offenders and require that FD officers appear as witnesses. The officers indicated that this takes too much of their time at the expense of other important forestry matters.

After the ban, prices of forest products have risen sharply as earlier mentioned. This is accompanied by problems of lack of products and general unemployment. Due to this, in all areas surveyed, incidences of theft have increased. With increased cases of the theft, this is affecting the forest estate. Indiscriminate felling means that silvicultural activities loose meaning. This is because thieves do not routinely select trees to cut but do cut where they think there are lesser chances of being apprehended. In addition, it was noted that their cutting style would cause problems, as the stumps left behind may be a habitat for pests and diseases. Latest complainant is PPM whose allocation is poached leading to operation at about 30% of the miller's capacity. PPM is thus in a dilemma and may point the finger of blame at the Forestry Department.

Silvicultural Operations

As previously mentioned, this is a Presidential ban. It does not follow any laid down procedures for a logging ban. This has thrown the FD in to confusion, as none of the government officers is willing to contradict the President, even if there was scientific evidence to show that the ban is wrong. Among the silvicultural issues of concern are planting backlogs, un-harvested mature plantations, pruning, and thinning backlogs. These are hereby discussed:

Planting Backlog

Chagala et al indicate that the backlogs have been as follows 1986: 4,203 ha, 1996: 16,000ha, 1999: 46,000ha and 2002: 21,000ha. This clearly shows a steady upsurge in backlogs. However, after the ban, there have been reduced backlogs. This has been mainly due to the increased availability of labor provided by Non Resident Cultivators (NRC). However, this is bound to cause problems for the forest estate. There are no management plans in operation that incorporate the increased planting. If the ban is not lifted, the planted area will still face problems, as the accompanying forest operations cannot be done. The net effect will be lower quality plantations that cannot suffice for timber production.

Un-harvested Mature Plantations

Over 1,000ha of mature plantations have not been cut. Over mature trees left lying around means that FD is making losses on investment. In addition, the site occupied by these plantations is also out of production effectively. This affects all other subsequent operations and has negative implications for forestry development. It has also been argued that old plantations may harbor pests and diseases. As the trees grow older, some are prone to attack by pests and diseases. This has implication for the rest of the plantations in Kenya. It will take longer to achieve full recovery.

Pruning Backlogs

This has risen from 2,599ha in 1998 to 11,674ha by 2002. As indicated earlier, there has been strong opposition to any silvicultural activities other than planting coming from the non-professional officers appointed by the President and the provincial administration. As such even routine activities such as pruning have not been done. This means that all forestry works are affected. Effectively, what this implies is that future forest products from these un-pruned logs will not be good for timber. The timber working cycles having been interfered with means that it will take FD many years to recover from the impacts of the logging ban. This is not good for the forest estate in Kenya.

Thinning Backlog

The first thinning backlog has increased from 3,117 in 1998 to 3,514ha in 2002. Although only the first thinning is recorded here, the second and third are also affected. On maturity, quality logs cannot be produced from such areas. This also has an impact on the forest estate. Delayed first thinning implies that other activities will also be postponed. Even if these are done later, the plantation cycle is corrupted. The whole purpose of raising trees is therefore meaningless if activities cannot be done as per management plans.

CONCLUSIONS

After careful examination of Kenya's forest act and policy, and the origin of the ban, we conclude that the ban diverges from the law and policy. This means that the logging ban does not originate directly from the FD. Hence, its purpose is not clearly stated. The lack of rule of law is not good for sustainable forest management. If logging bans should ever be used, there is need to examine existing laws and policies before the ban is introduced.

Impacts of the ban clearly contradict sections of the policy. The impacts contradict proper management of the forest estate, relations with timber utilization industries, employment creation, and interfere with running of private forests. We can therefore argue that in case of plantations, logging bans are not necessary unless if the forests are being converted to permanent conservation status. Logging bans should not contradict well-stated national forestry objectives. This is a lesson that countries that would like to go the Kenyan way can learn form this study. Logging bans do not enhance proper management of forest plantations. If logging bans should ever be used as management tools then more research is required into when, how and what should e included. Otherwise, abrupt policy changes do not augur well for forest plantations.

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(Received 30 September 2003)
(Accepted 14 February 2004)

Article

Deforestation Detection in Kinabalu Area, Sabah, Malaysia by using Multi-sensor Remote Sensing Approach

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ABSTRACT

This paper examines use of multi-sensor remote sensing approach for deforestation detection in the tropics. Multi-sensor satellite data of Landsat-MSS of 1973 and Landsat -TM of 1991 and 1996 were employed. Accuracy of image-to-image registration was below 1 pixel. Relative radiometric normalization of Landat-MSS 1973 and Landsat-TM 1991 to Landsat-TM 1996 as the reference image was carried out to remove the unwanted variabilities between all the satellite images. Image differencing algorithm with Normalized Difference Vegetation Index (NDVI) was examined for deforestation detection. The performance of the NDVI image differencing algorithm for deforestation detection between 1973 and 1996 was investigated at three test sites covered with reliable ground truths. The accuracy of detection was satisfactory that the algorithm was used in deforestation detection of the whole study area in two change periods i.e. I: 1973-1991 and II: 1991-1996. Although false deforestation pixels in period I were also detected, it can easily be rectified using a land use map of 1984. In total, 2,445ha of forest, which is almost 1% of the study area, were cleared from 1973-1996 and most of them were deforested in period I (2,090ha). This study concludes that the multi-sensor approach is a useful solution for deforestation detection because of better temporal coverage. It can also provide more satellite data for the application and thus lessen data acquisition problem due to cloud cover which is a consistent problem for the tropics.

Keywords: Deforestation detection, Multi-sensor remote sensing, Kinabalu Area

INTRODUCTION

Anthropogenic Activities and Deforestation

Deforestation has been one of the most important issues in the world especially in the tropics over the twentieth century. In this study, deforestation is defined as removal of forest cover to a state where the land surface becomes bare land. For mountainous areas, detecting and monitoring deforestation is even more important because of environmental impacts especially those related to landslide and soil loss. It is reported that agriculture is the main activity in the Andean countries that cause deforestation and habitat destruction. The habitat destruction in the neotropic region has been concentrating at lower slope and elevation areas, especially below 1500m. Montane bird species have relatively narrow elevation ranges (STOTZ, 1998). Besides, many of the elevation migrants are intolerant of non-forest habitats (POWELL and BJORK, 1995). Disruption of the movement pattern may provoke ecosystem-wide consequences due to the loss of their pollination and dispersal services (STOTZ, 1998). In Kinabalu area, land use activities have resulted forest clearings of steep slope areas. At the southern boundary area, ultra-basic forest which supports numerous endemic species, is found (KITAYAMA, 1991a).

At a landscape scale, the anthropogenic activities can lead to habitat destruction that may cause some species become more vulnerable to extinction. Forest clearing as well as management activities for commercial timber production can fragment populations of forest dependent wildlife (LAMBERSON *et al.*, 1994). The relationships between the species number and some landscape indices have been investigated (e.g. COLLINGE, 1996; DRESCHSLER and WISSEL, 1998).

Changes such as deforestation can easily be observed at

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the field but it is not easy to quantify the changes in terms of area, rate and distribution in the field. In fact, characteristics of deforestation may differ from place to place and thus need to be periodically examined and monitored.

Remote Sensing for Deforestation Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Deforestation is a type of change can be detected using satellite remote sensing. The basic premise in using remote sensing data for deforestation detection is that changes in the forest cover will result in changes in radiance values that are separable from changes caused by other factors, such as differences in atmospheric conditions, illumination and viewing angle, soil moisture etc. It may further be necessary to require that changes of interest be separable from expected or uninteresting events, such as seasonal, weather, tidal or diurnal effects.

There have been many change detection studies in place (e.g. SINGH, 1989; COHEN and FIORELLA, 1999; DHAKAL, 1999; ANDRÉFOUËT *et al.*, 2001). The common thing they share is that these studies usually employ single sensor data. This enables various techniques to be employed and tested for effectiveness in detecting temporal changes. However, change detection with single sensor data is restricted to the temporal coverage of the sensor. In contrast, the multi-sensor remote sensing approach has the absolute advantage for detecting changes in longer period and has more satellite images to choose from. The use of Lansat-MSS, in addition to the Landsat-TM, for instance, enables changes occurred back to 1972 when the Landsat-1 mission launched, to be investigated. Despite the absolute advantages, the use of this approach is relatively rare. MUNYATI (2000) exploited the temporal advantage for detecting wetland change using the Landsat-MSS and Landsat-TM data. Instead of using the widely recognized techniques such as image differencing, only classification was conducted but satisfying results were reported.

The objective of this study is to detect deforestation in Kinabalu area, Sabah, Malaysia by using multi-sensor remote sensing approach. It is also intended to examine the deforestation detection accuracy of the Normalized Difference Vegetation Index (NDVI) image differencing technique using the multi-sensor data. The multi-sensor data offer temporal coverage from 1970s to 1990s for detecting deforestation at Kinabalu area. The areas and distribution of deforestation at the study area are derived and causes are discussed.

STUDY AREA

Kinabalu area is located at the northeastern part of Kota Kinabalu, the capital of the state of Sabah, Malaysia (Fig. 1). Average, minimum and maximum rainfall of the study area are 3,274mm, 2,451mm and 5,487mm, respectively. The Kinabalu

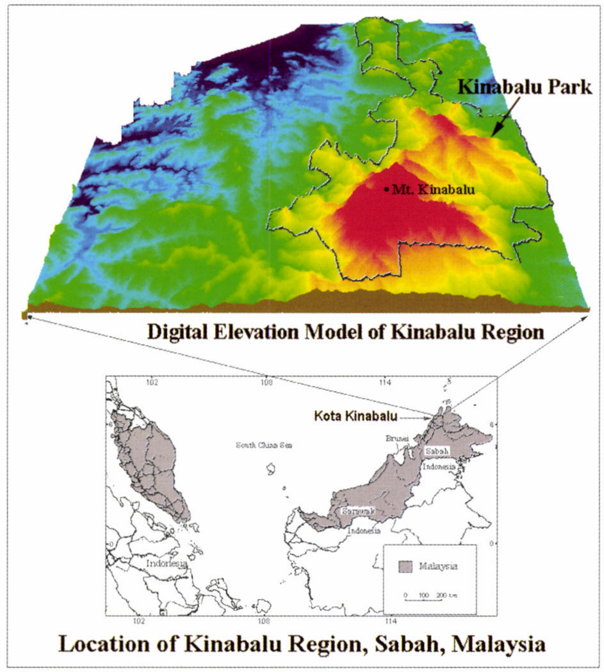

Fig. 1 Location and digital elevation model of the study area

area is diverse in its ecosystems. This area consists of low-lying flood plains at coastal areas to a rocky mountain at 4,095m (Mount Kinabalu). This is the highest peak between the Himalayas and Mount Whelm in Irian Jaya. Mount Kinabalu has been protected by Kinabalu Park since 1964. The mountain is characterized by difficult terrains, vast areas & most importantly, it comprises fragile ecosystems. Mean air temperature decreases from over 30℃ at lowland areas to about 10℃ at 3,700m.

Forest ecosystems of Kinabalu area are very diversified, from mangroves at the coastal area to lowland rain forest, montane rain forest and sub alpine forest. The altitude gradient is the main factor for the altitudinal zonation of the vegetation. Ultra basic forest, originating from special geological substrates is also found. Based on the dominant type, species composition and structure, KITAYAMA (1991b) has classified the vegetation into lowland, lower and upper montane rain forests, lower and upper sub alpine forests and alpine scrub. In general, the biodiversity of the vegetation decreases with altitude. Though, the pattern is modified by the factor of geological substrate. As altitude increases, the biodiversity of ultra basic forest decreases with a greater rate than that of the non-ultra basic forest (AIBA and KITAYAMA, 1999).

MATERIALS AND METHODS

The satellite images (path: 118, row: 56) acquired were Landsat-MSS data on January 12th, 1973 (MSS73) and Landsat-

TM data on June 14th, 1991 (TM91) and on April 8th, 1996 (TM96).

Pre-processing and Geometric correction

The MSS data has very light striping effect and histogram matching was carried out to make the apparent distribution of brightness values in the two images as close as possible. Accurate geometric co-registration of a multi-temporal image set, with root mean square error (RMSE) of 0.25-0.5 pixel or 1 pixel at the most, is necessary for accurate change detection (MOUAT *et al.*, 1993, MUNYATI, 2000). In this study, the TM96 image was firstly geocoded to the Universal Transverse Mercator projection and other images were registered to the TM96. The TM96 image was geocoded with an affine transformation model by collecting 22 ground control points (GCPs) on a shade image constructed based on topographic maps (1:50,000). RMSE of 44.12m or less than 1.5 pixels were resulted. Nonetheless, this will not have major influence on the detection analysis because the geometric registration accuracy of the MSS73 and TM91 to TM96 were within 1 pixel. The RMSE of the registration of the TM91 to the TM96 with 39 GCPs was 10.3m or 0.34 pixels. The RMSE of the registration of the MSS73 to the TM96 with 30 GCPs was 18.78m or 0.63 pixels.

Radiometric Correction

Atmospheric correction especially the path radiance component should be removed prior to normalization. Varying conditions of the atmosphere caused by meteorological and solar angle variations, influence and change the spectral reflectance of materials on the ground. Amount of electromagnetic energy detected by a sensor influenced by the atmosphere through scattering, absorption and refraction. Degree of influence is wavelength dependent. Of these, scattering account for the biggest part of the influence (SIEGAL *et al.*, 1980). Other effects can be ignored because they account for relatively small proportion of the satellite brightness values. The scattering effect on Landsat data is an additive component and can be corrected by dark object subtraction. The dark object for each band of a scene is obtained from the histogram method. The left part of histogram of each band of the Landsat images is examined interactively on the computer screen for probable haze influence. To avoid obtaining local minimum values, the histograms of the whole scenes are used. The haze influence is indicated by a sharp increase in the number pixels at some non-zero digital number (DN). Started with the minimum DN, if the number of pixels of a DN in a particular band increases sharply, it can be regarded as a haze value (CHAVEZ, 1988).

Absence of *in situ* data of the atmospheric conditions in the study area during the satellite overpass has made the correction of other atmospheric effects a difficult task. Accuracy of atmospheric correction with a standard atmospheric model cannot be verified and any error in the correction process might have propagated undetected into subsequent analysis (ADAMS *et al.*, 1995). For change detection studies that involve multi-temporal satellite data, correcting and calibrating these effects one by one are usually beyond the financial and technical means in most cases (ELVIGE *et al*, 1995).

Relative radiometric normalization which substantially reduces the inter-scene variability resulting from the changes other than the land cover change, is preferred (e.g. MUNYATI, 2000 and ELMORE *et al.*, 2000). It uses one image as reference and adjusts the brightness values of other images to match the reference image. In this study, the relative radiometric normalization based on pseudo-invariant features (SCHOTT *et al.*, 1988) is adopted to correct at once all the inter-scene radiance variability due to factors mentioned, including atmospheric factors (e.g. VOGELMANN, 1988, AWAYA and TANAKA, 1996, MUNYATI, 2000 and ELMORE *et al.*, 2000). It uses one image as reference and adjusts the brightness values of other images to match the reference image. The TM96 is chosen as the reference image for the relative radiometric normalization procedure because it is most recent and has more ground truth sources.

The pseudo-invariant features or constant reflectors over time, common to all images, were carefully selected. The so-called pseudo-invariant features are bare surface and calm water surface do not, in theory, change over time in terms of reflectance. The samples of the pseudo-invariant features have to be selected very carefully to ensure that they are the genuine ones. Theoretically, they should occupy the upper end and lower end of the feature space between every two images for each band so that the image can be normalized to the reference image. For this, water samples, which occupy the lower end space, were taken from bay area where sea surface condition is calm. The bare surface samples were acquired on bare land and rock areas, and they occupy the upper end space. Normalization equations were then derived from regression analyses for adjusting the DN values of the multi-temporal satellite images to the TM96. The regression models contains an additive component that corrects for differences in path radiance between dates which are not fully accounted in the individual scene based subtraction, and a multiplicative term that corrects for the differences in detector calibration, solar angle, earth/sun distance, atmospheric attenuation and phase angle between dates (MUNYATI, 2000). Upon removal of these variations, changes in the DN values can be related to changes in cover surface conditions. The normalization equations are shown in Fig. 2.

Detection Algorithm

There are many change detection algorithms available and are usually based on the original band data or transformed

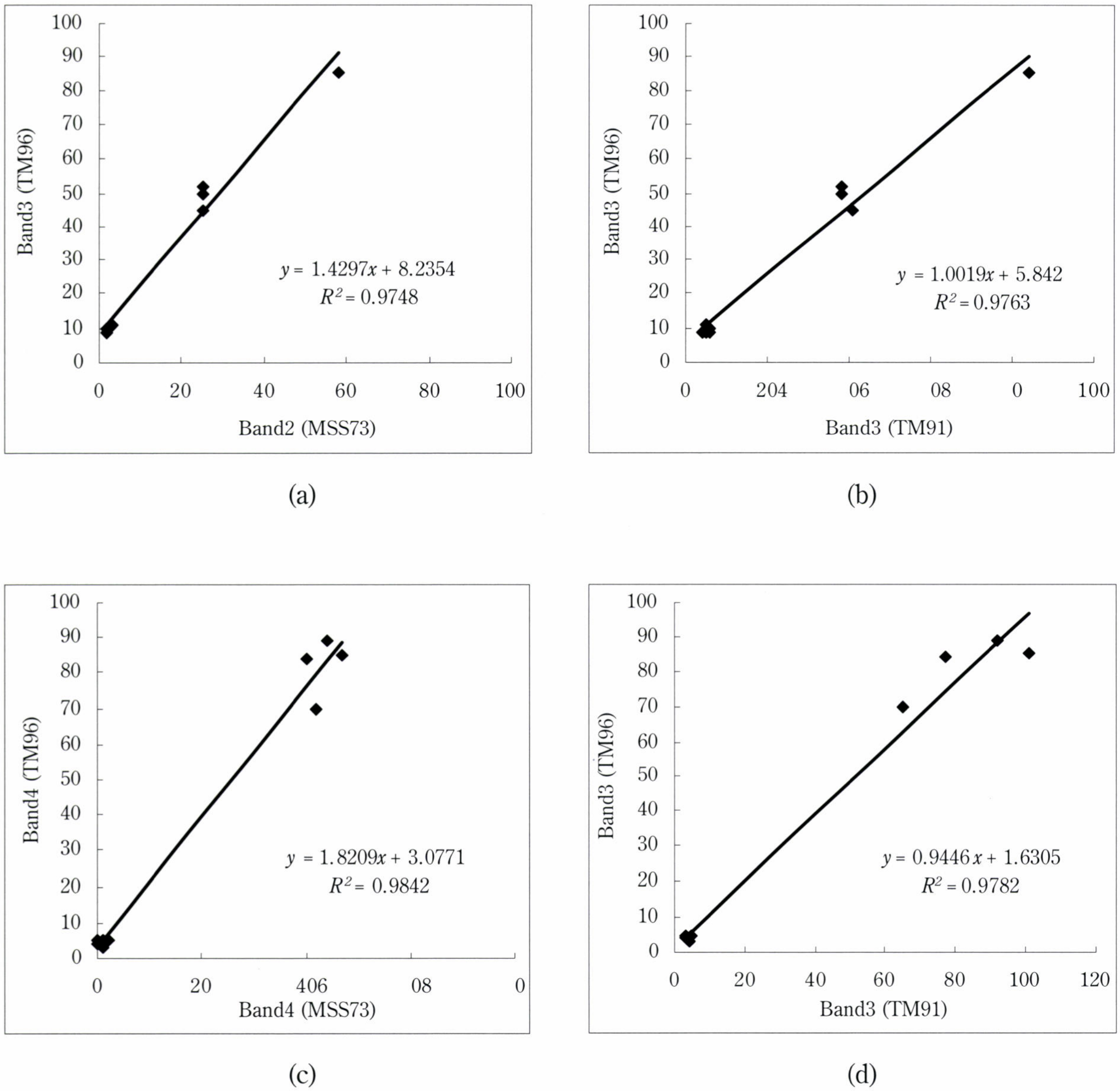

Fig. 2 Normalization of Landsat-MSS of 1973 (MSS73) and Landsat-TM of 1991 (TM91) to Landsat-TM of 1996 (TM96). (a) Band2 of MSS73 to Band3 of TM96, (b) Band4 of MSS73 to Band4 of TM96, (c) Band3 of TM91 to Band3 of TM96 and (d) Band4 of TM91 to Band4 of TM96.

variables. Vegetation index is one of the most widely used transformed variables. It is usually developed by taking the difference between the Near Infrared (NIR) and Red (R) regions. The R region comprises absorption wavelengths of chlorophyll of green vegetation while the NIR region consists of highly reflected wavelengths due to internal leaf structure of the leaf (TUCKER and MAXWELL, 1976).

This study employs the most widely-used NDVI in an image differencing algorithm. The NDVI is defined as below:

$$NDVI = \frac{NIR - R}{NIR + R}$$

The NDVI is a commonly used indicator of vegetation parameters in remotely sensed data because there is a reasonable correlation with vegetation abundance and other important ecological parameters, such as leaf area index (ELMORE *et al.*, 2000). The NDVI computed using the equation is added with value of one and multiplied with a hundred so that the non-vegetation pixels will have a value of 100. Figs. 3a,

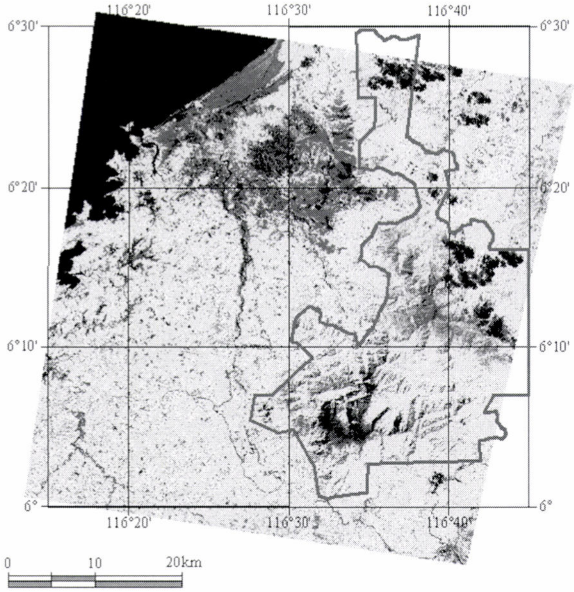

Fig. 3a The NDVI Image of MSS73
Note: Brighter colors mean higher vegetation biomass, in general.

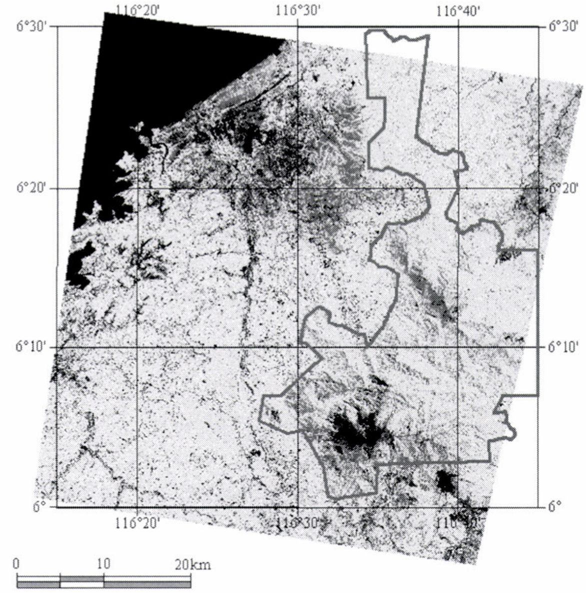

Fig. 3b The NDVI Image of TM91
Note: Brighter colors mean higher vegetation biomass, in general.

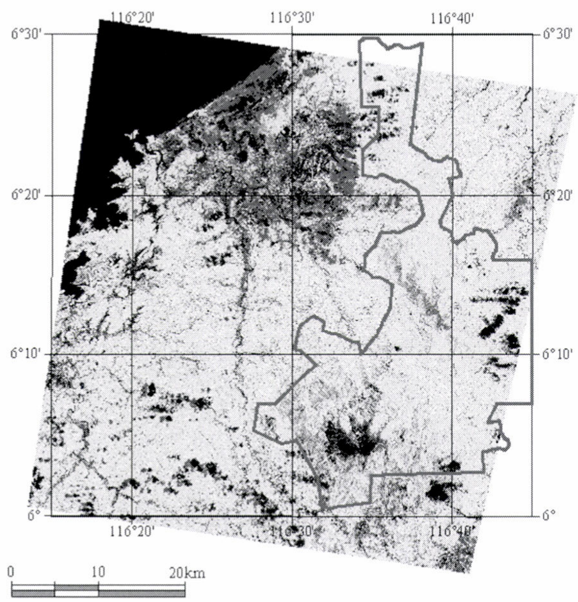

Fig. 3c The NDVI Image of TM96
Note: Brighter colors mean higher vegetation biomass, in general.

3b and 3c show the NDVI images of MSS73, TM91 and TM96, respectively. Brighter colors in the images indicate higher biomass or vigor of the vegetation cover and vice-versa.

To detect the deforestation, we used the NDVI with image differencing technique. This technique requires that each pixel's value in the image be subtracted from its corresponding pixel's value in another image. The image resulted represents the changes between the two time periods. Pixels exhibiting a significant value change can be expected to lie in the tails of the distributions of the difference image, whereas the remaining pixels should be grouped about the mean. Image differencing may be applied to a single band (in which case it is called univariate image differencing) or to multiple bands.

The image differencing with NDVI or NDVI image differencing algorithm has been used in change detection studies such as forest canopy change (NELSON, 1983), landslide detection (DHAKAL, 1999), and vegetation change in semi-arid area (ELMORE *et al.*, 2000). It is a simple and straightforward approach where changes in a pixel at line *i* and column *j* of band *k* ($\Delta NDVI_{ij}$) is computed as below:

$$\Delta NDVI_{ij} = NDVI_{ij}(t2) - NDVI_{ij}(t1) + C$$

where
t2 and *t1*: date 2 and date 1, respectively
C: constant (taken as 127)

The date 2 image is subtracted from that of the date 1 image to generate a change image. A constant of 127 to make the no change pixels in the midpoint of the 8-bit data space. To its left, it represents decreases in biomass or vegetation amount for the NDVI. To its right, increase in biomass or vegetation amount for the NDVI is expected. We are interested only in deforestation and thus the left tail of the change image is of interest.

Accuracy Assessment

There is no theoretical basis on how a threshold of change or no change can be established. Standard deviation from the mean is often employed and has been usually found suitable (JENSEN, 1996). RIDD and LIU (1998) derive the optimal threshold by testing the thresholds from 0.1 to 3 standard deviations. This is especially useful for investigating area, which is not familiar to researchers. On the other hand, MICHALEK *et al.* (1993) derived the threshold by examining the pixel values of deep water. It was however too relaxed and generated a large number of insignificant change pixels.

In general, the approach that determines the optimal threshold is not other than the one that gives the best result. That means ground truth is the most critical factor. While it is possible to collect ground reference information for the most recent remotely sensed data, it is impossible to go back in time and collect the historical ground reference information (JENSEN *et al.*, 1995). Thus, ground truths for historical images are totally dependent on any data available especially aerial photographs, maps and photographs. It is not difficult to sample areas of no change but it is difficult to sample on areas of change. An intuitive straightforward interpretation of the word of "change areas" necessitates samples of same location to know if changes have taken place over the period. Moreover, changed area is usually a very small percentage of the total area so that the available ground truth source may not include any of the changed area. If ground truth is available, threshold level can be modified until it gives highest accuracy (DHAKAL, 1999).

Accuracy assessment strategy employed was to first verify the effectiveness of the NDVI image differencing with the multi-sensor data at test sites. The accuracy of change detection was assessed using a pair of images (TM96 and MSS73). Three test sites covered by reliable groundtruths in both periods were identified. One of the sites is located at the northwestern part of the study area in Kota Belud area. The remaining sites are in Kundasang area and Mamut area, in the southern part of the study area (Fig. 4).

The accuracy was assessed using the error matrix of change and no-change. Both overall accuracy and Kappa coefficient were used to determine the most accurate threshold. The overall accuracy measures accuracy of the detected changes as a whole i.e. the ratio of the total number of correctly classified samples to the total number of samples. However, the overall accuracy has a tendency to be biased toward the category with a larger number of samples (NELSON, 1983; SINGH, 1986), which are the samples of no change areas. In contrast, the Kappa coefficient takes into account the degree of agreement expected by chance by using all the elements of the error matrix and not just main diagonal to its calculation. The accuracy it gives is the proportion of agreement obtained after removing the proportion of chance agreement as it uses all the elements in the error matrix to derive an accuracy measure. It is widely used in accuracy assessment in remote sensing studies (CONGALTON, 1991).

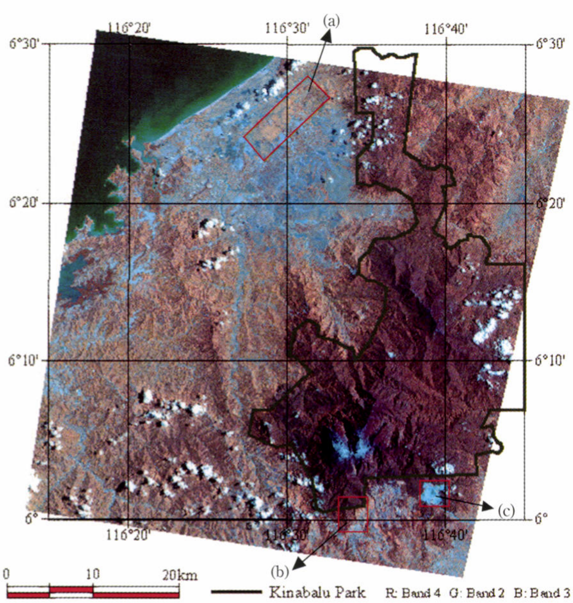

Fig. 4 Location of test sites.
(a) Kota Belud area; (b) Kundasang area;
(c) Mamut area. The background image is TM96.

RESULTS AND DISCUSSION

Accuracy of Deforestation Detection

Based on the ground truth points at the three test sites, the optimal threshold was evaluated iteratively using the two accuracy measures. Fig. 5 shows how the accuracy measures change with the thresholds. The optimal threshold was determined when the Kappa coefficient and overall accuracy were highest i.e. 63% and 93% , respectively. However, false deforestation on paddy areas were also detected. The accuracy was improved after the false change pixels were removed. The

Table 1 Accuracy of NDVI image differencing for the deforestation detection before and after removal of false deforestation pixels

Accuracy measure	NDVI[a]	NDVI (corrected)[b]
Khat accuracy	62.99	67.89
Overall accuracy	93.05	94.26

a: NDVI image differencing. b: Accuracy after false change pixels on paddy areas were corrected.

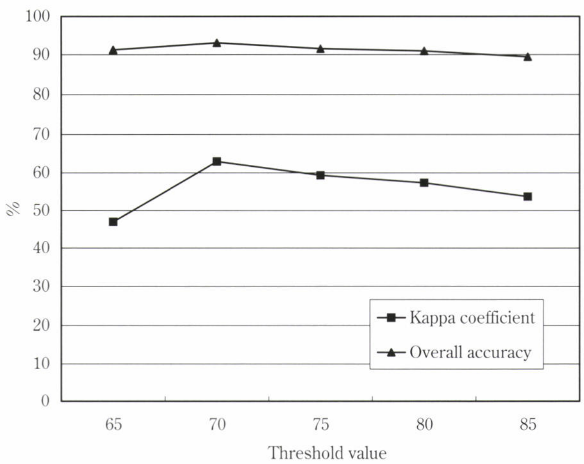

Fig. 5 Accuracy of various threshold values. Threshold of 70 gives the best deforestation detection accuracy.

improvement for the Kappa coefficient was 5% whereas the total accuracy only improved marginally (Table 1).

Deforestation for the Two Detection Periods

The results of deforestation detection are shown in Figs. 6 and 7 for period I and period II, respectively. In general, the threshold detects distinctive changes of vegetation cover i.e. from vegetation to non-vegetation. This means crop harvest may also be detected as 'deforestation'. In this study, some of the deforestation detected in period I were actually paddy areas. The paddy areas are found in the Kota Belud area where the establishment was started before the Landsat program in 1972. The forests at the coastal plains in the northeastern areas were wiped away by mainly paddy cultivation, and cattle ranching in post-war periods. The paddy areas can be interpreted on aerial photographs of 1972 and confirmed through field interview. The confusion was because of different growing condition in the two images. The paddy was growing actively in MSS73 but was not in the active growing condition in TM96. The paddy areas were intepreted as active growing green vegetation when MSS73 was taken because the NDVI value was relatively high. In TM96, its relatively low NDVI value indicated that the paddy was not growing actively. The false deforestation areas were easily removed with the availability of a land use map of 1984.

The algorithm has estimated 2,090ha of forest cleared during the first period or 0.8% of the total land area. In second period, deforestation is small, at 355ha or 0.13% (Table 2). Arbitrarily, the first period has a deforestation rate of 116ha/year, which is more than 1.5 times than that of the second period. In total, 2,445ha of forest were deforested in Kinabalu area from 1973 to 1996.

While the remote sensing technology gives the

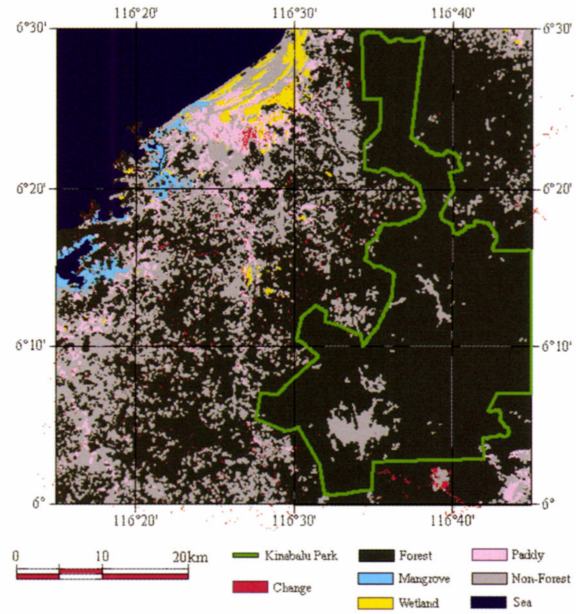

Fig. 6 Deforestation between 1973 and 1991 detected by the NDVI image differencing algorithm. The background image is the land use map of 1984. Red color areas on the pink color areas are false deforestation areas.

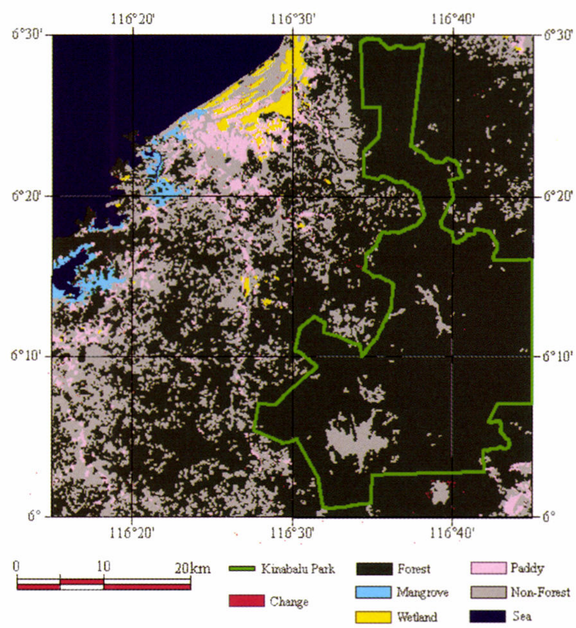

Fig. 7 Deforestation between 1991 and 1996 detected by the NDVI image differencing algorithm. The background image is the land use map of 1984.

deforestation estimate, the types, distribution and causes have to be interpreted. In period I, relatively large-scale deforestation concentrates at areas near the southern part of the park. Forest clearing at the mining site has contributed to

Table 2 Estimates of Deforestation in the Two Change Periods

Change Period	Change (ha)	No Change (ha)	Total Area (ha)	Percent of Change (%)
I : 1973-1991	2,089.98	263,345.94	265,435.92	0.79
II : 1991-1996	355.14	265,080.78	265,435.92	0.13

a major portion of the deforestation in period I. In fact, the copper mine was established at a 25km^2 forest, which legally excised from Kinabalu Park in 1974. The park was compensated with Mount Templer area (93km^2) in the northern part and the state government was granted administrative authority in 1984. Under the new Parks Enactment 1984, boundary of the park was redefined but this has resulted in the loss of Pinosuk Plateau, the main site of the Royal Society Expeditions in 1961 and 1964, and Bukit Hampuan, a valuable site for studying ultra basic vegetation (LIEW, 1996). Pinosuk Plateau is alluvial flatland that is relatively fertile for cultivation. The de-gazetted lands were developed for a large scale diary farm, and temperate vegetable cultivation. Some areas were converted to housing lots. Commercial agriculture has significantly cleared some forests in the southern part. It can easily be observed in the field that the forest clearings are getting very close to the park boundary.

In the period II, deforestation at the mining site continued at a much smaller rate. Small scale slash-and-burn agriculture has been clearing the forest in both periods. Differs from the large scale development, the slash-and-burn agriculture scatters over the whole area. Despite elevation more than 1,200m and slopes steeper than 30°, shifting cultivation has been practiced by the local community. The impacts of the shifting cultivation on the environment, including soil, water and biodiversity, were documented in JOSHI and KAR (1993). The impacts of land use activities can also be identified by using an environmental impact matrix where the environmental impacts of development activities are evaluated on various resources (SENES and TOCCOLINI, 1998).

The relatively low annual deforestation rate over the study period gives an impression that no significant deforestation has occurred. In fact, the results have shown that the Kinabalu Park has played an invaluable role in protecting the last big piece of primary forest in the area. It is expected to continue with such role in future. The change detection study has two implications on conservation sector. The first is that conservation target in this region is the secondary forest that is recovering from previous disturbance. Certain degree of degradation on the secondary forest is expected. To identify forests important to be conserved, appropriate conservation planning approach is essential. Second, the results also suggest the needs to strengthen forest conservation management of Kinabalu Park. This is because of the fact that Kinabalu Park contains the big piece of primary forest which is rich in timber resource and thus subject to illegal logging activity. The relatively low deforestation rate also means higher pressures on the remaining high forests. Agricultural activities in the surrounding areas are expected to pose more pressures on the protected forests. Commercial agricultural activities (temperate vegetable) are restricted by the Southern boundary of the Kinabalu Park. In other surrounding areas, shifting cultivation activities should be monitored from time to time. The boundary areas adjacent to villages are more exposed to encroachment.

The Multi-sensor Remote Sensing Approach

Nevertheless, it is noted that the estimate of the total deforestation may be an underestimate. The temporal interval for period I (1973-1991) was considerably long and provide sufficient time for deforested areas to regenerate. The vigorous regenerated vegetation in 1991 may exhibit very similar NDVI value compared with that of the corresponding forest area in 1973. Actually, many of the available images of Landsat-TM and Landsat-MSS were covered by clouds. Cloud coverage has been a limiting factor to the use of satellite remote sensing in the tropics. In that regards, multi-sensor remote sensing approach offers more satellite data for deforestation detection as well as for other change detection in the tropics.

Although multi-sensor remote sensing approach may have fewer options of techniques, it is advantageous in terms of temporal resolution. The use of Lansat-MSS, in addition to the Landsat-TM, for instance, enables changes occurred back to 1972 when the Landsat-1 mission launched, to be investigated. The main obstacle is that different wavelength range of sensors. MUNYATI (2000) used post-classification comparison technique on the three common bands of the Landsat-MSS and TM for detecting wetland change. However, it is often reported that the post-classification comparison technique has relatively low accuracy because the accuracy of this technique is the product of the accuracy of classification in two dates (YUAN *et al.*, 1999). It can be argued whether the NDVI of Landsat-TM and Landsat-MSS are comparable because the wavelengths of the NIR and R bands of the two sensors are slightly different. However, with the reliable ground truths, this study shows satisfactory results for the deforestation detection. In some studies, various sophisticated techniques were applied without sufficient ground truth of the changes detected especially in the tropics where ground truth data are very limited (SINGH, 1989). After the relative normalization, the values of the NIR and R bands of Landsat-MSS should approximate the Landsat-TM. However, this issue should be investigated further. Image fusion techniques (e.g. CARPER *et al.*, 1990; PELLEMANS *et al.*, 1993) should be explored to enable integration of more types of sensor data for change detection.

CONCLUSIONS

This paper presents a case study of deforestation detection at Kinabalu area, Sabah, Malaysia by using multi-sensor remote sensing approach. While there are issues to be investigated further, we were able to show how the approach can provide information about deforestation in terms of area and distribution so that causes can be interpreted. These information are important for planning purposes. Given the size of the park with a perimeter of 205 km (PHUA and MINOWA, 2000) and very inaccessible in certain parts, the multi-sensor remote sensing approach is potentially very useful especially to the management of Kinabalu Park. This approach is relatively simple and straightforward to be used by the authority. The approach provide more opportunities to obtain 'cloud-free' satellite images so that it is possible to identify areas that subject to high deforestation risks in terms of deforestation area and frequency that are neighboring the park. This could aid the improvement in resource optimization for protection.

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(Received 8 December 2003)
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