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Article

Predicting Forest Understory Vegetation Types for Wildlife Management*[1]

—A Case Study for Japanese Serow (*Caricornis crispus*) protection area in the Upper Miya River Basin, Mie Prefecture—

Tsuyoshi Yoshida*[2,3], Tetsurou Morita*[2], Ko Nagase*[2] and Kazuhiro Tanaka*[2]

ABSTRACT

This paper proposes a simple model to use in mapping forest understory vegetation types. Cartographic modeling, with the aid of GIS (Geographic Information System) technologies, was used for this study. Understory vegetation maps were produced by GIS-based prediction, and the result was applied to the analysis of the Japanese serow (*Caricornis crispus*) protection area in the upper Miya River Basin, Mie Prefecture, Japan. We used a simple boolean logic known as crosstab with a raster-based GIS. Our procedure and approach were focused on verification and effective use of what resource managers already know. The existing information on forest ecosystems, which included soil moisture, bioclimate, and overstory vegetation types, was used to predict forest understory vegetation. The results of our study showed there were various forest understory stratum types (bamboos, ferns, shrubs, and lower tree layers) in the species' protection area, and these varieties were considered to be preferred diet sources for serows.

Keyword: forest understory vegetation, GIS, cartographic modeling,

INTRODUCTION

Forest ecosystems are often the focus of wildlife management (Hunter 1990). Managing and planning forestlands for wildlife in general involves maintaining and creating forest environments that accommodate the habitat requirements of the species of interest (Mannan *et al.*, 1994). Effective management of wildlife therefore largely depends on understanding species habitat needs (Clark *et al.*, 1993; Yoshida *et al.*, 1998). Forest ungulate species such as sika deer (*Cervus nippon*) and Japanese serow (*Caricornis crispus*) are primary examples of species associated with various habitat-related factors of the forests. Among various factors in forest management, understory vegetation is probably the most significant for many wildlife species, because forest understory vegetations offer forage for some species and protective cover for many species (Hayes *et al.*, 1997). The types, richness, height, and available nutrients of understory vegetation determine the preferred habitats of wildlife species like serow and deer in Japan.

Forest scientists and managers have used the relationship between terrain, climate, moisture, and vegetation to map forest communities (Bolstad *et al.*, 1998). In addition, landscape models that consider spatial properties such as plant cover have proven "useful" to manage natural resources (Ostendorf and Reynolds, 1999). Nevertheless, studies using the forest landscape-level approach to address resource issues in Japan are still limited, because ecological data such as digital wildlife habitats at the landscape level are not fully available for the diverse needs of natural resource management (Yoshida *et al.*, 1998).

Japanese natural resource managers are certainly required to prepare forest and wildlife habitat data. However, Davis *et al.* (1990) indicates that it is unrealistic to

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postpone action to preserve wildlife diversity until "complete" information is collected. Researchers must make effective use of what they already know, while they are expanding their knowledge base (Davis *et al.*, 1990). Herein, we propose the use of existing information from phytosociological studies and GIS (Geographic Information System) technologies to predict forest understory vegetation types of the upper Miya River Basin in Mie Prefecture, Japan. We believe this study is a necessary precursor to estimating the diversity of the region and stimulating further spatial dynamics work and management efforts for forestry and wildlife, particularly Japanese serow. Local governments and the Environmental Agency of Japan (EAJ) have been actively collecting information on the ungulate's habitat and vegetation. Accumulation of these biological or geographical data makes its possible for us to map preliminary understory vegetation types for serow management. The objective of this paper is thus to describe an alternative mapping approach and to produce preliminary maps of forest understory vegetation types for future use in serow habitat analyses and forest management.

FUNCTION OF FOREST UNDERSTORY

Hayes *et al.* (1997) indicates that increased understory forage promotes use of thinned stands by ungulates in the Pacific Northwest, U.S.A. Maeji *et al.* (1999) investigated the population density of sika deer on the Ohdaigahara in the Kii Peninsula among five vegetation types-open grassland, sparse mixed forest with coniferous and broad-leaved trees, dense mixed forests with coniferous and broad-leaved trees, sparse coniferous forest, and dense coniferous forest. Their study indicates that population density of sika deer is the highest in the open grasslands with less than 20% crown cover, because the deer tend to feed on a dominant ground cover of Sasa bamboo grasses (*Sasa nipponica*). The deer may browse on bark, and cause dieback of overstory trees (Sekine and Sato, 1992; Maeji *et al.*, 1999). However, overstory vegetation dieback is common in the Ohdaigahara in which forest understory vegetation is already overgrazed by the deer, or winter snow lies higher than the ground vegetation level. Understory vegetation is the most important factor for serow as well as many other species in determining habitat preferences (Mie, Nara and Wakayama Prefectures Education Committees, 1989; 1994). The tooth arrangement of serow is notsuited for browsing large woody plants (Kudo, 1996). There are no canine teeth in the upper jaw of serow, so a serow can only take in vegetative matter by its molar teeth. The main food sources of serow therefore are annual or perennial herbs and twigs of woody shrubs or lower tree layers (Kudo, 1996).

In addition, a well-developed understory provides cover for other wildlife such as birds that nest on the ground including species of juncos (*Junco* spp.), warbler (*Wilsonia* spp.), and thrushes (*Turdas* spp.) in the Pacific Northwest, U.S.A. (Hayes *et al.*, 1995; 1997). Abundance of some species of small mammals that are prey for reptilian, avian, and mammalian predators is also positively related to understory vegetation (herbs and shrubs) and coarse woody debris (Carey and Johnson, 1995). Based on these previous studies, it is probably reasonable to assume that the habitats of many wildlife species including Japanese serow in the central Kii Peninsula are highly dependent on understory vegetative composition. It is consequently important for foresters and wildlife managers to map forest understory vegetation for the future protection of both wildlife species and the forest ecosystem.

STUDY AREA

The study area is in the upper Miya River Basin. Part of the area is known as the Ohsugidani Valley, which is located in the west part of Mie Prefecture (Fig. 1). The Miya River drains its water from Mt. Hidegatake, on the border of Nara and Mie Prefectures. The highest mountains in the Basin are over 1,600m on the prefectures' border. The area, ranging from 1,600m to 300m in elevation, includes rich natural forests such as sub-alpine, cool temperate and warm temperate forests. This study area is also well-known for its heavy rainfall. Annual precipitation averages over 4,000mm. The basin therefore is a habitat for 23 species of mammals, 46 species of birds, 20 species of reptiles and amphibians, 1,827 species of arthropods, and 943 species of vascular plants (Takeda, 1998).

The Ohsugidani Valley Forest Ecosystem Preserve is a part of the study area. The area is a deep V-shaped valley with strata comprising sand stone, shale, chert, and limestone, where it is a part of the Chichibu Geology Zone (Kume, 1999). The Ohsugidani National Forest and a part of Yoshino-Kumano National Park are also included in the study area.

In recent years, the area west of Mt. Hidegatake, which is known as the Ohdaigahara, has been a focal point of forest preservation because of over-browsing on virgin Touhi spruce (*Picea jezoensis*) by deer (Sekine and Sato, 1992). As a result many biologists and foresters are actively involved in the Ohdaigahara. The Ohsugidani Valley however is the subject of relatively few research activities related to forestry. With limited public access, forest researchers need to use alternative approaches for vegetation mapping in the study area.

METHODS

Direct observations are the traditional approach in understory vegetation mapping. Based on the phytosociological studies and wildlife research in the Miya River Basin, this study however developed a presumption-based forest understory map. Differences among taxa in moisture response and growth potential interact with climate, soils and topography to produce in changes in vegetative species composition at both regional and local scales (BOLSTAD *et al.*, 1998). We focused our efforts on the small landscape scale. The development of landscape-level management and conservation of forest resources has been enhanced with tools such as GIS (FORMAN and GODRON, 1986).

Our approach was based on the model in "*Special Reports on Serow Protection in the Kii Mountains,* 1994" (MIE, NARA and WAKAYAMA PREFECTURES EDUCATION COMMITTEES, 1994). We used GIS techniques to predict forest understory vegetation types from the following three factor maps (1) soil moisture, (2) local bioclimate, and (3) overstory vegetation. All factor maps were converted with a raster-based GIS software package, IDRISI. In this study, we used raster-based GIS, rather than vector formats, because it was more applicable for analyzing and overlaying the boolean images in the study process. Our raster pixel size was 250 m x 250 m, because it was compatible with the format of other natural resource digital data in Japan (YOSHIDA and TANAKA, 2000). This method resulted in each GIS pixel having its own predicted understory vegetation type.

PROCEDURES

GIS procedures and cartographic modeling

GIS-based modeling approaches developed to integrate wildlife habitat concerns in forest management are relatively new (NICHOLS´and ROSS, 1998). Forest areas with limited access require adequate indoor preparation with resource management tools such as GIS. Our procedure was to retrieve data by using rules of "boolean logic" to operate on the attributes and spatial properties (BURROUGH, 1986). Although a simple table model is available, it is possible to map and classify understory vegetation with the boolean logic, "crosstab". Its role in the cartographic model used in this study is shown in Fig. 2. The cartographic model is a graphic representation of the data and analytical procedures used for the study. Its purposes are to help the

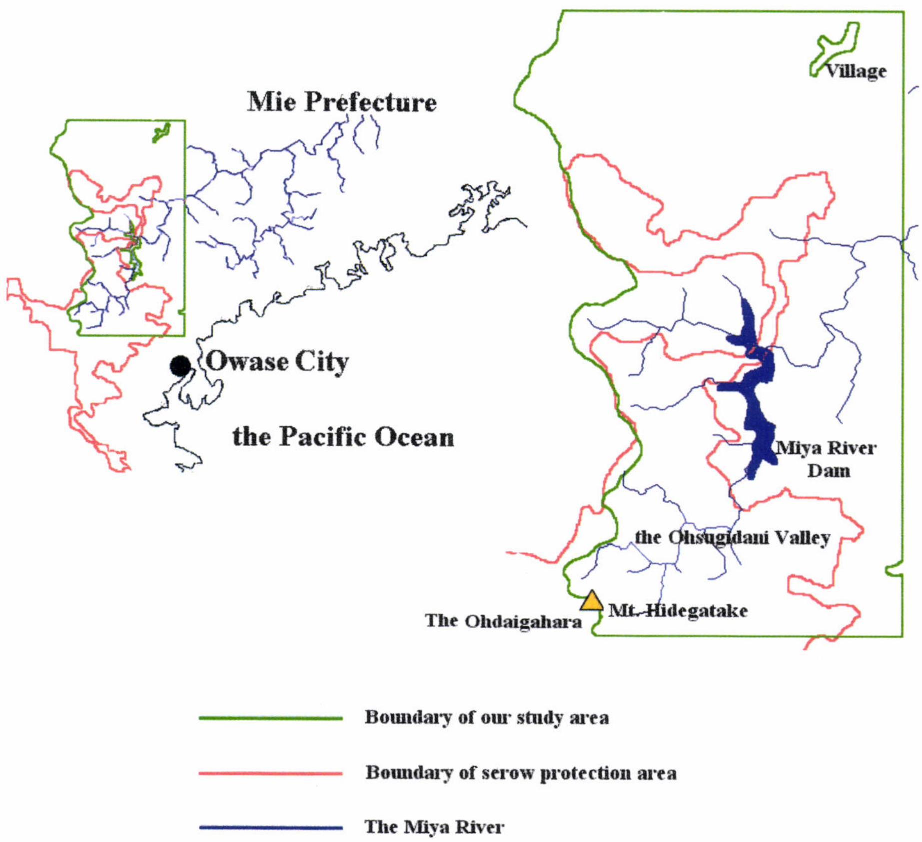

Fig. 1 The study area,upper Miya River Basin, Mie Prefecture, Japan
*Location of our study area in Mie Prefecture, Japan on left, and details of the study area on right

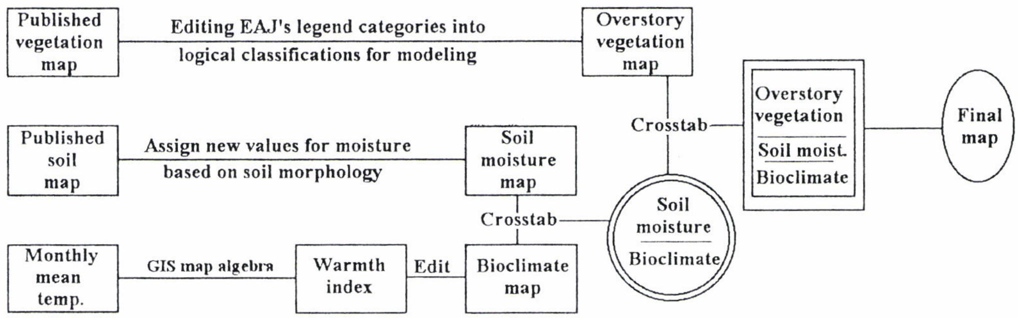

Fig. 2 Cartographic modeling process for the study

Table 1 Bioclimate types for understory vegetation

Bioclimate	Forest Soils	
	Dry soil	Intermediately wet soil
Sub-arctic forests		[*Picea jezoensis*] *Carex fernaldiana*, *Sasa nipponica*, *Dryopteris expansa*
Cool temp. forests	[*Tsuga sieboldii*] *Rhododendron degronianum*	[*Fagus crenata*] *Sasa nipponica*. *Sasamorpha borealis*. [*Q. crisupula*] *Sasa nipponica*. *S. borealis*, *Pieris japonica*, NUV** [*Cryptomeria japonica*] *Lindera umbellata*, *L. triloba*, *S. borealis* [*Chamaecyparis obtusa*] *L. umbellata*. *L.triloba*, *S. borealis* [*Sciadopitys verticillata*] *Rhod. degronianum* [*T. sieboldii*] *S. borealis*, *P. japonica*, *Rhod. serpyllifolium* [*Abies homolepis*] *Sasa nipponica*
Warm temp. forests	[*Castanopsis cuspidata*] *Gleichenia japonica* [*Chamaecyparis obtusa*] *Rhod. degronianum*, *Dicranopteris linearis* [*Pinus densiflora*] *D. linearis* [*Quercus phillyraeoides*] *Myrsine sequinii* *Acer distylum* [*Cryptomeria japonica*] *G. japonica**	[*Castanopsis sieboldii*] *Cleyera japonica*, *Trachelospermum asiaticum* [*Castanopsis cuspidata*] *Cley. japonica*, NUV** [*Q. acuta*] *P. japonica*, *Arachniodes sporadora* [*Q. gilva*] *Symplocos glauca* [*Q. salicina*] *A. sporadora*, NUV** [*Elaeocarpus sylvestris*] *Polystichopsis aristata*, NUV** [*Q. serrata*] *S. borealis*, *Rhod. macrosepalum*, *D. dichotoma*, *Sasa nipponica* [*Carpinus tschonoskii*] NUV** [*Zelkova serrata*] *Camellia japonica* [*Q. acutissima*] *Pleioblastus chino*, NUV** [*Chamaecyparis obtusa*] *G. japonica*, *C. japonica*, *Rhus trichocarpa* [*Cryptomeria japonica*] *G. japonica*, *C. japonica*, *Alpina japonica* [*Sciadopitys verticillata*] *S. borealis* [*Pinus thunbergii*] *Eurya japonica*, *Miscanthus sinensis* *Ligustrum japonicum* [*Pinus densiflora*] *E. japonica*, *R. macrosepalum* [*Phyllostachis pubescens*] NUV**

[ ] indicates overstory vegetation cover

*Our field observations

**NUV indicates no dominant understory vegetation

Modified from Mie, Wakayama, and Nara Prefecture Education Committees (1994)

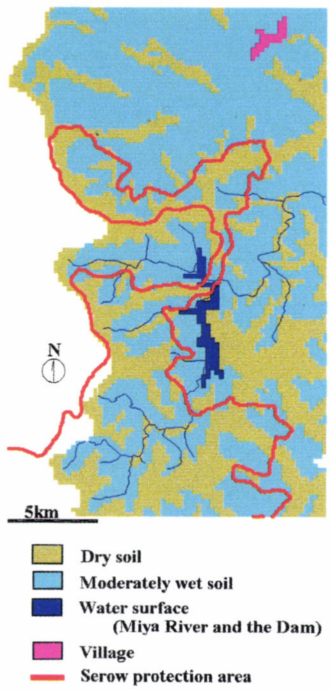

Fig. 3 Soil moisture map

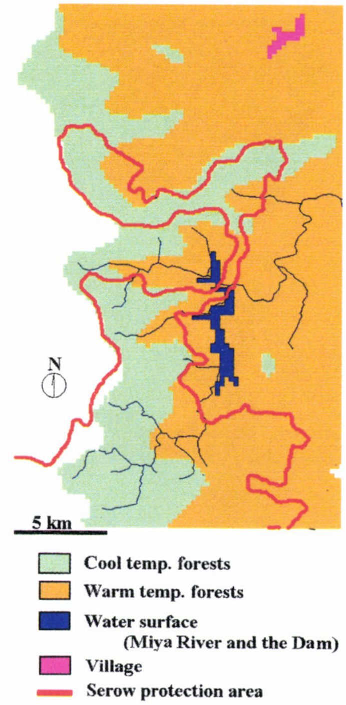

Fig. 4 Bioclimate map

analyst in organizing and structuring the procedures and to identify the data needed to complete analyses.

Standardized data

For collecting understory vegetative information systematically, it is important to use standardized data. There are two sets of standardized vegetative information in Japan - Miyawaki's Japanese vegetation surveys (MIYAWAKI, 1990), and the EAJ's census reports on vegetation (2nd and 3rd National Environmental Surveys of Japan). MIE, NARA and WAKAYAMA PRDFDCTURDS EDUCATION COMMITTEES (1994) used their own research results from 1988 and 1989 surveys to make a model arranged in a simple table in Table 1. Based on Japan's standardized vegetative information, this table shows the presumed dominant understory vegetation based on three categories - overstory vegetation, soil moisture, and bioclimate.

Soil moisture maps

We first digitized the Geographical Survey Institute's paper-printed soil-type map of Mie Prefecture in Universal Transverse Mercator (UTM) coordinated vector files using GIS software, ArcInfo. Then, the soil-type map coverage was exported into a raster GIS format, IDRISI. This conversion process was important for assigning new values to describe soil moisture. We assigned "dry soil" for dry podzol (P-d), dry brown forest soil (B-d), and rock and lithosols (R and RL). The other soil types in the study area, yellow soil (Y), brown forest soil (B), kuroboku soil (A), and fine gray alluvial soil (GL-f) were translated into "moderately wet soil". These conversions were mainly based on literature reviews of soil morphology. Fig. 3 is a soil moisture map of the study area, showing two soil moisture classes.

Bioclimatic regions

Bioclimatic regions have been associated with broad changes in species composition (BAILEY, 1996). Regional bioclimates, which are typically identified by the growth of the dominant vegetation in relation to climate, are derived from a warmth index. In this study, a warmth index (WI) was calculated from mean temperature derived from the Japan Meteorological Agency's annual CD-ROM report. Monthly mean temperatures of pixels of the study area were computed with the GIS database, and the mean temperature data were used to calculate WI by GIS map algebra with the following formula:

$$\text{Warmth Index } (WI) = \Sigma(t-5),$$

where t is mean monthly temperature above 5 degree centigrade, summed over all 12 months.

According to KIRA (1949), five major bioclimatic regions can be identified in Japan, based on the WI : $0 < WI < 15$ as tundra or alpine, $15 < WI < 45$ as cold temperate

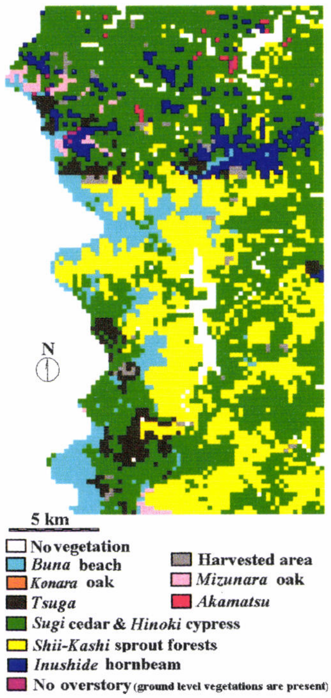

Fig. 5 Overstory vegetation map

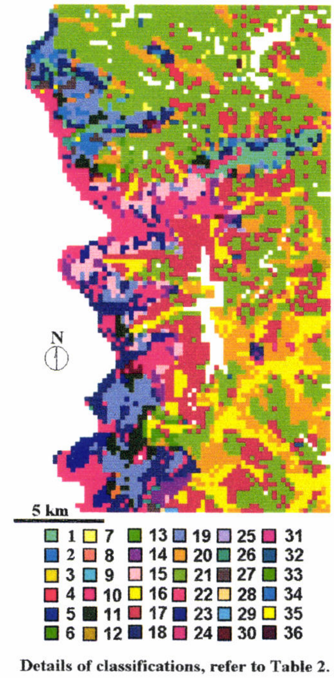

Fig. 7 Crosstab result of three factors map

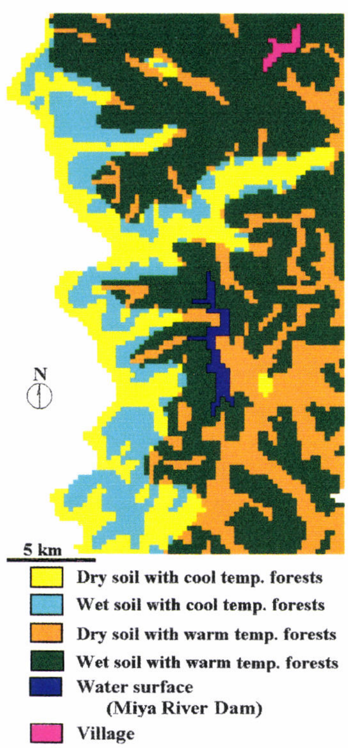

Fig. 6 Crosstab result of soil moisture and bioclimate

evergreen forests, $45 < WI < 85$ as cool temperate forests, $85 < WI < 185$ as warm temperate forests, and $180 < WI < 240$ as sub-tropical forests. Our WI-based calculations showed that the study area consisted of two types of local bioclimate: "cool temperate forests" and "warm temperate forests" as shown in Fig. 4.

Overstory vegetation maps

The EAJ's vegetative classification system was reclassified into suitable categories for modeling purposes. Our classifications included (1) Inushide hornbeam (*Carpinus tschonoskii*), (2) Akamatsu (*Pinus densiflora*), (3) Konara (*Quercus serrata*), (4) Tsuga with *Tsuga sieboldii*, (5) Shii-Kashi sprout forests with species such as *Castanopis cuspidata*, *C. sieboldii*, *Q. gilva*, and *Q. acuta*, (6) Hinoki cypress (*Chamaecyparis obtusa*) and Sugi cedar (*Cryptomeria japonica*), (7) Buna beech (*Fagus crenata),* (8) Mizunara (*Q. crispula*), (9) harvested area, (10) no overstory vegetation, but understory vegetations such as bamboo (*Sasamorpha borealis*) and bamboo grasses (*Sasa nipponica*) are present. Others, for instance, the EAJ's categories of open water, agricultural area, rice paddy field, and human-used lands were classified into "no vegetation". For the modeling process, it was important to reclassify overstory vegetation into these reliable categories, so that the predictive model could be applied more adequately. The converted overstory vegetation map of the study area is shown in Fig. 5.

Table 2 Forest understory vegetation types based on GIS crosstab

Crosstab results	Soil moist	Bio-climate	Overstory vegetation type	Dominant understory Species[1]	Stratum type[3]	Stratum richness[4]	Diet Source[5]
1	Dry	Cool	*Carpinus laxiflora*	NA (no information available)	NA	NA	NA
2	Wet	Cool	*C. laxiflora,*	NA	NA	NA	NA
3	Dry	Warm	*C. laxiflora,*	NUV	NUV	0	NA
4	Wet	Warm	*C. laxiflora,*	NA	NA	NA	NA
5	Wet	Cool	*Pinus densiflora*	NA	NA	NA	NA
6	Dry	Warm	*P. densiflora*	*D. linearis*	F	1	PA
7	Wet	Warm	*P. densiflora*	*Eurya japonica, R. macrosepalum*	ES, S	2	G
8	Dry	Warm	*Quercus serrata*	NA	NA	NA	NA
9	Wet	Warm	*Q. serrata*	*S. borealis, S. nipponica R. macrosepalum, D. linearis*	F, B, S	3	B
10	Dry	Cool	*Tsuga sieboldii*	*R. degronianum*	ES	1	G
11	Wet	Cool	*T. sieboldii*	Perennial grasses *S. borealis, Pieris japonica, R. serpyllifolium,*	B, HG, ES, S	4	PA
12	Dry	Warm	*T. sieboldii*	NA	NA	NA	NA
13	Wet	Warm	*T. sieboldii*	NA	NA	NA	NA
14	Dry	Cool	*Castanopi spp.* sprout forests	NA	NA	NA	NA
15	Wet	Cool	sprout forests	NA	NA	NA	NA
16	Dry	Warm	sprout forests	*M. sequinii, A. distylum*	ET, DT	2	PA
17	Wet	Warm	sprout forests	*Cleyera japonica, Tra. asiaticum, P. japonica*	ET, V, ES	3	PA
18	Dry	Cool	*Chamae. obtusa, Cryptomeria japonica*	NA	NA	NA	NA
19	Wet	Cool	*C. obtusa, C japonica*	*L. umbellata. L.triloba, S. borealis, P. japonica*[2]	B, ES, DS	3	PA
20	Dry	Warm	*C. obtusa, C. japonica,*	*D. linearis, R. degronianum*	F, ES	2	PA
21	Wet	Warm	*C. obtusa, C. japonica*	*G. japonica, C. japonica A. japonica, R. trichocarpa*	F, HG, ET, DS	4	G
22	Dry	Cool	*Fagus crenata*	*S. borealis*	B	1	G
23	Wet	Cool	*F. crenata*	*S. borealis, S. nipponica*	B	1	G
24	Dry	Warm	*F. crenata*	*S. borealis*	B	1	G
25	Wet	Warm	*F. crenata*	*S. borealis*	B	1	G
26	Dry	Cool	*Quercus crispula*	*S. borealis*	B, ES	2	G
27	Wet	Cool	*Q. crispula*	*Pie. japonica, S. nipponia*	B, ES	2	G
28	Dry	Warm	*Q. crispula*	*Pie. japonica, S. nipponia*	B, ES	2	G
29	Wet	Warm	*Q. crispula*	*Pie. japonica, S. nipponia*	B, ES	2	G
30	Dry	Cool	Harvested area	*L. umbellata*[2], *L.triloba2*, *Stuartia monadelpa*[2] *C. japonica*[2], *M. sequinii*[2]	DS, ET, DT	3	G
31	Wet	Cool	Harvested area	*L. umbellata*[2], *L.triloba*[2], *Stuartia monadelpa*[2] *C. japonica*[2], *M. sequinii*[2]	DS, ET, DT	3	G
32	Dry	Warm	Harvested area	*L. umbellata*[2], *L.triloba2,*[2] *Stuartia monadelpa*[2] *C. japonica*[2], *M. sequinii*[2]	DS, ET, DT	3	G
33	Wet	Warm	Harvested area	*L. umbellata*[2], *L.triloba*[2], *Stuartia monadelpa*[2], *C. japonica*[2], *M. sequinii*[2]	DS, ET, DT	3	G
34	Dry	Cool	No overstory veget.	*S. borealis*[3], *S. nipponica*[3]	B	1	G
35	Wet	Cool	No overstory veget.	*S. borealis*[3], *S. nipponica*[3]	B	1	G
36	Wet	Warm	No overstory veget.	*S. borealis*[3], *S. nipponica*[3]	B	1	G

1: For details, refer Table 1; 2: Our field observation results, 3: Documented by the EAJ, 4: F=ferns, B=bamboo and bamboo grasses, HG=evergreen herbs and grasses, V=evergreen vines, ES=evergreen shrubs, DS=deciduous shrubs, S=neither evergreen nor deciduous shrubs, ET=evergreen lower tree and tree layers, DT =deciduous lower tree and tree layers, 5: Numbers of understory stratum types, 6: G=majority of plants are diet source, PA= partially available

Integrating the Data and Factor Analysis

The first step in integrating the spatial data was applying "crosstab" to two maps - soil moisture and bioclimate. The IDRIS module of crosstab created a new image based on the combination of classes in the two input images. The soil moisture map which had 2 classes (dry and moderately wet) was cross-classified with the bioclimate map (cool and warm temperate forests). Fig. 6 shows the four classes in the resulting cross-classification of soil moisture and local bioclimate maps.

Then, we again overlaid this cross-classified map to produce a second crosstab image, based on the cross-classification of the soil-bioclimate crosstab map and the actual overstory vegetation map. The second crosstab image contained a total of thirty-six classifications as shown in Fig. 7. These crosstab results were analyzed, and the corresponding relationship to the table model (Table 1) was examined with deliberation.

RESULT

The resulting thirty-six classifications from our cross-tabulations, together with our prediction results for understory species, are shown in Table 2. We used our personal field observations and literature reviews (Takahashi, 1991; Miyawaki, 1990) to validate the results. We observed little difference between our predictions and actual understory vegetation types found in our field surveys and literature reviews. Our understory vegetation classification was evaluated by visual inspection and matching of general trends with environmental and forestry knowledge because it is difficult to statistically prove the accuracy of our prediction at this stage of study. We therefore still need to maintain surveys and terrain samplings for future analysis. It is nevertheless possible to conclude that our predicted understory vegetation map is valuable for various management purposes including serow habitat analyses.

All thirty-six classes (Fig. 7) could be grouped into sixteen classifications as shown in Fig. 8, based on the dominant forest understory vegetation stratum types present in the study area. We classified stratum types, for example, ferns (F) included *Gleichenia japonica* and *Dicranopteris linearis*. Bamboo and bamboo grasses (B) included species such as *Sasamorpha borealis* and *Sasa nipponica*. Vine (V), for example, was species such as *Trachelospermum asiaticum*. *Rhododendron degronianum* and *Pieris japonica* were major species of evergreen shrubs (ES). We classified *Rhus trichocarpa, Lindera triloba*, and *L. umbellata* in deciduous shrubs (DS). *Rhododendron macrosepalum* and *Rhododendron serpyllifolium* were species of neither evergreen nor deciduous shrubs (S). Examples of evergreen lower trees and tree layers (ET) included *Myrsine sequinii* and *Cleyra japonica*. *Acer distylum* was the major type of deciduous tree layers (DT) in the study area. We also found multiple layers of *Stuartia monadelpa* (DT) by our personal observations.

The stratum richness map (Fig. 9) is based on the number of available understory stratum types, and shows that the richest category in our study area has four stratums. Multilayered canopies are usually considered to be good wildlife habitats for many animal species (Hayes *et al.*, 1997).

A map of possible diet sources was derived from the previous studies on serow's plant intake (Mie, Nara and Wawkyama Prdfectures Educktion Committees, 1989; 1994). For example, understory vegetation such as *Sasamorpha borealis*, *Sasa nipponica*, and *Stuartia monadelpa* were considered to be diet sources for serow; but others such as *Pieris japonica*, and *Dicranopteris dichotoma* were not suited for serow diet. Based on these previous studies of serow's diet, we derived an understory diet map with two classifications - good and moderate diet sources (Fig. 10).

DISCUSSION AND CONCLUSION

We used these study results to identify preferred conditions of forest understory vegetation. As Table 3 indicates, a variety of stratum types are available in the forests of the serow protection area. In addition, as Table 4 and 5 show, the serow protection area in our study site seems to maintain a high level of understory diversity and source of foods for serow. As a result, based on our analyses and observations of forest understory in the study area, we conclude that the serow protection area in our study site is well suited for the species' habitat. However, for 26% of the serow protection area, or 16% of the whole

Table 3 Available stratum types in serow protection area

Dominant stratum types	% (% based in the study area)
NA	25.2 (16.3)
B	16.7 (8.6)
ET, V, ES	12.8 (13.2)
B, ES, DS	10.3 (5.7)
F, HG, ET, DS	9.8 (30.0)
ET, DT	9.3 (8.6)
F, ES	5.4 (11.2)
B, HG, ES, S	4.3 (1.7)
ES	3.1(1.4)
DS, ET, DT	1.8 (1.4)
B, ET	1.4 (1.1)
NV	0 (0.5)
ES,S	0 (0.5)
F, B,S	0 (0.1)
F	0 (0.1)

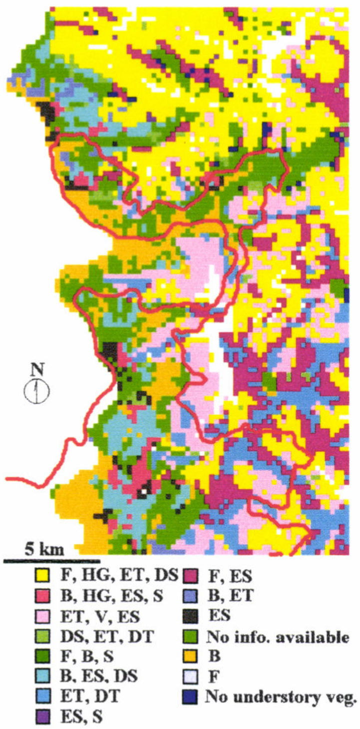

Fig. 8 Available stratum types

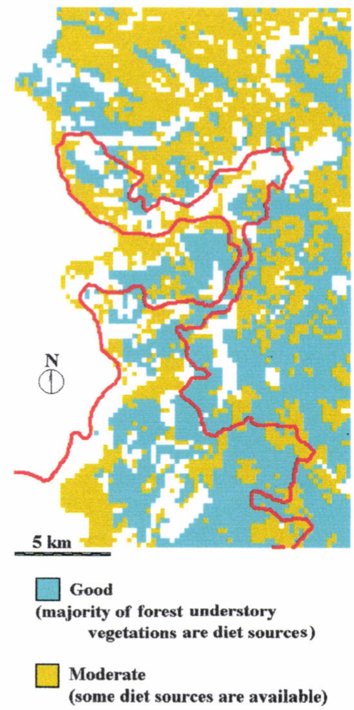

Fig. 10 Diet source availability for serow

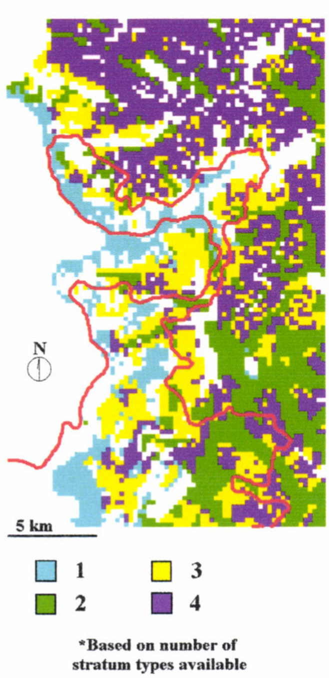

Fig. 9 Stratum richness map

Table 4 Stratum type richness in serow protection area*

Numbers of stratum type available	% (% based inthe study area)
1	23.4 (11.8)
2	19.2 (25.5)
3	29.7 (24.5)
4	27.7 (38.2)

*Not including NA(no information) area

Table 5 Diet source availability in serow protection area*

Diet source	% (% based in the study area)
Good	58.3 (50.4)
Moderately good	41.7 (49.6)

*Not including NA

study area, the forest understory was not examined with GIS technologies (Table 3).

As for forest management, thinning is indispensable for making coniferous plantations vigorous and healthy; otherwise the closed canopy does not allow the establishment of understory vegetation (TANAKA *et al.,* 1998). Consequently, it should be noted that understory vegetation tends to vary with stand age, stand condition, and silvicultural practices, particularly in coniferous plantation forests. Moreover, we need to conduct continuing terrain samplings and surveys to improve accuracy in predicting understory vegetation. Vegetative sampling, however, is more strongly associated with ecological implications and researches rather than forest planning and management. Although our approach might not be of value for ecological implications, we believe that it is important to make an effective use of what foresters and resource managers already know. We therefore only focused on the management implications of understory species prediction in this study.

The results of our study indicate that a GIS-based prediction model can be an effective tool for better understanding of forest understory vegetation and serow habitat. The understory vegetation map from this study should expand the potential of GIS-based wildlife habitat analyses, especially for the ungulate species, since many GIS-based ungulate species analyses require understory vegetation maps for modeling processes. Previous studies, for example in the United States, indicate the importance of understory vegetation for various types of wildlife habitat modeling (CLARK *et al.*, 1993). Although our approach in understory vegetation mapping was rather "coarse-filter," we believe that it developed the use of GIS and expanded our knowledge for wildlife and forest management.

We also believe that a continuous inventory program should decrease errors in modeling processes and maintain required accuracies for this type of study and mapping approach. For instance, in the United States, forest understory vegetation type is already mapped and distributed to GIS users in a compatible digital format. The CISC (Continuous Inventory of Stand Condition Program) by the U.S Department of Agriculture, Forest Service (USDA-FS) produces and maintains digital forest understory vegetation maps for almost all national forests of the United States. We strongly hope to start such a continuous inventory system for the future conservation and sustainable management of Japanese forests.

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Article

Stand Dynamics of Dipterocarp Trees in Cambodia's Evergreen Forest and Management Implications
—A Case Study in Sandan District, Kampong Thom[*1]—

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ABSTRACT

The purpose of this study was to explore the stand dynamics of dipterocarp species in evergreen forest as a basis for devising suitable management systems for Cambodia's forests. The data for this study were obtained from a two-year UNDP-funded forest inventory project in Sandan district of Kampong Thom province. A sample of 18 clusters located in evergreen forest were analyzed. Based on the average stand volume per hectare, this evergreen forest was further divided into poor (less than 200m³), medium (200-300m³) and rich (greater than 300m³) forests. Dipterocarps contributed 50m³ (36%), 109m³ (43%) and 163m³ (53%) in poor, medium and rich forests, respectively. The dominant dipterocarps species were CHBG (*Dipterocarpus turbinatus*), CRMS (*Vatica astrotricha*) and PHDK (*Anisoptera glabra*).

To estimate the forest potential and allowable cut of dipterocarps stands, trees of DBH greater than 45cm were analyzed. Cambodia's silvicultural treatment prescribes that only 30% of stands are extracted on a selective felling cycle of 25-30 years. On the basis of this silvicultural treatment and management experience in Southeast Asia, the harvest potential of Cambodia's forest was estimated to vary from 20m³/ha (6 trees) to 54m³/ha (13 trees); approximately 65% of which was dipterocarps. These figures are more than double the current harvest rate of 10 m³/ha. However, applying such a new management system might cause forest degradation if there is no long-term political commitment to management and research from the government and parties involved. Permanent and regular research on stand dynamics and other influential factors are required to ensure the sustainability of forest resources. Forest management can no longer be concerned solely with timber production; thus, harvesting and research in non-timber forest products should also be included in the management plan.

Keyword: Cambodia, dipterocarps, evergreen forest, forest management

INTRODUCTION

Tropical forests occupy only 7% of the Earth's land area, but they contain the majority (approximately 50-90%) of the Earth's species (World Resources Institute, 1989). Many functions of a tropical forest can be best met by careful natural forest management which is able to produce wood and other products with low inputs, provide a livelihood for people living in the forest and preserve ecological functions to a high degree (Weidelt, 1996). Unfortunately, as a result of rapid development and fast growing population, the sustainability of tropical forests has been problematic in recent years. Although several

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attempts have been made to bring the forests under sustainable use and management, sustainability still remains dependent on the search for balance between the needs of present and future generations. Lack of knowledge of stand dynamics of different forest types might be one of the causes of mismanagement; hence the un-sustainability of use of the world's tropical forests today. Dipterocarps are dominant in tropical forests, and commercially important. Dipterocarp forests of Southeast Asia constitute a major and particularly valuable component of the world's tropical rain forests. The bulk of tropical timber comes from Dipterocarp ecosystems (Choong and Achmadi, 1996).

Over the past 30 years of political instability, Cambodia's forests were left unmanaged and since then no forestry research has been done to improve the current forest management systems. Therefore, this study's purpose was to explore the stand dynamics of evergreen forest, focussing mainly on dipterocarp stands as a basis for devising suitable management systems for Cambodia's forests.

Table 1 Recording procedure in each sample plot

Dimension of sample plots (m)	Area (ha)	DBH Classes (cm)
10×10	0.01	5-9.9
20×20	0.04	10-29.9
60×20	0.12	>30

STUDY METHODS

Forest inventory

With the financial assistance of UNDP (United Nations Development Program), an executive agency of FAO, and a counterpart of the Department of Forestry and Wildlife, a two-year forest inventory project was initiated in 1995 and started operationally in January 1996. This inventory project covered 0.5 million ha of forests in Cambodia's two largest districts, Sandan and Santuk of Kampong Thom province.

Under this two-year inventory project, cluster sampling was chosen for practical reasons (DFW, 1998a). The clusters were set on 4×4-km grid lines (Fig. 2). Approximately 131 clusters were identified on the map for sampling; however, due to security and other reasons, only 66 clusters were successfully measured, of which 23 were located in evergreen, 36 in mixed, and 4 in deciduous forest, respectively. Only 18 of the 23 clusters in evergreen forest were analyzed. Each cluster contains 9 plots of 20×60m size; three plots in a line at equidistant intervals of

Table 2 Tree Species of Dipterocarpaceae family in Cambodian forests

Scientific name	Local name	Species code	Commercial group
Anisoptera glabra	Phdeak	PHDK	
Dipterocarpus costatus	Chhieutiel Neandeng	CHND	Keruing
Dipterocarpus tuberculatus	Khlong	KHLG	Keruing
Dipterocarpus intricatus	Trac	TRAC	Keruing
Dipterocarpus alatus	Chhieutiel Tiek	CHTK	Keruing
Dipterocarpus dyeri	Chhieutiel Chgor	CHCG	Keruing
Dipterocarpus turbinatus	Chhieutiel Beng	CHBG	Keruing
Dipterocarpus obtusifolius	Tbeng	TBEG	Keruing
Hopea recopi	Chramas Tiek	CHMT	Merawan
Hopea ferrea	Korki Thmor	KKTM	Merawan
Hopea pierrei	Korki Ksach	KKKS	Merawan
Hopea odorata	Korki Masao	KKMS	Merawan
Hopea helferi	Korki Deck	KKDE	Merawan
Vatica astrotricha	Chramas	CRMS	Resak
Vatica philastreana	Tralat	TRLT	Resak
Vatica odorata	Chramas Tmor	CRTM	Resak
Shorea thorelli	Pchek Udom	PCUD	Meranti
Shorea siamensis	Ring Phnum	RIPM	Meranti
Shorea hypochra	Korki Pnorng	KKPN	Meranti
Shorea farinosa	Lumbior	LMBI	Meranti
Shorea obtusa	Pchek	PCEK	Meranti
Shorea vulgaris	Chor Chong	CHRH	Meranti
Shorea cochinchinnensis	Po Peil	PPEL	

100m with 100m between the lines which are oriented to the north. All trees within DBH classes of 5-10, 10-30 and greater than 30cm were recorded in 0.01ha, 0.04ha and 0.12ha sample plots, respectively (Table 1).

Data analysis

The data for this study were made available by FAO's representative in Cambodia, with the approval of DFW.

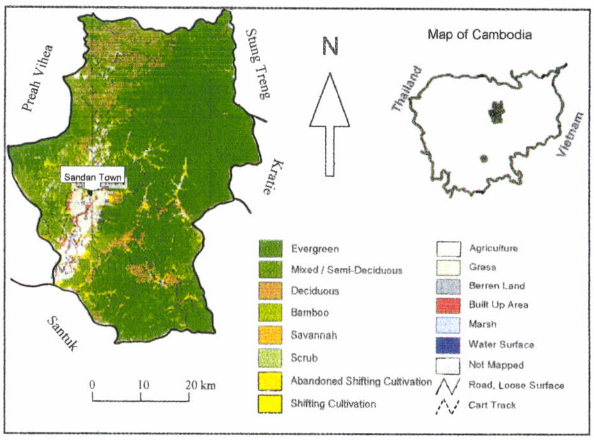

Fig. 1 Forest and land cover map of Sandan
Note: This map was prepared by DWF in 1997

As agreed in discussion with DFW, analysis based on a single cluster is not considered adequate to represent the whole forest. Thus, the authors analyzed data in 18 clusters, and took the average result of each plot by grouping into dipterocarps, non-dipterocarp, and unknown trees in order of diameter class of 5-9, 10-19, 20-29, 30-39, 40-44, 45-49, 50-59, 60-69, and greater than 70cm. To estimate the harvest potential, the authors split the diameter class of 40-49cm into 40-45cm and 45-49cm due to the fact that the diameter limit for harvest of some trees is set at 45cm DBH. Dipterocarp trees were further classified into their genera and species for the stand dynamics study. In addition to these data, fieldwork was carried out between April and May 1999 to check some of the sampled clusters.

LITERATURE REVIEW OF DIPTEROCARPS

Dipterocarp trees generally are very dominant in the tropical forests and are now the major source of timber in Southeast Asia (Choong and Achmadi, 1996). All dipterocarpaceae species are arborescent and tropical. The family type genus is the Asian *Dipterocarpus* Gaertn f. Dipterocarps are trees with alternate entire leaves and pentamerous flowers. The family Dipterocarpaceae *sensu stricto* is homogeneous and limited to Asia, while the Dipterocarpaceae *sensu lato* include three subfamilies: Dipterocarpoideae in Asia, Pakaraimoideae in South America; and Monotoideae in Africa and South America

Table 3 Changes in land use in Sandan district

Type of land	Area (1992-'93)		Area (1996-'97)		Change	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest area	261,974	89.9	260,798	89.5	−1,176	−0.4
Evergreen dense	41,516	14.2	41,516	14.2	0	0.0
Evergreen disturbed	174,922	60.0	173,177	59.4	1,745	−0.6
Evergreen mosaic	5,986	2.0	6,775	2.3	789	0.3
Mixed dense	732	0.2	732	0.2	0	0.0
Mixed disturbed	7,332	2.5	7,287	2.5	−45	−0.0
Mixed mosaic	3,597	1.2	3,597	1.2	0	0.0
Deciduous	10,976	3.8	10,976	3.8	0	0.0
Deciduous mosaic	1,282	0.4	1,282	0.4	0	0.0
Forest regrowth	15,630	5.4	15,455	5.3	−176	−0.1
Non-wood	29,524	10.1	30,700	10.5	1,176	0.4
Wood/Shrub evergreen	3,809	1.3	3,659	1.3	−149	−0.0
Grassland	91	0.0	91	0.0	0	0.0
Wood/shrub dry	5,288	1.8	5,288	1.8	0	0.0
Mosaic of cropping (<30%)	2,682	0.9	3,471	1.2	790	0.3
Mosaic of cropping (>30%)	602	0.2	650	0.2	48	0.0
Agricultural land	16,930	5.8	17,417	6.0	488	0.2
Water surface	124	0.0	124	0.0	0	0.0
Total	291,498	100.0	291,498	100.0	0	0.0

Source: DFW (1998)

(MAURY-LECHON and CURTET, 1998). Consequently the family contains 15-17 genera or 470-580 species. In Cambodia alone there are 5 genera or 23 species of Dipterocarp trees. The 5 genera includes *Anisoptera* (1 species), *Dipterocarpus* (7 species), *Hopea* (5 species), *Shorea* (7 species) and *Vatica* (3 species) (Table 2). There are two major forest types in Cambodia - dryland and edaphic forests. Dipterocarps are the dominant species in all evergreen, mixed and deciduous forests of dryland forests.

OVERVIEW OF STUDY SITE

According to meteorological data, the provincial town of Kampong Thom's average rainfall was 1,305mm and temperature 27.1°C between 1990 and 1993. Sandan is one of the seven districts of Kampong Thom, containing 9 communes or 71 villages. Sandan has a population of 37,098 of whom 19,023 are female. Nearly 75% of the population are engaged in farming and forestry for their livelihood. Sandan (Fig. 1) has a total land area of 291,498ha, 89% of which is forested. Forest area has declined from 261,974ha in 1993 to 260,798ha in 1997. In terms of percentage, only 0.1% of the forest area has been converted to other forms of land use. By contrast, agricultural land has increased 488ha or 0.04% per year over the same period (Table 3). The main economic development factors include logging, fishing and labor hire.

ANALYTICAL RESULTS

Before this two-year inventory project, evergreen forest in Sandan district had never been logged for any commercial purpose. Data used in this study were taken from 18 inventoried clusters (19.44ha). For all trees with DBH greater than 5cm, an average density of 1105.5 trees/ha and stand volume of 235.2m^3/ha were recorded. Within these totals, dipterocarps comprised 194.1 trees and 107.1m^3, non-dipterocarps 405.1 trees and 70.6m^3, and unknown species 506.3 trees and 57.4m^3 for density and stand volume, respectively (Table 4). Table 4 also shows that mean stand density and stand volume per hectare varied from 982.5 trees and 96.6m^3 (No. 1) to 1,075.7 trees and 210.9m^3 (No. 5), and to 1,290.4 trees and 300.1m^3 (No. 12). In order to allow more accurate

Table 4 Mean stand density and volume per hectare in Sandan's evergreen forest (DBH≧5cm)

Sample Cluster No.	Dipterocarps		Non-dipterocarp		Unknown		Total	
	Density (trees)	Volume (m^3)	Density (trees)	Volume (m^3)	Density (trees)	Volume (m^3)	Density (trees)	Volume (m^3)
Poor forest								
1	145.4	34.8	323.7	19.3	513.4	42.5	982.5	96.6
2	111.1	34.9	363.2	70.6	437.2	27.8	911.5	133.3
3	204.6	42.6	375.5	87.7	430.2	29.3	1010.3	159.6
4	70.6	87.1	387.6	40.8	397.1	31.3	855.3	159.2
Mean	132.9	49.9	362.5	54.6	444.5	32.7	939.9	137.2
Medium forest								
5	263.3	68.5	404.6	80.2	407.8	62.2	1075.7	210.9
6	190.7	79.7	401.2	67.0	635.9	79.2	1227.8	225.9
7	181.5	130.0	360.2	71.1	498.2	56.1	1039.9	257.2
8	192.1	106.6	318.9	74.5	613.6	78.5	1124.6	259.6
9	200.7	139.6	418.5	56.3	489.8	71.2	1109.0	267.1
10	216.4	99.2	511.4	114.3	497.6	67.2	1225.4	280.7
11	188.9	139.2	356.6	62.5	307.9	77.3	853.4	279.0
Mean	204.8	109.0	395.9	75.1	493.0	70.2	1093.7	254.3
Rich forest								
12	322.0	134.3	410.6	70.8	557.8	95.0	1290.4	300.1
13	145.4	169.6	478.2	56.0	611.1	76.4	1234.7	302.0
14	232.9	165.3	328.5	68.5	592.1	70.4	1153.5	304.2
15	193.5	129.7	354.4	126.5	562.3	51.0	1110.2	307.2
16	233.3	151.6	522.6	87.1	575.2	76.5	1331.1	315.2
17	317.6	183.8	586.8	96.0	469.2	41.1	1373.6	320.9
18	267.6	203.6	516.7	69.2	703.3	75.5	1487.6	348.3
Mean	244.6	162.6	456.8	82.0	581.6	69.4	1283.0	314.0
Mean (all)	194.1	107.1	405.1	70.6	506.3	57.5	1105.5	235.2

evaluation, Sandan's evergreen forest was further classified into poor (stand volume less than 200m³/ha), medium (stand volume between 200-300m³/ha) and rich forest (stand volume greater than 300m³/ha) (Fig. 2).

Poor forest

Poor forest comprised 4 of the total 18 clusters. On average per hectare, this forest has 939.9 trees and 137.2 m³, of which 132.9 trees (14.1%) and 49.9m³ (36.3%) were Dipterocarps. Non-dipterocarps trees were 362.5 trees (38.6%) and 54.6m³ (39.8%), of which Myrtaceae, Ebanaceae and Caesalpinaceae were 12.8% and 9.8%, 6.4% and 2.0%, and 4.0% and 6.8% for stand density and stand volume, respectively (Table 5). Approximately 39.8% of total trees and 55.5% of stand volume for trees of DBH greater than 45cm belonged to the Dipterocarpaceae family (Table 5). The distribution of the stand volume across DBH classes clearly indicated that Dipterocarps mainly dominated the upper story and were therefore canopy and emergent trees.

In the four clusters, six dipterocarp species were recorded: CHBG, CRMS, PHDK, LMBI, CHRH and TRAC. Since the last three (LMBI, CHRH and TRAC) are rare in this forest, they were grouped into OTHR (others) for analysis purposes. For DBH less than 45cm,

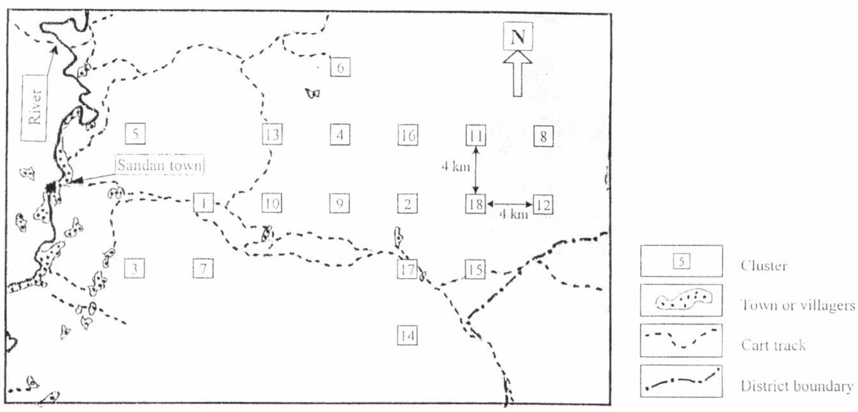

Fig. 2 Map of inventoried clusters

Table 5 Mean stand density and stand volume per hectare of poor evergreen forest

Family	Total (DBH<45cm)				Total (DBH≧45cm)				Total (DBH≧ 5 cm)			
	Density		Volume		Density		Volume		Density		Volume	
	trees	%	m³	%	trees	%	m³	%	trees	%	m³	%
Dipterocarpaceae	125.7	13.6	11.8	17.2	7.2	39.8	38.1	55.5	132.9	14.1	49.9	36.3
Myrtaceae	119.7	13.0	11.6	16.9	0.9	5.2	1.8	2.7	120.6	12.8	13.5	9.8
Ebenaceae	60.0	6.5	2.8	4.1	0.0	0.0	0.0	0.0	60.0	6.4	2.8	2.0
Caesalpinaceae	36.1	3.9	5.5	8.0	1.6	9.0	3.9	5.6	37.7	4.0	9.4	6.8
Euphorbiaceae	33.1	3.6	3.4	5.0	0.5	2.5	0.8	1.2	33.6	3.6	4.3	3.1
Rosaceae	23.2	2.5	3.1	4.5	1.4	7.6	5.3	7.8	24.5	2.6	8.4	6.1
Rhizophoraceae	17.6	1.9	1.0	1.4	0.0	0.0	0.0	0.0	17.6	1.9	1.0	0.7
Sapotaceae	13.4	1.5	1.4	2.0	0.2	1.4	0.4	0.6	13.6	1.5	1.8	1.3
Hypericaceae	13.4	1.5	1.8	2.6	0.0	0.0	0.0	0.0	13.4	1.4	1.8	1.3
Crypteroniaceae	10.7	1.2	2.3	3.4	1.4	7.7	3.6	5.2	12.0	1.3	5.9	4.3
Meliaceae	9.0	1.0	0.5	0.7	0.0	0.0	0.0	0.0	9.0	1.0	0.5	0.3
Clusiaceae	5.1	0.6	0.3	0.5	0.5	2.5	1.0	1.4	5.6	0.6	1.3	0.9
Lauraceae	5.1	0.6	1.5	2.1	0.0	0.0	0.0	0.0	5.1	0.5	1.5	1.1
Sterculiaceae	3.9	0.4	0.5	0.8	0.2	1.3	0.9	1.4	4.2	0.4	1.5	1.1
Lythraceae	3.0	0.3	0.3	0.4	0.0	0.0	0.0	0.0	3.0	0.3	0.3	0.2
Fagaceae	2.1	0.2	0.2	0.3	0.0	0.0	0.0	0.0	2.1	0.2	0.2	0.2
Combretaceae	0.2	0.0	0.2	0.2	0.2	1.3	0.6	0.8	0.5	0.0	0.7	0.5
Unknown	440.5	47.8	20.5	29.8	3.9	21.8	12.3	17.8	444.5	47.3	32.7	23.9
Total	921.8	100.0	68.5	100.0	18.1	100.0	68.7	100.0	939.9	100.0	137.2	100.0

125.9 trees (stand density) and 1.8m³ (stand volume) were recorded, of which CRMS, CHBG and PHDK comprised 108.6 trees (86.3%) and 8.1m³ (68.6%), 6.3 trees (5.0%) and 1.4m³ (11.9%), and 10.5 trees (8.3%) and 1.8m³ (15.3%), respectively, while OTHR covered the rest (Fig. 3). For DBH greater than 45cm, 7.1 trees and 38.1m³ were recorded, of which PHDK, CHBG and CRMS were 4.0 trees (56.3%) and 24.5m³ 64.3%), 2.7 trees (38%) and 12.4m³ (35.2%), and 0 trees, respectively, and the rest was OTHR (Fig. 3). Based on Fig 3, it can be

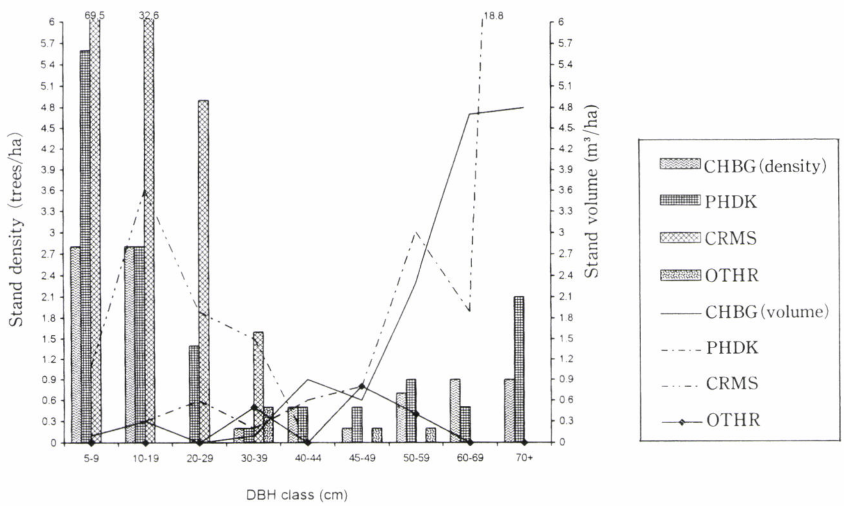

Fig. 3 Distribution of mean stand density and volume of dipterocarps in poor overgreen forest by DBH class

Table 6 Mean stand density and volume per hectare of medium evergreen forest

Family	Total (DBH<45cm)				Total (DBH≧45cm)				Total (DBH≧ 5 cm)			
	Density		Volume		Density		Volume		Density		Volume	
	trees	%	m³	%	trees	%	m³	%	trees	%	m³	%
Dipterocarpaceae	188.7	17.9	22.4	21.2	16.1	43.9	86.6	58.2	204.8	18.7	109.0	42.8
Myrtaceae	115.5	10.9	16.9	16.0	2.8	7.6	5.7	3.8	118.3	10.8	22.6	8.9
Ebenaceae	102.8	9.7	3.8	3.6	0.0	0.0	0.0	0.0	102.8	9.4	3.8	1.5
Euphorbiaceae	63.6	6.0	5.4	5.1	0.7	1.8	1.3	0.8	64.3	5.9	6.6	2.6
Caesalpinaceae	18.3	1.7	3.0	2.8	2.0	5.4	6.0	4.0	20.2	1.8	9.0	3.5
Clusiaceae	19.3	1.8	2.2	2.1	0.7	1.8	1.5	1.0	20.0	1.8	3.8	1.5
Meliaceae	18.0	1.7	1.0	0.9	0.0	0.0	0.0	0.0	18.0	1.6	1.0	0.4
Lauraceae	12.8	1.2	1.5	1.4	0.0	0.0	0.0	0.0	12.8	1.2	1.5	0.6
Sterculiaceae	7.3	0.7	1.2	1.1	0.9	2.5	6.7	4.5	8.2	0.8	7.8	3.1
Rosaceae	4.3	0.4	2.0	1.9	2.9	7.9	9.0	6.1	7.2	0.7	11.0	4.3
Crypteroniaceae	6.1	0.6	2.6	2.5	0.0	0.0	0.0	0.0	6.1	0.6	2.6	1.0
Rhizophoraceae	3.6	0.3	0.2	0.2	0.1	0.4	0.3	0.2	3.7	0.3	0.5	0.2
Hypericaceae	3.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0	3.6	0.3	0.1	0.0
Lythraceae	2.3	0.2	0.3	0.3	0.3	0.7	0.5	0.3	2.5	0.2	0.8	0.3
Sapotaceae	1.2	0.1	1.0	0.9	0.7	1.8	2.0	1.4	1.9	0.2	3.0	1.2
Verbenaceae	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	0.0
Ochanaceae	1.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	0.0
Moraceae	1.5	0.1	0.5	0.5	0.1	0.4	0.3	0.2	1.6	0.1	0.8	0.3
Combretaceae	0.8	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.8	0.1	0.3	0.1
Anacardiaceae	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.1	0.0
Fagaceae	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Unknown	483.5	45.7	41.2	39.0	9.5	25.9	29.0	19.5	493.0	45.1	70.2	27.6
Total	1,057.0	100.0	105.6	100.0	36.7	100.0	148.7	100.0	1,093.8	100.0	254.3	100.0

said that poor forest is comprised of three layers of dipterocarps-the upper layer (PHDK and CHBG), the middle layer (CRMS) and low layer (OTHR). The presence of TRAC here meant that this forest has been gradually converted to mixed and deciduous forests. In Cambodia, TRAC is usually found in deciduous forest.

Medium forest

In the seven clusters, the average per hectare of stand density and stand volume recorded were 1,093.7 trees (DBH≥5cm) and 254.3m³ of which dipterocarps, non-dipterocarps and unknown trees contributed 18.7% and 42.8%, 36.2% and 29.6%, and 45.1% and 27.6 for stand density and stand volume, respectively. Non-dipterocarps comprised Myrtaceae 118.3 trees (10.8%), Ebenaceae 102.8 trees (9.4%), Euphorbiaceae 64.3 trees (5.9%), etc. (Table 6). For stand density and stand volume of trees with DBH<45cm, dipterocarps comprised 188.7 trees (17.9%) and 22.4m³ (21.2%), non-dipterocarps 384.8 trees (36.5%) and 42.0m³ (39.9%) and unknown trees 483.5 trees (45.7%) and 41.2m³ (39.0%), respectively (Table 6). For the DBH class greater than 45cm, the figures for mean stand density and stand volume of dipterocarps, non-dipterocarps and unknown trees, respectively, were 16.1 trees (43.9%) and 86.6m³ (58.2%), 11.1 trees (30.2%) and 33.1m³ (22.3%), and 9.5 trees (25.9%) and 29.0m³ (19.5%) (Table 6). The larger the diameter, the more dominant were the dipterocarps.

In the seven clusters, nine dipterocarp species were recorded, namely CHBG, CRMS, PHDK, CHRH, PPEL, KKKS, LMBI, TRAC and TRLT, with an average of 204.8 trees/ha and 109.0m³/ha for stand density and stand volume. The last four species were grouped into OTHR (others). With respects to stand density and stand volume (DBH<45 cm), CRMS, CHBG and PHDK comprised 137.8 trees (73.0%) and 13.3m³ (59.2%), 8.5 trees (4.5%) and 3.6m³ (16.0%), and 21.2 trees (11.2%) and 3.5m³ (15.8%), respectively, while CHRH, PPEL and OTHR shared the rest. For DBH greater than 45 cm, CRMS was only 0.9 trees (5.7%) and 3.6m³ (4.2%), PHDK and CHBG were 36.1% and 40.3%, and 49.3% and 50.8% for density and stand volume, respectively (Fig. 4).

Rich forest

There were seven clusters of rich forest, with average stand density of 1,283.0 trees/ha and volume 314.0 m³/ha for trees of DBH≥5cm. Of these, dipterocarps, non-dipterocarps and unknown trees contributed 244.6 trees (19.1%) and 165.7m³ (52.8%) 456.8 trees 35.6%) and

Table 7 Mean stand density and volume per hectare of rich evergreen forest

Family	Total (DBH<45cm)				Total (DBH≧45cm)				Total (DBH≧ 5 cm)			
	Density		Volume		Density		Volume		Density		Volume	
	trees	%	m³	%	trees	%	m³	%	trees	%	m³	%
Dipterocarpaceae	224.1	18.0	32.8	28.3	20.5	52.0	132.9	67.1	244.6	19.1	165.7	52.8
Myrtaceae	174.6	14.0	12.0	10.3	1.7	4.3	4.6	2.3	176.3	13.7	16.6	5.3
Ebenaceae	101.8	8.2	3.2	2.7	0.3	0.7	0.6	0.3	102.1	8.0	3.7	1.2
Euphorbiaceae	46.6	3.7	2.0	1.7	0.4	1.1	0.5	0.3	47.0	3.7	2.5	0.8
Clusiaceae	18.7	1.5	3.6	3.1	0.3	0.7	0.5	0.2	18.9	1.5	4.0	1.3
Lauraceae	16.8	1.4	1.0	0.9	0.0	0.0	0.0	0.0	16.8	1.3	1.0	0.3
Caesalpinaceae	13.6	1.1	3.3	2.8	2.1	5.4	9.1	4.6	15.7	1.2	12.3	3.9
Meliaceae	11.0	0.9	0.5	0.4	0.0	0.0	0.0	0.0	11.0	0.9	0.5	0.1
Crypteroniaceae	9.4	0.8	3.6	3.1	0.1	0.3	0.6	0.3	9.5	0.7	4.2	1.3
Rhizophoraceae	9.4	0.8	3.3	2.8	0.0	0.0	0.0	0.0	9.4	0.7	3.3	1.0
Sapotaceae	7.7	0.6	2.3	2.0	1.3	3.4	3.8	1.9	9.0	0.7	6.0	1.9
Anacardiaceae	8.5	0.7	0.7	0.6	0.0	0.0	0.0	0.0	8.5	0.7	0.7	0.2
Fagaceae	7.5	0.6	0.3	0.2	0.0	0.0	0.0	0.0	7.5	0.6	0.3	0.1
Sterculiaceae	6.3	0.5	2.1	1.8	1.1	2.7	5.0	2.5	7.4	0.6	7.1	2.2
Rosaceae	5.2	0.4	3.8	3.3	2.1	5.4	6.1	3.1	7.3	0.6	9.9	3.2
Mimosae	3.6	0.3	0.1	0.0	0.0	0.0	0.0	0.0	3.6	0.3	0.1	0.0
Moraceae	3.4	0.3	0.5	0.4	0.0	0.0	0.0	0.0	3.4	0.3	0.5	0.1
Lythraceae	2.5	0.2	0.2	0.2	0.0	0.0	0.0	0.0	2.5	0.2	0.2	0.1
Mimosaceae	0.5	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.5	0.0	0.2	0.1
Anonaceae	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Unknown	572.1	46.0	40.8	35.2	9.5	24.2	34.4	17.4	581.6	45.3	75.2	24.0
Total	1,243.6	100.0	116.1	100.0	39.4	100.0	198.0	100.0	1,283.0	100.0	314.0	100.0

73.1m³ (23.2%), and 581.6 trees (45.3%) and 75.2m³ (24.0%), respectively. Non-dipterocarps comprised Myrtaceae 176.3 trees (13.7%), Ebenaceae 102.1 trees (8.0%), Euphorbiaceae 47.0 trees (3.7%), etc (Table 7). In east Kalimantan, Indonesia, by comparison, an average stand volume of 402m³/ha (DBH>10cm) was recorded (Sist and Saridan, 1998). On average per hectare for trees of DBH less than 45cm, Dipterocarps comprised 224.1 trees (18.%) and 32.8m³ (28.3%), non-dipterocarps were 477.4 trees (36.%) and 43.3m³ (36.5%), and unknown trees 572.1 trees (46.0%) and 40.8m³ (35.2%), for mean stand density and stand volume, respectively (Table 7). For DBH class greater than 45cm, dipterocarps were 20.5 trees (52.0%) and 132.9m³ (67.1%), non-dipterocarps 9.4 trees (23.8%) and 30.5m³ (15.5%), and unknown trees 9.5 trees (24.2%) and 34.4m³ (17.4%) for stand density and stand volume, respectively (Table 7).

From the detailed analysis of the seven clusters, six dipterocarps species were found: CHBG, CRMS, PHDK, CHRH and OTHR (KKTM and LMBI) with an average mean stand density and stand volume of 244.6 trees/ha and 165.7m³/ha. For DBH less than 45cm, CRMS, CHBG and PHDK comprised 178.3 trees (79.6%) and 22.9m³ (69.8%), 17.0 trees (7.6%) and 3.5m³ (10.7%), and 23.2 trees (10.4%) and 4.6m³ (14.0%), respectively, while other species shared the rest (Fig. 5). For DBH greater than 45cm, CRMS, CHBG and PHDK were 0.6 trees (2.9%) and 1.9m³ (1.4%), 10.2 trees (49.8%) and 65.8m³ (49.5%), and 8.7 trees (42.4%) and 60.6m³ (45.6%) respectively, and CHRH and OTHR shared the

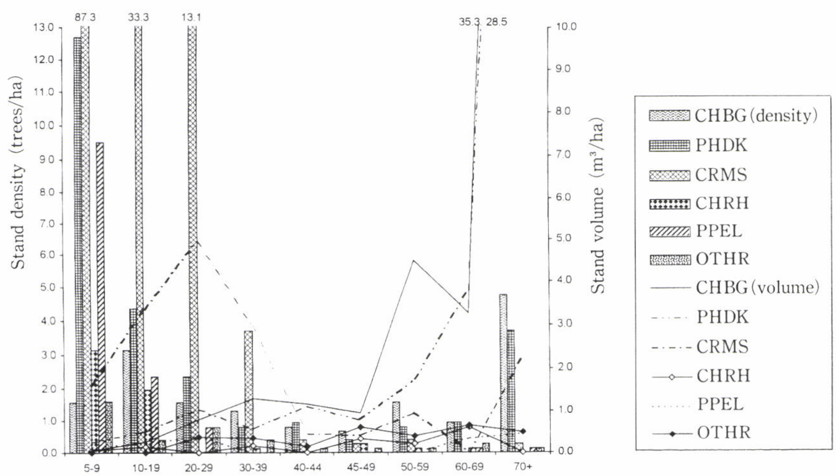

Fig. 4 Distribution of mean stand density and volume of dipterocarps in medium evergreen forest by DBH class

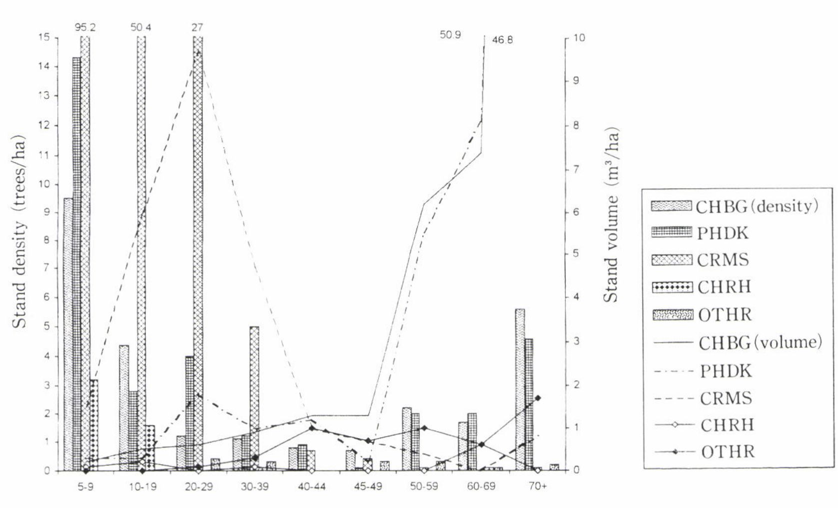

Fig. 5 Distribution of mean stand density and volume of dipterocarps in rich evergreen forest by DBH class

rest (Fig. 5).

MANAGEMENT SYSTEMS IN SOME SELECTED COUNTRIES IN SOUTHEAST ASIA

Forest management in neighboring countries, Vietnam and Thailand

Forests in Vietnam are classified into three main types based on the stand volume per hectare, namely rich (more than 150m^3), medium (80-150m^3) and poor (less than 80m^3) forests. The harvest volume per hectare is 24 m^3/ha on average (VAN, 1999). Further information on forest management in Vietnam is not available at present.

A selective cutting cycle of 30 years is implemented in Thailand. With a mean annual increment of 1m^3/ha/year or 2% of standing volume (ITTO, 1994), the annual allowable cut per hectare is 30m^3 for evergreen and semi-evergreen forests, 80m^3 for dry mixed deciduous with teak and 45m^3 for those without teak, and 20m^3 for dry dipterocarp forest (FAO and UNEP, 1981). Evergreen forest is distributed through southern and eastern regions (near Cambodian border) where annual rainfall exceeds 2,000 mm, while semi-evergreen forests is distributed throughout the country where rainfall is around 1,000-2000mm/year (SUTTHISRINN, 1999).

Forest management in Malaysia

i) Malayan Uniform System (MUS)

Basically it is a system for converting the virgin tropical lowland rain forest to a more or less even-aged forest, containing a greater proportion of the commercial species. This is achieved by a clear-felling release of selected natural generation of varying ages, aided by systematic poison-girdling of defective and non-commercial species. This system has been successfully applied to the lowland dipterocarp forest, particularly in peninsular Malaysia. The cutting volume is set at 40m^3/ha of trees with DBH greater than 45cm.

ii) Selective Management System (SMS)

SMS was introduced in 1978, when it was found that MUS was not suitable for hill dipterocarp forest because of the comparatively more difficult terrain, uneven stocking, lack of natural regeneration before logging and uncertain seedling regeneration after logging (ITTO, 1994). SMS allows for more flexible timber harvesting regimes which are consistent with the need to safeguard the environment and at the same time to take advantage of the demands of the timber market. Under SMS the next cut is expected in 25-30 years after the first harvesting with an expected net economic outturn of 30-40m^3/ha enriched with dipterocarp species. The cutting limits prescribed for the group of dipterocarp species are that trees cut should not be less

Table 8 Harvest potential per hectare of Sandan's evergreen forest

Species code	Poor forest		Medium forest		Rich forest		Average	
	Density (trees/ha)	Volume (m^3/ha)	Density (trees/ha)	Volume (m^3/ha)	Density (trees)	Volume (m^3)	Density (trees/ha)	Volume (m^3/ha)
CHBG	1.8	9.5	5.7	38.6	7.3	58.3	4.9	35.5
PHDK	4.0	24.5	5.8	34.9	8.7	60.6	6.2	40.0
CRMS	1.6	1.5	5.0	7.0	6.3	7.6	4.3	5.4
OTHR	(P)0.4	(P)1.2	(M)1.4	(M)4.1	(R)1.0	(R)4.6	0.9	3.3
Subtotal	7.8	36.7	18.0	84.5	23.3	131.1	16.4	84.1
30% cut	2.3	11.0	5.4	25.4	7.0	39.3	4.9	25.2
Non-dipterocarp	6.9	18.3	11.1	22.3	9.3	15.5	9.1	18.7
Unknown	3.9	12.3	9.5	29.0	9.5	34.4	7.6	25.2
Subtotal	10.8	30.6	20.6	51.2	18.9	49.9	16.8	43.9
30% cut	3.2	9.2	6.2	15.4	5.7	15.0	5.0	13.2
Grand total	18.6	67.3	38.6	135.7	42.2	181.0	33.1	128.0
30% cut	5.6	20.2	11.6	40.8	12.7	54.3	10.0	38.4

Note: The diameter limits for harvest: CHBG≧60cm, PHDK≧45, CRMS≧30, OTHR (assumed for all)≧45cm, non-dipterocarps and unknown (assumed)≧45cm

OTHR(P): LMBI, CHRH, TRAC

OTHR(M): CHRH, PPEL, KKKS, LMBI, TRAC and TRLT

OTHR(R): CHRH, KKTM, LMBI

than 50cm DBH, and for non-dipterocarp species not less than 45cm DBH, and the residual stocking should have at least 32 sound commercial trees per hectare.

Forest management in Indonesia

Until recently, no detailed data on growth rates of natural stands were available for Indonesia. For dipterocarp forests, estimates of 1-2m³/ha/year in currently commercial species have been made. In such places as Sulawesi, Maluku and Irian Java, the commercial growth in the forests is assessed at less than 1m³/ha/year (FAO and UNEP, 1981). There are two forest management systems in Indonesia: the Indonesian selective cutting system and Indonesian selective felling and replanting.

i) Indonesian selective cutting system (TPI)

Before 1988 this was the main management system which prescribed minimum cutting diameter according to forest type. Under TPI, concessionaires were required to contribute a deposit to a reforestation fund, which was refundable after they carried out the reforestation work prescribed. The system, however, was found to be impractical as only 10% of the concessionaires complied with the regeneration requirements on only 6% of the area logged. Simply, the cost for regeneration was much higher than the contribution to the reforestation fund. The TPI was then modified to require replanting, which is called Indonesian selective felling and replanting (TPTI). The TPTI was formulated to manage natural production forest with adequate young trees for regeneration.

ii) Indonesian selective felling and replanting (TPTI)

Under TPTI, forest concessionaires are required to manage their concession areas on a 35-year cutting cycle. Therefore, the annual allowable cut is based on this cutting cycle and the area given. Tree felling is bound by regulations on the minimum diameter to be cut and leaving behind a certain number of trees of certain diameter for future stock. Guidelines for TPTI which were prepared by the ministry of forestry required loggers to submit plans for inventory, road construction, felling, residual stand inventory and replanting, and protect 25 mother commercial species trees per hectare. On average, approximately 7-8 trees/ha were extracted (ITTO, 1994, Indonesia). In east Kalimantan under this system, dipterocarp forest is capable of growing about 1.3m³/ha/year.

HARVEST POTENTIAL OF SANDAN'S EVERGREEN FOREST

Understanding the harvesting potential of a forest is a prime consideration for forest management and forest investment. As mentioned in Kim Phat (1999), in the selective cutting systems applied to Cambodian forests, harvesting intensity is expressed in terms of the volume of merchantable timber to be removed during each entry to the harvesting area or in terms of percentage of the standing merchantable volume to be removed. On the basis of a 30 year selective cutting cycle and Cambodian silviculture prescriptions under which only 30% of merchantable timber is removed (Decree 50), Sandan's harvest potential per hectare is 20.2m³ (5.6 trees), 40.8m³ (11.6 trees) and 54.3m³ (12.7 trees) in poor, medium and rich evergreen forests, respectively (Table 8). The average harvest potential per hectare of all tree species for Sandan's evergreen forest is approximately 38.4m³ (10.0 trees), of which 65.6% comes from dipterocarps.

DISCUSSION AND CONCLUSION

The analysis of the structure of the Sandan's evergreen forest shows wide variations in both stand density and stand volume (Table 5, 6 and 7). On average for stand density, 1,105.5 trees (235.2m³/ha) were recorded ; of which dipterocarps represented 17.3%. After the dipterocarps, other major species were Myrtaceae (12.5%), Ebenaceae (7.9%) and Euphorbiceae (4.4%).

The structure of poor evergreen forest is not much different from those of medium and rich evergreen forests. The difference is in quantity; as poor evergreen forest has been repeatedly logged over recent years. Poor evergreen forest should be designated as forest reserve for at least 30 years. Firewood, however, should be allowed to be extracted because about 100% of Cambodia's villagers depend mainly on firewood for cooking energy.

On a selective cutting cycle of 30 years, the harvest potential of medium and rich evergreen forests theoretically varies from 40.8m³/ha to 54.3m³/ha. However, due to the fact that there is no information on the growth rate of Sandan's evergreen forests and a number of unknown trees are not commercial species, the annual allowable cut (ACC) should be set at 40m³/ha (based on assumption of growth rate of 0.56% of total stand volume). This figure is more or less the same as in Malaysia and Thailand. Forests in Vietnam were widely destroyed during the Vietnam War; thus their ACC must be less than that of evergreen forest in Cambodia.

The most likely species to be harvested are CHBG, PHDK and CRMS. Since unknown trees still represent a big proportion of the forest, any further study on such trees should be encouraged. The Cambodian government is still short of funds and human resources to reforest and properly manage the forests, and only logging companies have such resources. Thus, a selecting felling and replanting system as implemented in Indonesia should be introduced to Cambodia.

Forest management can no longer be concerned solely with timber production. The values of non-wood forest products are frequently overlooked, yet locally they may be much more important than wood products, and their production may be the key to involving people in participatory forest management. Non-wood forest products should be an integral part of the survival and development strategy for the continuing well-being of man, livestock and native flora and fauna (Wickens, 1994).

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Article

An Analysis of the Socioeconomic Conditions of the Rural People based on Caste —Implications for Suitable Watershed Management in the Kaski District, Nepal—

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ABSTRACT

Watershed management is important in Nepal to stabilize the physical environment and to improve the livelihood of watershed residents. Recently, people's participation has been a fundamental government policy in forest/watershed conservation. Although participation of all the stakeholders is necessary for the success of the program, their participation largely depends upon the extent of the reflection of their needs in watershed management activities. With caste-related discrimination still prevalent in Nepal, this paper attempted to identify the caste differences as reflected in their socioeconomic condition. The findings revealed that there are wide gaps between the caste/ethnic groups regarding their socioeconomic condition. The gap is particularly wide between the higher caste/ethnic group and the lower castes. Radar chart analysis showed that the local people are more concerned with socioeconomic problems compared to the natural resource aspects. Regression analysis showed that shortage of cereals is the biggest positive predictor variable of the concern for food availability. The proportion of illiterate households and livestock population are the other predictor variables. On the other hand, the amount of paddy produced, walking distance to piped water in the wet season, and walking distance to fuelwood forest are the negatively related predictor variables of the concern for food availability. Total area of Bariland (rainfed farmland) is the most important negative predictor variable for concern for fuelwood availability, followed by the area of Khetland (irrigated farmland). Walking distance to fuelwood forest, production of maize and membership in community forest are the positive predictor variables. The differences in socioeconomic conditions have deep implications for the participatory approach, as conflict of interest may arise between the groups with different socioeconomic backgrounds. It is recommended that such differences in watershed management planning be addressed so as to gain broader participation from all the stakeholders.

Keyword: people's participation, caste, watershed management, socioeconomic condition

INTRODUCTION

Nepal, a small mountainous country covering an area of 147,481 km², has a population of 18,491,097 (Central Bureau of Statistics, 1997). More than 80% of the economically active population is involved in farming. Nepal consists of three geographical regions-the Terai (plain area), the Hills and the Mountains (Fig. 1). Forestland is an integral part of the farming system in the Hills of Nepal. A feature of the integral relationship between the forests and the farming system in the Hills is the significance of watershed conservation in Nepal.

However, past forest policies failed to recognize this relationship, and were generally counterproductive in forest/watershed conservation. All forestlands were brought

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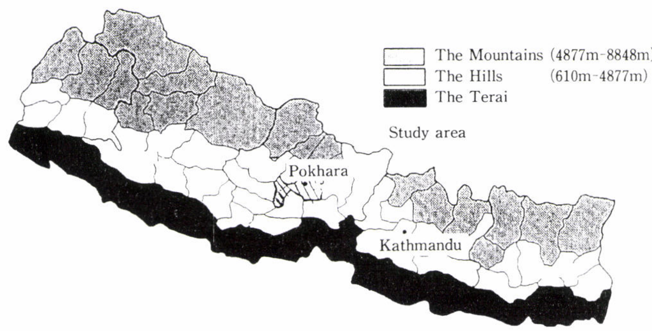

Fig. 1 The Geographical regions of Nepal

under government control (Mahat *et al.,* 1986) and state ownership was guaranteed through legal arrangements. The local people; however, continued to use the forest resources from the national forest, even though it was illegal.

The continuous exploitation of forests resulted in a decrease in the forest area in the Terai and the degradation of watersheds in the Hills. His Majesty's Government (HMG) of Nepal realized that forest/watershed conservation could not be achieved by the government alone; and, there was a need for involvement of local people (National Forestry Plan, 1976, as quoted by Bajracharya, 1992).

Even though the caste system was legally abolished in 1963, caste-based discrimination is still alive in Nepal. Since it is important for all sections of the society to take part in watershed management activities, it is useful to study the socioeconomic condition of various caste/ethnic households for a more pragmatic watershed management approach.

The main objective of this paper is to analyze the socioeconomic condition of the caste/ethnic households in the Kaski District and to discuss its implications for watershed management in the context of the current participatory approach.

WATERSHED MANAGEMENT IN NEPAL

Terrace construction on the hill-sides and planting of fodder and fuelwood trees are some of the numerous traditional watershed management practices in the Hills. However, at the government level, more concerted efforts started after the establishment of a separate Department of Soil Conservation and Watershed Management (DSCWM)*5 in 1974. Watershed management is one of the six primary components of the Master Plan for Forestry Sector (MPFS, 1989). Over the years, the Department has experienced a major paradigm shift in approaches to watershed management.

Past watershed management approach

Until the late 1980s the Department focused on the large watersheds, implementing activities throughout the watershed area. The operational approach was on a project basis and many agencies were involved in carrying out various activities.

Further there was more emphasis on the erosion control aspects such as gully control, landslide treatment, torrent control etc. Work was carried out in the field either by directly hiring local laborers or by operating through contractors. The beneficiaries were scarcely involved (Meiman *et al,* 1985; Shakya *et al.,* 1991 quoted by Bogati, 1996). The projects contributed almost all the costs required for watershed management activities and people's participation was non-existent.

Integration among various line agencies and effective mechanism for involvement of local people were found to be lacking in the implementation of such large watershed projects. The implementation strategy consisted of top-down planning, implementation and monitoring of watershed projects. This approach did not encourage farmers' participation and hence proved to be unsustainable (Wagley, 1997).

Current watershed management approach

While most of the projects were implemented on a broad watershed basis, some projects, which adopted a different approach, were already demonstrating some promising results at the grass-roots level in the early 1990 s. The Begnas Tal Rupa Tal Watershed Management Project (BTRT/WMP) jointly implemented in the Kaski District by the DSCWM and CARE International, was one such Project. The Begnas and Rupa lake watersheds, the working area of the Project, consist of $19km^2$ and $30km^2$ respectively. The Project adopted people's participation as

*5 Then Department of Soil and Water Conservation its fundamental strategy and was considered as a successful project in terms of contribution of local people and ownership of the completed activities (BOGATI,1996).

Lessons from such projects; persistent financial and manpower constraints; the need to produce more visible impacts in a short time, and further strengthening the mechanism of people's participation, entailed shifting to the sub-watershed approach. At present, functional sub-watersheds of 5-25km^2 are identified for management with emphasis on people's participation (ACHET,1998). The DSCWM implements a wide range of watershed management activities such as gully treatment, torrent control, conservation planting, fruit and fodder tree planting, training, extension etc. which are broadly categorized as:

- Land Use Planning
- Land Productivity Conservation
- Development Infrastructure Protection
- Natural Hazard Prevention
- Community Soil Conservation

In 1993, the 'Guidelines for People's Participation in Soil Conservation and Watershed Management' was promulgated by the Department. The Guidelines makes it mandatory to work through the Users' Groups (UG) for detailed planning of activities, implementation, maintenance and follow-up and benefit sharing. However, the willingness of the people to participate in the watershed management activities also depends upon the significance of the activities in their daily life. Hence, it is crucial to understand the people's concerns and their socioeconomic condition in order to formulate more pragmatic watershed management policies. Although the guidelines are silent about the ultimate objective of people's participation, they did however provide an impetus for strengthening the participatory watershed management approach in Nepal.

Unlike in the past when all the cost was borne by the projects, now the local people have to provide unskilled labor, and the projects or the DSCO (District Soil Conservation Office) provide construction materials and cash for the skilled labor. Therefore, contribution of unskilled labor by the local people is a condition in the current watershed management approach.

Nevertheless, despite the formulation of more progressive policy measures, there are still problems to overcome in the present situation. The tradition of fixing targets is still pursued. Despite the wide flexibility demanded by the participatory approach, all the watershed management activities are fitted into the predefined framework. The voice of high caste and elite dominates the users' groups (KAYASTHA, 1997; OLTHETEN, 1995).

However, recently the need for a paradigm shift from the physical target-oriented development strategy to one focusing on process strengthening and capacity building of the local people has been emphasized (SHARMA, 1997; NAGAME, 1997; DANIDA 1996; OLTHETEN,1995). In this context, the definition of watershed management given by SHARMA *et al.* (1997) deserves particular attention.

Sustainable participatory integrated watershed management is defined as utilization and conservation of land, water, and forest resources, at farm household and community (or given watershed) level for continuously improved livelihood and human development (SHARMA et al., 1997)

People's participation is a rich concept which is interpreted differently in different situations (WORLD BANK, 1996; OLTHETEN, 1995). However, two aspects are found most commonly in descriptions of people's participation. The first is the involvement of the disadvantaged group who have been previously excluded in the development process; and, the second is the stakeholders' influence and control of the development processes which affect them. (BOGATI, 1995; FAO, 1991; OLTHETEN, 1995; SHARMA *et al.*, 1997; WORLD BANK 1996). Following this it can be concluded that in the people's participation process, people's empowerment is vital so that they can take initiatives and contribute to and control the development process.

METHODOLOGY

This study is mainly based on the data obtained from the socioeconomic survey conducted by Japan International Cooperation Agency (JICA) in the Western Hills of Nepal. Observations made by this author in the field surveys in one of the Village Development Committees (VDC), the lowest administrative unit in Nepal, have also been utilized wherever appropriate. A socioeconomic baseline survey for the JICA Development Study on Integrated Watershed Management in the Western Hills of Nepal was carried out from December 1995 to September 1996. This study was conducted in two districts, namely Kaski and Parbat. It covered 19 VDCs in the Kaski district. The area covered by the survey is approximately 29,521 ha.

The survey comprised a Household Survey, which included a survey of the household heads; and a Household Members Survey, which included a survey of the household members. Approximately 4,668 households and 10,624 household members were surveyed in the Kaski district (JICA/HMG, 1998).

Survey method

The survey method consisted of structured questionnaires for the household survey and household member survey. An administrative survey was conducted through contact with key informants such as school teachers, local political leaders, leading farmers etc. The survey team consisted of 5 groups, each having 6 enumerators and a group supervisor. These survey groups were supervised by the Field Supervisor. The information collected by the enumerators was verified by the Group Supervisors and the Field Supervisor.

CASTE SYSTEM IN NEPAL

As it is diverse in geographical and ecological setting, Nepal is inhabited by various caste and ethnic groups with diverse culture, social customs and life style. The caste system was legalized in the entire country in 1854 (Bista, 1991). Although it was legally abolished in 1963, the traditional taboos based on caste are still prevalent in the society.

Caste composition in the Kaski district

Kaski district is inhabited by various caste households e.g. Brahmin, Chhetri, Thakuri, Gurung, Magar, Kunwar, Kami, Damai, Sarki etc. In Kaski district, the sample households consist of 48% Brahmin/Chhetri, 17% Gurung/Magar/Kunwar and 23% Damai/Kami/Sarki caste households. The rest consist of various other castes. For the purpose of this study the sample households have been categorized into the following three groups, which comprise more than 88% of the sample population.

i) Brahmin/Chhetri (BC):

Brahmins rank highest in the caste hierarchy and along with Chhetris they form a majority of the influential and wealthy people of traditional Nepal (Bista, 1996). The main occupations of Brahmin and Chhetri are farming and government service.

ii) Gurung, Magar and Kunwar (GMK):

Gurung and Magar are ethnic groups. Gurung and Magar are famous for their service in the army. They generally live in the upland and many people work away from home.

iii) Kami, Damai, Sarki (KDS):

These are the lower caste people, also known as the occupational caste. Kami, Damai and Sarki are blacksmiths, tailors and cobblers respectively. They are considered as untouchables by the rest of the social groups. The situation of low caste is characterized by their ownership of only marginal cropland or no land at all, serving higher castes through trade of skills for food, lack of access to credit, and poor nutrition and education (Evans, 1997).

SOCIO-ECONOMIC CONDITIONS OF THE CASTE/ETHNIC HOUSEHOLDS

The socioeconomic variables considered for the purpose of analysis are land ownership, source of cash income, fuelwood, drinking water, livestock , crop production and

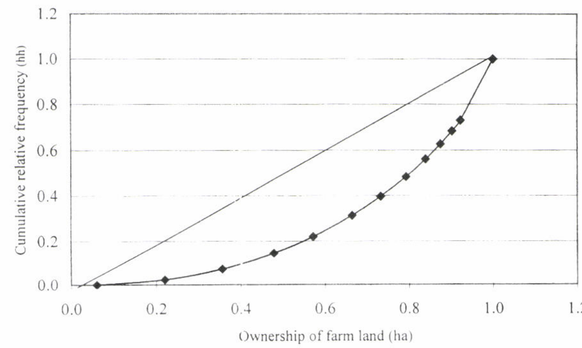

Fig. 2 Ownership of farmland by sample households

people's concerns.

Land ownership by caste/ethnic households:

Farmland in Nepal is basically categorized as Khetland (irrigated lowland) and the Bariland (rainfed upland). Rice, maize, wheat etc are grown in the Khetland, whereas maize, wheat, mustard, millet etc. are grown in the Bariland. Fodder trees are mostly grown in the Bariland. The size of the landholding determines food production, animal fodder, production of crop residues, number of livestock to be supported and overall livelihood of a family.

i) Overall land ownership pattern in the study area:

The inequality of land ownership among the households in general is illustrated in Fig. 2. It shows that about 80% of the households own approximately half of the farmland whereas the remaining 20% own the other half showing a great disparity.

ii) Households without farmland:

The number of households without farmland differs significantly among the caste/ethnic groups. About 1.6% of the BC, 5.5% of the GMK and 13.2% of the KDS households do not own any farmland.

iii) Ownership of Khetland:

Both the BC and the GMK own a significantly greater area of Khetland than the KDS. Ownership of Khetland is a status symbol in Nepal. On average, BC households own 0.43 ha of Khetland followed by 0.34 ha by GMK and 0.07 ha by KDS households. About 70% of the KDS households do not own any Khetland.

iv) Ownership of Bariland:

The KDS households own an average of 0.09 ha of Bariland compared to 0.19 ha owned by the BC and GMK households. Households that do not own any Bariland comprise 15.5% of total households for the KDS, but only 9.3 and 6.7% for the BC and GMK respectively.

Table 1 Source of cash income of caste/ethnic households

Source of cash income	BC	GMK	KDS
People's concern for cash income (score	78	77	92
Remittance from family members	18.2	28.8	18.8
Wage from temporary jobs	10.2	3.6	14.3
Private business	5.9	4.0	5.2
Pension	6.3	37.4	3.4
Salary from permanent job	21.8	7.2	2.4
Selling livestock/Dairy products	12.6	3.3	0.4
Selling crops	7.0	1.3	0.2
Selling forest products	0.7	0.4	0.0
Others	17.1	14.1	55.3

BC=Brahmin/Chhetri unit-%hh
GMK=Gurung/Magar/Kunwar
KDS=Kami/Damai/Sarki

Table 2 Ownership of private trees by sample households

Type of trees	BC	GMK	KDS
Fodder trees	21.1	17.2	5
Fuelwood trees	48.8	53.2	10.5
Timber trees	9.2	12.7	2.2
Horticultural trees	19.3	9.6	4.6
Total (no)	98.4	92.7	22.3

BC=Brahmin/Chhetri
GMK=Gurung/Magar/Kunwar
KDS=Kami/Damai/Sarki

Source of cash income

The sample households derive their income from various sources such as selling crops, selling livestock and dairy products, pensions, salary from permanent jobs, remittance from family members, wages from temporary jobs, private business and other sources (Table 1). The 'other' sources of income include poultry farming, house rent, bank interest, wage labor, selling fruit, tailoring, mechanics, portering etc.

The major sources of income for the BC households are salaries from permanent jobs (22%), remittances from family members (18.2%), selling crops and livestock products (20%). The GMK households derive most of their income from pensions (37%) and remittances from family members (29%). On the other hand the KDS households mainly derive their income from 'other sources' (55%), mainly daily wage labor. They also depend on remittances from family members (19%).

Members of all caste households have a generally high degree of concern for cash income. KDS household members have the highest degree of concern for cash income. This is justified by the fact that the BC and the GMK households have relatively stable sources of income such as salaries from permanent job and pensions, compared to the KDS households who are mainly dependent on wages from temporary jobs and other sources.

Fuelwood

Wood is the basic source of fuel in Nepal, supplying about 73% of the total energy consumption (CBS, 1996). More than 97% of the households in the Kaski district consider it as the major source of fuel for cooking, heating and other related needs. Fuelwood collection is an important activity in the rural area. Depending on various factors such as ownership of private land, access to the community forest, supply of forest products from the private lands etc., villagers have to spend considerable time on fuelwood collection.

i) Fuelwood consumption:

In the Kaski district, average per capita consumption of fuelwood is 427kg per year. High caste households consume 429kg, GMK consume 467kg and KDS consume 422kg of fuelwood per person per year.

ii) Households purchasing fuelwood:

About 5.7% of the total households purchase fuelwood. There is not much difference among the caste/ethnic groups regarding the purchasing of fuelwood-5.6, 5.3 and 6.4% for BC, GMK and KDS respectively. Per capita purchasing is highest among the GMK with 324 kg, while the BC and KDS purchase 257kg and 235kg respectively.

iii) Walking distance to fuelwood forest:

The KDS have to walk approximately 65 minutes to reach the fuelwood forest compared to 48 minutes by the BC and GMK households.

iv) Ownership of private forest:

About 15% of the sample households own private forest. Approximately 20% of the BC households and 22% of the GMK households own private forest, compared to only 4.5% of the KDS households. About 64% of the total private forest is owned by the BC group, 25% by the GMK, 5% by the KDS households and 6% by others.

v) Ownership of private trees by caste households:

Trees on farmland are an important source of fodder, fuelwood and fruits. The trees found on the farmland are mainly fodder trees, fuelwood trees, timber trees and horticultural trees. The caste households show a significant ownership pattern of these various types of trees.

The BC and GMK households own significantly more trees than the low caste. Table 2 shows that BC households own more fodder and horticultural trees, whereas the GMK households own more fuelwood and timber trees.

vi) Membership of community forest:

An analysis was done to examine whether there is any difference among the caste households pertaining to the membership of the community forest. The analysis showed that approximately 65% of all the caste groups have become members of the community forest and did not show a significant difference among the caste/ethnic groups.

Drinking water

i) Source of drinking water:

The main sources of drinking water in the Hills are piped water and spring water. A small proportion of the households also uses river water. There are four types of households based on their use of water in the dry and wet seasons-the households who use piped water in both seasons, households who use spring water in both seasons, households who use piped water in wet season and spring water in dry season, and the others who use piped water in dry season and spring water in wet season.

The GMK households have the highest percentage (76%) using piped water in both seasons, followed by 63% of the BC households and 59% of the KDS households. About 22% of the BC households and 23% of the KDS households use spring water in both seasons compared to only 11% of the GMK households. As more water is available during the wet season, there are some households who use piped water in the wet season and spring water in the dry season. A very small proportion of the households use piped water in the dry season and the spring water in the wet season.

ii) Walking distance to drinking water source:

There is significant difference in the walking distance depending on the type of drinking water source. Generally, the time taken to get piped water is shorter than for spring water. Similarly, it takes more time to fetch drinking water in the dry season than in the wet season. There is not much difference in the time for fetching piped water for drinking among the three caste groups. The range is between 12 minutes for the GMK households in the wet season and 17 minutes for the KDS households in the dry season.

However, there is remarkable difference in the time spent on fetching drinking water from the springs in the dry season. BC households spend the shortest time of about 14 minutes, followed by GMK spending about 35 minutes, while the KDS have to spend the most time i.e. 43 minutes to fetch drinking water from the spring in the dry season. GMK spend only about 13 minutes to fetch water from the spring in wet season whereas the BC and KDS spend 25.5 and 30.5 minutes respectively. In general, the KDS spend more time collecting drinking water than the other two caste groups.

Table 3 Ownership of livestock by sample households

Livestock	BC	GMK	KDS
Cow	1.01	1.01	0.57
Buffalo	1.54	1.23	0.82
Goat	0.68	0.67	0.23
Sheep	0.06	0.22	0.01
Pig	0.01	0.04	0.08
Chicken	2.87	2.96	1.57

BC=Brahmin/Chhetri
GMK=Gurung/Magar/Kunwar
KDS=Kami/Damai/Sarki

iii) Walking distance to drinking water source for KDS households based on their location:

Further investigations were made to verify whether the time spent by KDS households differed with regard to their settlement in caste/ethnic majority wards. The KDS have to spend more time fetching drinking water regardless of their settlement in BC or GMK majority wards.

Livestock

Livestock is an integral part of the farming system in Nepal. In the Hills livestock rearing is considered as the second most important activity and it contributes about 27% of the total household income (Rajbhandari *et al.*, 1981). In a cropping systems research study conducted in Pumdi Bhumdi VDC of the Kaski district, Rana et al. (1981) found that livestock contributed 24% of the household income. Five main reasons are given by the farmers for owning livestock (Rana *et al.*, 1981):

1. Cash income
2. Food for household consumption
3. Draught power
4. Compost; and
5. Festivals and other occasions

Cattle, buffalo, goats, pigs, sheep and chickens are the major livestock and poultry raised by the caste households in the study area.

Table 3 shows that both the BC and the GMK households own more livestock than the low caste households. This is possibly because the supply of fodder and forage is greater on the farmland. This situation gives the high caste households easy access to animal products such as milk, meat, butter etc. A larger number of animals also means more manure for crop production.

Tree fodder is an important source of feed for the

Table 4 Corrrelation matrix for people's concerns

Concerns	Crop productivity	Irrigation	Landslides and soil ero.	Flood	Maintenance of terrace	Fuelwood availability	Fodder availability	Forest resources	Drinking water	Foot trails	Electricity supply	Motorable roads	Communication facility	Health facility	Meeting on com. dev.	Worship of God	Labour force availability	Family planning	Education of children	Self education	Cash income	Food availability
Crop productivity	1																					
Irrigation	0.49	1																				
Landslides	0.20	0.03	1																			
Flood	0.19	0.02	0.73	1																		
Maint. Of terrace	0.32	0.27	0.75	0.73	1																	
Fuelwood	-0.06	0.00	-0.25	-0.25	-0.31	1																
Fodder	0.17	0.16	-0.26	-0.15	-0.20	0.80	1															
Forest resources	-0.03	-0.07	-0.11	-0.22	-0.33	0.74	0.49	1														
Drinking water	0.25	0.28	0.06	0.09	0.18	0.06	0.18	-0.14	1													
Foot trails	0.42	0.32	0.26	0.33	0.46	-0.28	-0.04	-0.23	0.39	1												
Electricily supply	0.17	0.28	-0.01	0.13	0.09	-0.26	0.00	-0.25	-0.01	0.22	1											
Motorable roads	0.37	0.48	0.08	0.11	0.22	-0.15	0.09	-0.18	0.20	0.46	0.42	1										
Communication	0.33	0.50	0.20	0.33	0.36	-0.28	-0.06	-0.30	0.16	0.44	0.28	0.61	1									
Health facility	0.11	-0.28	0.19	0.16	0.07	0.04	-0.07	0.27	-0.08	0.02	0.06	-0.12	-0.25	1								
Meeting	0.34	0.19	0.07	0.19	0.22	-0.50	-0.29	-0.39	0.12	0.45	0.42	0.32	0.27	0.37	1							
Worship of God	0.18	0.38	0.10	0.24	0.21	-0.21	-0.06	-0.14	0.23	0.51	0.08	0.16	0.49	-0.30	0.15	1						
Labour force	0.16	0.30	0.22	0.17	0.21	-0.14	-0.07	0.03	0.08	0.44	-0.02	0.12	0.40	-0.32	-0.04	0.79	1					
Family planning	0.11	0.15	0.00	0.05	-0.09	0.19	0.24	0.38	0.06	0.30	0.01	0.18	0.07	0.07	-0.01	0.37	0.48	1				
Education of childrean	0.16	0.40	0.01	-0.05	0.04	-0.17	-0.02	0.06	0.10	0.33	0.00	0.21	0.27	-0.06	0.30	0.62	0.47	0.41	1			
Self Education	0.18	0.00	0.28	0.19	0.09	0.13	0.09	0.46	0.00	0.14	-0.10	0.00	0.02	0.27	0.08	0.25	0.36	0.41	0.29	1		
Cash income	0.21	0.26	-0.12	-0.01	-0.01	0.38	0.54	0.30	0.19	0.19	0.14	0.33	0.07	-0.31	-0.28	0.18	0.16	0.37	0.12	0.16	1	
Food vailability	0.11	0.12	0.06	-0.03	0.02	0.05	0.23	-0.12	0.18	0.24	0.28	0.16	-0.05	-0.18	-0.04	0.21	0.18	0.19	0.16	-0.07	0.38	1

animals in the dry season when forage grass is not available. The ownership of more trees provides the high caste households with a base for supporting more animals than the lower castes.

Crop production

The main crops grown in the study area are rice, maize, wheat, mustard etc in the Khetland, and maize, wheat, millet etc. in the Bariland. Among the crops produced by various caste households, rice contributes the major proportion. However, it is the highest in BC households (62%), then GMK households (57%) and least (45%) in the KDS households.

All castes produce maize in similar proportion (18-21%). Wheat contributes little to total crop production (4-7%). There is significant difference in the production of millet in the three caste households. Millet contributes 13%, 18% and 30% to total crop production for the BC, GMK and KDS households respectively.

i) Use of chemical fertilizer in various crops:

Generally there are more farmers who apply chemical fertilizer in the Khetland than in the Bariland. More of the BC households apply chemical fertilizer to all their crops than the other two castes. Generally the KDS households have the smallest percentage applying chemical fertilizer to their crops.

ii) Crop productivity:

Productivity of rice in the Khetland indicates a clear difference based on caste. High castes have higher crop productivity than the lower castes. There are mixed results in the Bariland. GMK households have the highest crop productivity in the Bariland across all crops. Productivity of millet is higher in the GMK and KDS households than in the BC households.

Degree of concern of caste/ethnic households

As there are differences in the socioeconomic conditions of the caste households, so there are significant differences in the degree of concern expressed by the caste households. The degree of concern reflects the percent of household members who answered that they have "strong concern" for a particular issue.

The high caste BC households have a high degree of concern for cash income, food, crop productivity, irrigation

Table 5 Category of concerns of sample houselds

Main Category	Sub-Category	Present concerns	Degree of Variance	Radar chart variables
A.Agriculture	1. Productivity	a. Crop productivity	High	
		b. Irrigation	Medium	
	2. Erosion	a. Landslides and soil erosion	High	*
		b. Flood	High	
		c. Maintenance of terrace	Medium	
B.Forestry	1. Forestry	a. Fuelwood availability	Very high	*
		b. Foddder availabilty	High	
		c. Forest resources	Medium	
C.Drinking water		a. Drinking water	High	*
		b. Foot trails	High	
D.Infrastructure		a. Electricity supply	Low	
		b. Motorable roads	Low	
		c. Communication facility	High	
		d. Health facility	High	*
		e. Meeting on community development	Medium	
E.Culture	1. Culture	a. Worship of God	Medjum	
	2. Labor	a. Labor force availability	High	
		b. Family planning	Low	
	3. Education	a. Educationof children	Medium	*
		b. Self education	Low	
F.Livelihood security	1. Cash	a. Cash income	Low	
	2. Kind	a. Food availability	High	*

and drinking water availability. The GMK households have a high degree of concern for cash income, irrigation, food, crop productivity, and forest resources. The low caste KDS households place their highest degree of concern for cash income, food, fodder availability, fuelwood availability and drinking water availability.

RELATIONSHIP BETWEEN SOCIOECONOMIC CONDITIONS OF THE CASTE/ETHNIC GROUPS AND THEIR CONCERNS

Categorization of people's concerns

i) General categorization:

Since there are too many variables for individual observation, it was necessary to categorize them into manageable numbers. A correlation matrix was constructed for all the concerns (Table 4). An initial grouping was done based on the highest correlation. As a result the concerns have been categorized into the following nine groups.

I. Fodder availability
Fuelwood availability
Forest Resources

II. Crop productivity
Irrigation

III. Motorable roads
Communication facilities

IV. Landslides and soil erosion
Maintenance of terraces
Floods

V. Meeting on community development
Electricity supply
Health

VI. Family planning
Education of children
Self education

VII. Cash income
Food availability

VIII. Worship of God

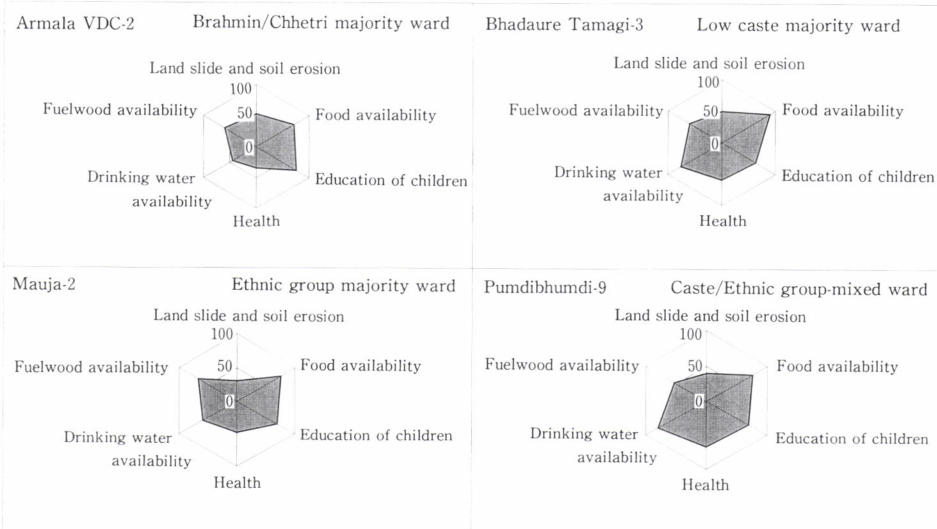

Fig. 3 Degree of concern of caste/ethnic households

Labor force availability

IX. Drinking water supply

Foot trails

ii) Categorization for radar chart analysis:

Radar chart analysis has been done in order to understand the characteristics, especially the needs, of the individual wards. There are nine wards in a VDC. There are 144 wards from 19 VDCs covered by the study. Each ward comprises of 32 to 160 households covering an average area of 196 ha (5.3-1,199 ha).

The concerns were further categorized into agriculture, forestry, drinking water, infrastructure, culture and livelihood security (Table 5). Wherever appropriate, subcategories have been formed under the main categories. For example agriculture is further divided into productivity and erosion subcategories. Concern for crop production and irrigation are included in the productivity subcategory, while the concerns for landslides and floods have been included in the erosion subcategory. One representative concern from each group was selected according to their degree of variance and relative importance in the group. The selected concerns are food availability, health facilities, education of children, landslides and soil erosion, fuelwood availability and drinking water availability.

Among the above six variables considered for the construction of radar chart, concerns for food availability, education of children and health care facilities are considered as the ones related to socioeconomic aspects. On the other hand, landslides and soil erosion, drinking water availability, and fuelwood availability are considered as the concerns related to natural resources aspects.

Generally the people are more concerned with the socioeconomic aspects (Fig. 3). However, there is wide variation among the VDCs and the wards within the VDC as well. In Thumki VDC, the radar chart is sharply tapered towards the natural resources side because of high concern for drinking water availability, although there is more shaded area on the socioeconomic side. In Mauja VDC, the shaded area in the radar chart forms closer to a rectangular shape with relatively moderate scores for all concerns. Two distinct trends are observed in this VDC. The ward nos. 2, 3, 4, 5 and 6 have low concern for landslides, while the others have high concern for landslides and soil erosion. Among them, wards 2, 3, 5 and 6 are ethnic group majority wards, and ward 4 is a low caste majority ward.

The Armala VDC has greater concern for fuelwood in ward no 7, 8 and 9. Armala-7 is an ethnic group majority ward, and Armala-8 and 9 are low caste majority wards, and these groups have only limited access to forest resources. Although the walking distance to fuelwood forest is shorter than other wards, difficult access to fuelwood forest can be the reason for high concern for fuelwood availability. All the wards have a large shaded area for socioeconomic concerns. In most of the wards of the Pumdi Bhumdi VDC, the radar chart is tapered to the socioeconomic side with high concern for food availability. In the Bhadaure Tamagi VDC there is high concern for landslides.

Adoption of an appropriate strategy for watershed management depends upon the characteristics of each ward. In this context it is desirable to have an understanding of the factors which influence the people's concerns.

Factors influencing people's concerns

Stepwise regression analysis has been conducted in order to determine the factors influencing the concerns for the availability of fuelwood and food.

i) Possible predictor variables considered for regression analysis:

X_1—Shortage of cereals-months/yr/household (hh)
X_2—Illiteracy-% of economically active population in the ward without any formal education
X_3—Livestock population-head/hh (cows, buffalo and goats)
X_4—Ownership of Bariland-ha/hh
X_5—Ownership of Khetland-ha/hh
X_6—Total Khetland-total area of Khetland-owned and rented ha/hh.
X_7—Total Bariland-total area of Bariland-owned and rented ha/hh.
X_8—Absentee family members-% in the ward
X_9—Production of paddy-kg/yr/hh
X_{10}—Production of wheat-kg/yr/hh
X_{11}—Production of maize-kg/yr/hh
X_{12}—Production of millet-kg/yr/hh
X_{13}—Flood damage-ha/hh
X_{14}—Landslide damage-ha/hh
X_{15}—Ownership of horticultural trees-no./hh
X_{16}—Walking distance to piped water in dry season-minutes
X_{17}—Walking distance to piped water in wet season-minutes
X_{18}—Walking distance to spring water in dry season-minutes
X_{19}—Walking distance to spring water in wet season-minutes
X_{20}—Walking distance to river water in dry season-minutes
X_{21}—Walking distance to river water in dry season-minutes
X_{22}—Participation in community forest-% of members in the ward
X_{23}—No. of trees on farmland-no./hh (horticultural, fodder, fuelwood and timber trees)
X_{24}—One-way walking distance to fuelwood forest-minutes
X_{25}—Forest area in the ward-ha
X_{26}—Proportion of forest area (%)
X_{27}—Population of the ward

Fuelwood availability

Regression model for degree of concern for fuelwood availability:

$$CFW = 65.824 + 0.217X_{24} - 116.629X_7 + 0.083X_{22} - 20.526X_6 + 0.020X_{11}$$
$$(t=11.220) \quad (t=5.798) \quad (t=-6.005) \quad (t=2.8) \quad (t=-2.616) \quad (t=2.016)$$

where

CFW = Concern for fuelwood availability (score)

Regression statistics:

R = 0.705
R square = 0.497
Adjusted R square = 0.478
Standard error = 12.8312

The above model suggests that area of total Bariland is the most influential predictor variable (negatively) of the concern for fuelwood availability, followed by walking distance to fuelwood forest (positively). Fodder and fuelwood trees are traditionally grown in the Bariland. Therefore, it is natural to have such an influence in the regression model. Although the Khetland is almost devoid of any trees, ownership of Khetland also has a negative effect on the concern for the fuelwood availability. Membership of households in community forests is positively related with the concern for fuelwood availability.

Food availability

Regression model for degree of concern for food availability:

$$CFA = 47.142 + 5.636X_1 + 1.269X_3 - 0.009X_9 - 0.088X_{24} + 0.261X_2 - 0.176X_{17}$$
$$(t=7.036)\ (t=8.705)\ (t=2.530)\ (t=-3.156)\ (t=-3.420)\ (t=2.927)\ (t=-2.179)$$

where

CFA = Concern for food availability (score)

Regression statistics:

R = 0.779
R squared = 0.606
Adjusted R squared = 0.589
Standard error = 8.4091

Shortage of cereals is the most important predictor variable for concern for food availability. Production of paddy has a negative effect on the degree of concern for food availability, but illiteracy and livestock have a positive effect. Illiteracy is negatively correlated with production of paddy, maize, millet; tree ownership etc. The poor households, especially the low castes, have little opportunity to get education. In the study area, the illiterate male household members comprise 44% in low caste households compared to 18.4% and 14.6% in the GMK and BC households respectively. The situation is worse in the case of females who are 81% illiterate in low caste households and 51% in the GMK and BC households. Therefore it is normal to have increasing concern for food availability with a higher percentage of illiterate households in the ward.

Lack of productive livestock can be one of the reasons for a positive relation between concern for food availability and number of livestock. Walking distance to piped water in wet season is negatively related. Walking distance to the fuelwood forest is also negatively related with the degree of concern for food availability. Although the effect is very marginal, the probable reasons could be that those who have settled on the lower parts of the hills with more level terraces have a greater walking distance to the forest.

IMPLICATION FOR SUITABLE WATERSHED MANAGEMENT

Appropriate watershed management is fundamental to stabilize the physical environment and to increase the productivity of the watershed resources. The Forest Act (1993) emphasizes the direct involvement of the local users in forest management in the form of community forests. People's participation is a fundamental strategy in watershed management (DSCWM, 1993).

An important assumption is that all the users of community forests are equal-a description made from the perspective of the membership pattern. Also, in watershed management the local people are required to contribute unskilled labor in order to implement various activities. Here also it is assumed that everybody can participate equally.

This study was based on the hypothesis that people's concerns are based on their socioeconomic background and the incentive for participation would come from the reflection of their concern in the proposed activities. The analysis in this study revealed that there is an apparent gap among the caste/ethnic groups regarding their socioeconomic condition. The gap is particularly wide between the upper castes/ethnic groups and the lower caste households.

The lower caste households have less farmland than the high caste and ethnic group. As found in the regression analysis, Bariland is the most important factor for concern about fuelwood availability. The less Bariland, the greater the concern for the fuelwood availability. Also the walking distance to the fuelwood forest, which is another important factor, is higher for the KDS households, and so concern for fuelwood availability is higher for them.

When the national forests are handed over to the users' groups, they impose strict rules about product harvesting and access to forests (Graner 1997). Quite often, access to forests is allowed only for a limited time of the year. It was observed in the Armala VDC that the forests are generally open for about two months in the winter i.e. January-February. The forest users told the authors that that is free time without major agricultural operations. However, the specific time for opening is further decided by each forest users' committee. In one of the community forests where the low castes are also members, the forest is open only for two days.

The low caste people who cannot supply much of their own forest products other than from community forests suffer the most due to long closure of the forest. In the absence of viable alternatives, the lower castes have to resort to illegal means to obtain forest products which leads to social conflicts. On the other hand, BC and GMK households may obtain fuelwood from their private land. Conflicts in community forests have already appeared, partly because of lack of involvement of low caste households (Poudel, 1996). This is particularly significant when more and more forests are being brought under community management.

Within a VDC, most of the activities are conducted on a ward basis. So it is important to know the characteristics of each ward regarding the people's needs. The radar chart analysis showed that generally the needs are more for socioeconomic aspects such as food availability, health facility and education of children. This means that people will be more attracted to the activities which help to solve the problem of food availability. Radar charts show that food availability is a high concern for the KDS majority wards whereas education of children is a bigger concern in the BC majority wards. Thus it is important to implement watershed management activities based on the characteristics of the particular ward or community.

It is obvious that since the low caste households own less farmland, they have more concern for food availability. The low caste households produce only 43% of cereals compared with the high caste households. Regression analysis also revealed that shortage of cereals is the biggest predictor variable for food availability. The shortage of cereals is more prominent for those who have lower crop production. Illiteracy is another factor which increases concern for food availability. There is negative correlation between the percentage of illiterate population in the ward and the ownership of Khetland (−0.33) and Bariland (−0.27). Eradication of illiteracy would lead to wider vision and enhance the analytical capabilities of the local people to find alternatives for income generation. Therefore, stronger measures for the education of local people are needed.

Lower crop production, which is partly related to ownership of fewer livestock, means that low caste households have to spend more time to solve their hand-to-mouth problems of daily survival. In such cases they will not have enough incentive to participate in watershed management activities which do not bring benefit in a short period. Any watershed management activity that emphasizes farmland does not contribute much to the benefit of the low caste people.

The upper castes have more stable sources of income compared to the low castes who mainly depend upon their temporary wage labor to solve their hand-to-mouth problem. It is evident from the analysis that the low caste people have the highest degree of concern for cash income. Therefore the lower castes will be more interested in income-generating activities which bring benefit in the short term. Only then we can expect them to participate in the activities related to forest/watershed conservation. It is necessary to implement income-generating activities in view of their socioeconomic condition.

One of their greatest daily concerns is the fetching of drinking water and fuelwood. It is important to consider how to reduce the time taken for these activities. This will not only reduce the burden of women but also allow them to be involved in other productive works. Piped water supply, as observed in the above analysis, has been quite effective in reducing the time taken to fetch drinking water.

Very little attention has been paid to the socioeconomic condition of the local people in watershed management planning (DSCWM, 1996). However, in the participatory approach it is important that households of all castes take part in the watershed management program. So unless we consider such differences, the low caste people will have less incentive to participate in watershed management activities. This will jeopardize the essence of the participatory approach of involving disadvantaged groups in the watershed management program and will limit the chance of improving their livelihood.

CONCLUSION

The present policy measures pertaining to forest watershed conservation have defined the local people by a single word 'user'. It is also assumed that all users can participate equally. The analysis in this study, however, revealed that even if the users are similar in their use of a particular resource, there is a wide gap among them in terms of their socioeconomic condition. This gap reflects their caste/ethnic background-the traditional social structure in Nepal.

Statistical analysis showed that the ownership of farmland is an important factor in relation to concerns about food and fuelwood availability. Those who do not own much farmland have high concern. For them the public forests are an important source of fuelwood and other forest products.

Relatively stable sources of income for the upper castes and ethnic groups place them in a better position than the lower caste households who have to depend on their daily wage labor. If the households have to spend their daily time in wage labor, they cannot be expected to participate in watershed management by making contributions for free. Also they have to spend more time in collection of fuelwood and drinking water which limits their opportunity to participate in watershed management activities. Their high concern for cash income necessitates implementation of a wide range of measures to improve their livelihood. In particular, income-generating activities need to be implemented in view of their socioeconomic condition.

It is important that these concerns of the local people be considered while undertaking various watershed management activities in order to improve their livelihood together with promotion of environmental conservation, even if such endeavors entail changes in the existing policy framework. In order to avoid conflicts and ensure equity in resource distribution, policy arrangements must ensure that the socially and economically disadvantaged people get a fair share.

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Short communication

Trends on Silviculture and Zoning Strategy in the Brazilian Amazonia

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ABSTRACT

International tropical timber trade demonstrated a turning point in the 1990's. Some of the southeast Asian countries such as Philippines and Thailand turned into importers of round-wood, after being big exporters up till 1994. This change reflects the presence of many logging companies of those Asian countries in the Brazilian Amazon in the late 1990's. In this paper, Amazonian timber production and the forest situation of Legal Amazonia (the nine Brazilian states of Amazonia) were studied based on a field-study carried out in August 1997. During the study, it was confirmed that, due to depletion of round-wood resources, international loggers were advancing further into the Amazonian rainforests. To promote the conservation of the Amazonian ecosystem, the Brazilian government has established a zoning strategy in Legal Amazonia, clearly dividing conservation areas and farming areas since 1990. For better understanding of the land-uses in that region, the zoning strategy was examined in the field, mainly in the Amazonas State and in Rondônia State, in August 1997. Also, ITTO's 1997 statistical data on tropical timber trade and Zachow's 1998 data on forest management were analyzed. As a result, it was found that most of that region has no proper control on the forests yet. In Rondônia, depletion of rainforest was observed along the BR-364 highway and adjacent roads, due to lack of infrastructure (supply of electricity and fuel gas). This fact accelerated the forest burning beyond the authorized rate of 20% for each settlers' land, which vary from 100ha to 25ha, depending on their settlement year. In heavily logged stands in Rondônia and Amazonas, there was a luxuriant growth of liana and palm trees, replacing the original (shade-tolerant) species. This kind of alteration clearly shows the induced anthropogenic change in the climax forest. Out of 3,648,000km^2 of Amazonian rainforest, only 26km^2 is under sustainable management treatment. Local people should be assisted more intensively by the government, to plan and implement the sustainable management of the forests. Zoning strategies should be clearly defined all over the region to avoid depletion of the virgin forest and to promote good use of the abandoned lands after burning.

Keyword: Legal Amazonia (Brazilian Amazonia), deforestation, tropical timber, sustainable management, silviculture

INTRODUCTION

Brazilian forests show different characteristics in the northern and southern regions. Amazonian rainforest and savanna (cerrado) mainly cover the northern region, with very little practice of silviculture. Pine forest and Eucalyptus plantations represent the major vegetation cover of the southern region, with wood production mainly based on silviculture. In this paper, log production and land-uses of the Brazilian Amazon, as well as causes of deforestation, are discussed, based on the field study carried out in August 1997. Development projects took place in that region in the early 1970's, including colonization projects and construction of national roads. The annual deforested area of Legal Amazonia achieved a peak of 29,059km^2 in 1995, decreasing to 16,926km^2 in 1998/99 (INPE-National Institute for

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Spatial Research), amounting to 10% deforestation of that region between 1970 and 2000. Among the ITTO (International Tropical Timber Organization) members, the top 4 round-wood producers in 1995-1997 were Brazil, India, Indonesia and Malaysia. Due to the round-wood production ban introduced by those southeastern Asian countries, Brazil has turned to be the main round-wood producer since 1995 (Fig. 1). There are two important forest management research programs within Legal Amazonia: one has been carried out in the National Forest of Tapajós (EMBRAPA-CPATU-The Brazilian Agricultural Research Organization-Agroforestry Research Center for the Eastern Amazonia) since 1978, and another one in Manaus (INPA-National Institute for Amazonian Research) since 1980. Some important experimental results on silviculture and forest management carried out in Legal Amazonia were presented by SILVA *et al.* (1993), and HIGUCHI (1997). Their experiments indicated that logging resulted in the first 3-4 years in mortality increase and growth of light-demanding species. However, the forest stand regained a positive balance after eight years, with growth rates nearly reaching those of a primary unlogged forest. Also, managed forest with proper silvicultural treatment showed an increase in the timber production rate compared to the primary forest. With the intention of addressing ecological problems and achieving social and economic benefits from proper land use, the Brazilian government introduced the zoning strategy to improve forest management. A field study was carried out in Rondônia State to evaluate the functioning of the zoning strategy.

The purpose of this paper was to analyze the actual rainforest depletion rate and examine how the silviculture and zoning strategy worked to achieve sustainable forest management in Legal Amazonia.

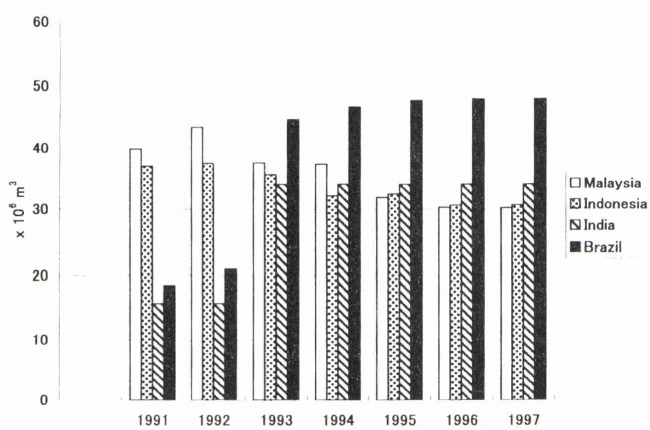

Fig. 1 Top four tropical log producers, 1991-1997
Source: ITTO, 1997

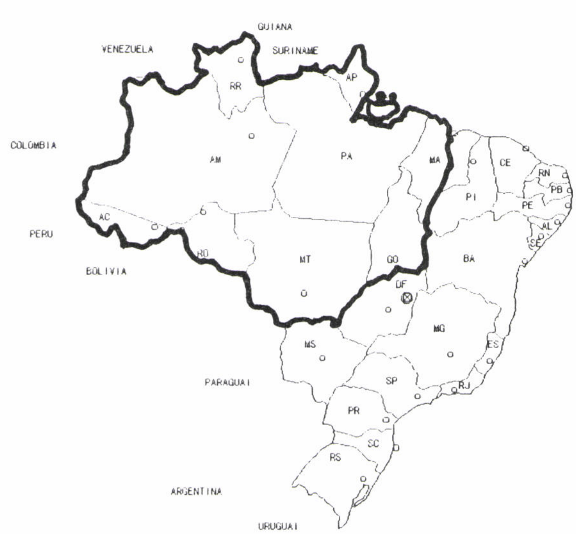

Fig. 2 The nine states of Legal Amazon

STUDY AREA

The field study was carried out in Legal Amazonia (Fig. 2) in August 1997, in the settlement lots administered by INCRA (National Institute for Colonization and Agrarian Reform) Jiparaná of Rondônia State and INPA Study Forest ZF-2, located 90km to the north of Manaus in Amazonas State. Area, population and deforestation rates of Legal Amazonia are shown in Table 1.

LOGGING IN THE BRAZILIAN AMAZON

Amazonian tree species are extremely heterogeneous and the average commercial tree yield is one m^3/ha/year in a natural forest. The forest crown can be seen below the INPA's ZF-2 45m Observation Tower, in the terra firme

Table 1 Deforestation in the Brazilian Amazon States since 1970 (km^2)

States	Area	Population	Deforested area (Aug. 1996)
Acre	153,149.9	483,726	13,742
Amapá	143,453.7	379,479	1,782
Amazonas	1,577,820.2	2,389,279	27,434
Maranhão*	333,365.6	5,222,565	99,338
Mato Grosso	906,806.9	2,235,832	119,141
Pará	1,253,164.5	5,510,849	176,138
Rondônia	238,512.8	1,231,007	48,648
Roraima	225,116.1	247,131	5,361
Tocantins	278,420.7	1,048,642	25,483
Legal Amazonia (Total)	5,109,810.4	18,748,510	517,069

* Only 50% of the state is in Legal Amazonian region.
Source: INPE, 1998 & IBGE, 1998

(upland) forest. However, there are some species with 50-60m heights (Fig. 3). The dominant botanic families in Amazonia are *Leguminosae*, *Lecythidaceae* and *Sapotaceae* in terra firme, and *Myristicaceae* in várzea (periodically flooded plain). The main species of lumber exported from Legal Amazonia in 1994 were *Carapa guianensis*, *Dinizia excelsa*, *Bagassa guianensis*, *Cedrella* spp., *Amburana cearensis*, *Hymenaea courbali*, *Cordia goeldiana*, *Astronium* spp., *Ocotea porosa*, *Tabebuia* spp., *Swietenia macrophylla*, *Bowdichia nitida*, *Cedrelinga catenaeformis* and *Virola surinamensis* (ITTO, 1997). Among these species, mahogany (*Swietenia macrophylla*) or mogno is commercially the most valuable, followed by virola (*Virola surinamensis*). In 1990-1996, 743,840m^3 of mogno was exported from Legal Amazonia (AIMEX, 1997). The main destinations of the Brazilian export timber in 1996 were Europe (45%), North America (40%), Central America and Andean countries.

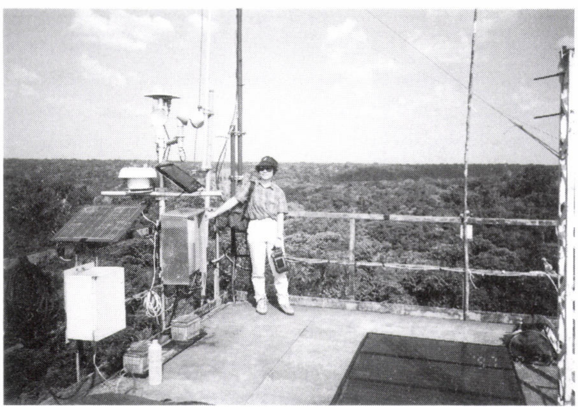

Fig. 3 Amazonian typical "terra firme" rainforest seen from the INPA ZF-2 45m Observation Tower, in Amazonas State. (Picture taken by Dr. Niro Higuchi of INPA, on August 21, 1997)

Tax incentives to carry out the farming projects in Amazonia were eliminated in 1990, following which felling and selective exploitation of timber became more intensive, mainly in southern Pará State (MCT-INPA/DFID, 1997). Demand for Amazonian timber is increasing, not only for the national market, but also for exports. In 1997, Brazilian production of logs was 48,000,000m^3, including 26,000,000m^3 from non-conifers (Amazonian hardwoods).

Most of the profit from Brazilian timber exports comes from paper and pulp production obtained from Eucalyptus in the southern regions. However, finished manufactures are also produced from Amazonian hardwoods (Fig. 4). Usually, they are harvested predatorily from virgin forest. However, some of them are produced from plantations: Teca (*Tectona grandis*), Albizia (*Albzia falcata*), Balsa (*Ochroma pyramidale*), Gmelina (*Gmelina arborea*) and Seringueira (*Hevea brasiliensis*).

Forest production in southeast Asia achieved its peak in the early 1990's after which some of the Asian tropical timber companies stepped up their operations in the Amazon. Philippines and Thailand, big tropical timber exporters in the past, turned to be importers in this decade because of depletion of timber resources in their own countries. The total tropical timber market has been stable in recent years, at an annual average of 136 million m^3.

Timber stocks in the Brazilian Amazonia are estimated to be 50 billion m^3, of which the viable yield may be only 10% of it. Among 4,000 to 5,000 tree species registered by INPA, less than 100 species are absorbed by the international market. An average of 300 species is usually found in a typical stand of one hectare of Amazonian terra

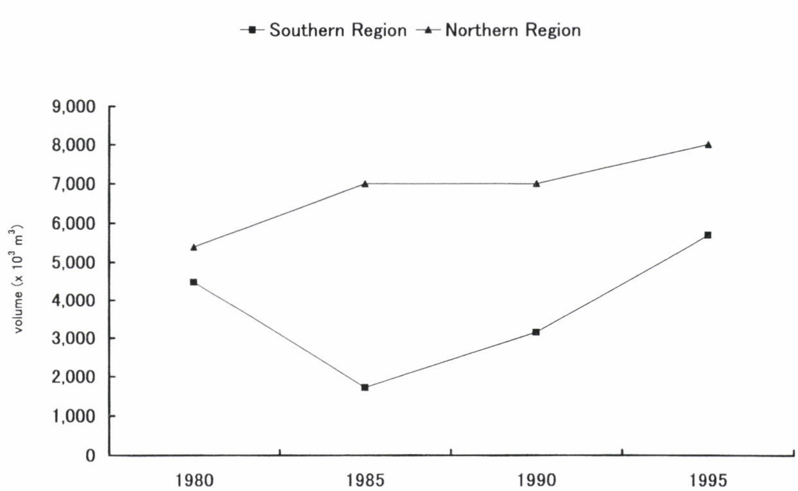

Fig. 4 Brazilian lumber production ($\times 10^3 m^3$)
Source: Brazilian Wood Profile (1994)

firme forest. Exported Amazonian lumber in 1993 comprised mogno (*Swietenia macrophylla*) 14.21%, jatobá (*Hymenaea courbaril* L.) 5.94%, curupixá (*Micropholis venulosa*) 5.76% and cedro (*Cedrella* spp.) 5.02%, totalling 395,272m³. Total Amazonian timber exports, including lumber, veneer, plywood and secondary processed wood products, were 665,663m³ in the same year.

As the Amazon's valuable timber has been exploited without silvicultural treatments over the decades, harvesting stands are continually becoming more distant from the mills. In Rondônia State, the average distance from harvest site to mill is 65.8 km. This figure varies according to the species, and for mills working only with "madeira branca" (less valuable commercial timber for domestic use), the distance is 57.3km, while for those including exportable timber it is 87.9km. For mills working only with export timber, the distance is 161.0km from the base point. This fact makes timber more expensive, affecting the harvesting sites. Forest sites containing mogno are shrinking each year, and loggers are travelling further to obtain it. During the field study, European loggers were often seen advancing south of Rondônia State, as far as Vilhena, due to depletion of that species. In Amazonas and in Pará State, loggers from Malaysia and other countries of southeast Asia were buying vast areas of virgin forest.

In Legal Amazonia, mogno spreads over an area of 1,518,964km², and the standing volume is 18,209,093.9m³. This species was the main Brazilian export timber before the new government regulation in 1990, contributing more than 70% of the total. However, a mogno quota system was introduced, with a harvesting limit of 150,000m³/year, reduced to 70,000m³/year in 1996, when a two-year moratorium was established by the government, due to the scarcity of this species.

In this region, harvesting is usually done with the practice of "correntao". This method disturbs the forest badly because the trees are felled using two bulldozers connected with a thick chain. Also, as mogno trees are usually distributed in widely scattered patches, the bulldozers and harvesting machines not only fell innumerable non-commercial trees and compact the soil, but also disturb the biodiversity of the Amazonian fauna and flora. General deforestation occurs with each mogno harvest.

FOREST MANAGEMENT IN THE BRAZILIAN AMAZON

The rainforests of Legal Amazonia spread over 3,648,000km², and the deforested area up till 1989 totalled approximately 500,000km². The deforestation rate from 1990 to 1995 was 127,720km² (ITTO, 1997).

According to Decree no. 1282 of 19 October 1995, the modern definition of forest management in the Brazilian Amazonia is: Forest administration for obtaining economic and social benefits, respecting the mechanism of ecosystem sustainability. If the forest management is economically viable, ecologically correct and socially just, sustainability is possible. The Brazilian government has been introducing zoning strategies in the states of Legal Amazonia, in order to clearly divide the land-uses for agricultural purposes and protect the fragile rainforest ecosystem. In Rondônia State a zoning strategy was being carried out (MARUYAMA, 1999); however, much improvement is expected to consolidate the division of land-uses.

Jiparaná, an Amazonian typical county created in the middle of Rondônia State for the farming community after felling the forest, can be seen in the imagery of Landsat5 TM Path231 Row067. In this scene, the deforested area was calculated to be 51% (MARUYAMA, 1996). In order to confirm the converted forest into farmlands, TN29, Lot 142 and TN33, Lot 112 were visited. A lot next to TN29, Lot

Fig. 5 Forest burnt a year earlier in INCRA TN33, Lot 112, with only 20 % of remaining forest left, in Jiparana. (Picture taken by the author on August 19, 1997)

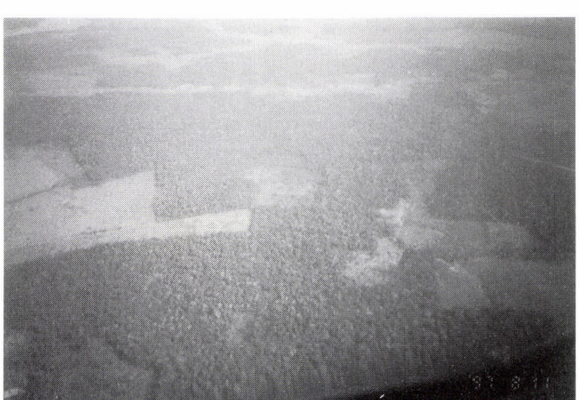

Fig. 6 INCRA settlement in Rondônia State. (Picture taken by the author on August 11, 1997)

Fig. 7 Liana growth in a heavily logged stand of "terra firme" rainforest, at the entrance of Karitiana Village, Rondônia. (Picture taken by the author on August 18, 1997)

Table 2 DBH increment of main commercial tree species of Legal Amazonia

Species	Diameter increment (mm/year)
Andiroba, *Carapa guianensis* Aubl. -*Meliaceae*	6
Tauari, *Couratari* spp. -*Lecythidaceae*	3
Maçaranduba, *Manilkara* spp. -*Sapotaceae*	4
Breu, *Trattinnickia burseraefolia* (Mart.) Willd. -*Burseraceae*	4
Ucuúba-da-terra-firme, *Virola* spp.	6
Freijó-branco, *Cordia goeldiana*	5
Parapará, *Jacaranda copaia* (Aubl.) D. Don. -*Bignoniaceae*	8
Cupiúba, *Goupia glabra* Aubl. -*Goupiaceae*	7

Source: (Silva, 1996)

142, was being burnt and in it there was a plantation of coffee, cacao, rice and cassava, an area burnt a year before, and 20% was remnant virgin forest (Fig. 5). The colonist of TN33, Lot 112 burned 100% of his forest and there was only converted farmland. There were very few lots respecting the law within INCRA's area, that is, retaining at least 50% (1970's rule) of the forest (Fig. 6).

Usually, soils become impoverished after two or three years of utilization for raising crops in the Amazon, and are soon abandoned or converted into pasture. That was the reason why there were so many pastures and abandoned lands in Rondônia State. Also, many of the colonists had gone to work in cassiterite mining, leaving their fam-

Fig. 8 Luxurious palm species growing in the INPA ZF-2 Study Forest in a logged stand. (Picture taken by the author on August 21, 1997)

Table 3 Growth of Amazonian commercial tree species

Vernacular name	Botanical name/ Family	Height (m) First 2 years after seedling	Height (m) &DBH (cm) after 25-35 years
Angelim vermelho	*Dinizia excelsa* Ducke/*Leguminosae-Mimosoideae*		50-60/100-180
Castanha do Pará	*Bertholletia excelsa* H.B.K. /*Lecythidaceae*		30-60/100-180
Pequia	*Caryocar villosum* (Aubl.) Pers/*Caryocaraceae*		20-45/90-180
Paricá grande	*Schizolobium amazonicum* Huber ex Ducke/ *Leguminosae-Caesalpinoideae*		40/80
Sumaúma	*Ceiba pentandra* (L.) Gaertn. /*Bombacaceae*	5.0-6.0	30-40/88
Pau de balsa	*Ochroma pyramidale* (Cav. Ex Lam.) Urb./*Bombacaceae*	5.0	10-30/60-90
Parapará	*Jacaranda copaia* (Aubl.) Don. /*Bignoniaceae*	4.0-5.0	20-30/60-90
Mogno	*Swietenia macrophylla* King. /*Meliaceae*	4.0	25-35/50-80
Morototó	*Didymopanax morototonii* (Aubl.) Dcne. *et* Planch. /*Araliaceae*	3.0-4.0	20-30/60-90
Cedro	*Cedrela fissilis* Vell. /*Meliaceae*	3.0-4.0	20-35/60-90
Ipê-roxo	*Tabebuia impetiginosa* (Mart.) Standl. /*Bignoniaceae*	3.5	20-30/60-90
Virola	*Virola surinamensis* (Rol.) Warb./*Myristicaceae*	2.5-3.0	25-35/60-90
Jatobá	*Hymenaea courbaril* L. var. *stilbocarpa*/ *Leguminosae-Caesalpinoideae*		15-25/100

Source: Lorenzi, 1992

ilies on their impoverished land. The puddles formed after deforestation, served as an excellent breeding ground for mosquitoes, and led to proliferation of malaria. Diseases caused by malaria have increased five-fold since 1970, when the colonization project began in that region. Malaria and poverty are the main barriers to carrying out silvicultural treatment in the remaining forests. According to the zoning strategy, 25% of the land in Rondônia was destined for rainforest conservation.

Forest harvesting directly degrades the forest if it is not properly managed. Logging in the Brazilian Amazon currently damages 60% of the vegetation cover or it destroys an average of two cubic meters of trees for each cubic meter of timber. The effect of logging lasts for 3-4 years in a heavily affected stand, promoting the growth of light-demanding commercial species. Crown illumination has a strong influence on tree growth, benefiting light-demanding species soon after logging, and lianas take the place of shade-tolerant species in heavily logged stands, in the terra firme forest of Amazonia (Fig. 7), followed by palm species (Fig. 8). Management efficiency is reflected at the end of the cutting cycle (an average of 25-35 years in a typical Amazon rainforest), and liana removal within a year before harvesting is essential for the exploitation of commercial trees, to protect the remaining young species from wasteful felling.

The study forest ZF-2 of INPA was established with six stands of 4 ha each: natural forest as a control, and others with cutting rates of 70%, 60%, 50%, 40% and 30%. Researchers periodically monitored the stands in order to measure the volume, DBH increment and mortality rate of trees for each case. The growth increments of Amazonian commercial species are shown in Table 2, and these data should be taken into account by the foresters in setting the length of the cutting cycle. Generally speaking, Amazonian commercial species grow very quickly, reaching 3m-9m height in the first two years. In the case of some potentially commercial species, the DBH increment is more than 2cm per year. More potential species should be incorporated into commercial species, thus avoiding over-exploitation of slow-growing species.

DISCUSSION AND CONCLUSION

Deforestation from logging was insignificant until 1990 in Legal Amazonia. However, it became an important source of income for the local people in the late 1990's. According to Brazilian forestry regulations, commercial size is considered as being DBH>=45cm. However, in Legal Amazonia, some of the local people cut valuable trees whenever and wherever they can, trading illegally with clandestine mills. Ignorance, poverty and greediness are the main barriers to putting sustainability into practice.

Sustainable management of tropical forests is economically viable, bringing enrichment of the explored area without losing the biodiversity. In 1998, there were 2,610 plans for sustainable management in that region; however, quite a few projects were properly monitored due to lack of experts and surveyors in the forests (Fig. 9). In Amazonas State, the biggest state of Legal Amazonia with 1,577,820.2km², there were only 19 inspectors of IBAMA (Institute for Environment and Renewable Natural Resources) to watch for illegal logging in 1996. In the Mamiraua Forest Reserve of the same state, an average of 7,000 valuable trees are cut illegally each year. Brazil is an official member of ITTO (International Tropical Timber Organization), but the actual situation does not conform to the main goal of ITTO-2000: all tropical timber exports should originate from sustained forests by 2000. Considering the 3,648,000km² of Amazonian rainforest, legally managed forests are limited to 26km². On the other hand, private companies as well as big ranchers and farmers have been making efforts at silvicultural treatment since 1993. In Legal Amazonia, sustainable management of forests was officially introduced in 1992. However, it has not yet been put into practice in Roraima, according to IBAMA.

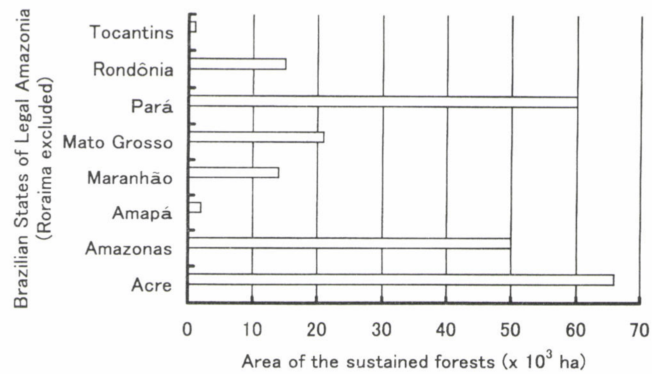

Fig. 9 Area destined for sustained forests in Legal Amazonia (Source: Zachow, 1998)

If proper forest management were enforced as a condition for granting logging permits by IBAMA, not only should the deforestation rate decrease, permitting sustainability of the ecosystem, but also it should bring economic and social benefits to local people. For that purpose, the Brazilian Native Forest Cutting Plan is encouraging the logging mills to plant at least four seedlings of native trees per hectare after logging. Local people should be technically and economically assisted by the government to achieve sustainability of their forests.

Silviculture is a very fruitful method for sustainability and for wood productivity; however, it does not result in the development of climax forest. It took hundreds and thousands of years to form the original forest. Zoning strategies are important in that sense, enabling natural climax forest to remain as it is, clearly distinguishing harvesting forest from conservation forest.

The field study has shown the grave consequences of the anthropogenic factor induced in the fragile ecosystem of the Brazilian Amazon. Of all the measures to be taken by the government, infrastructure consolidation is the most urgent need at present, in order to radicate the farmers in their converted lands and to diminish natural forest cutting for fuel wood.

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