ISSN 1341-562X

JOURNAL OF FOREST PLANNING

Vol. 9 No. 1

April, 2003

Japan Society of Forest Planning

JOURNAL OF FOREST PLANNING

Submission of Manuscripts

Manuscripts should be submitted to following Editorial Office.

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Subscription Information

JOURNAL OF FOREST PLANNING is pubished halfyearly. The subscription for 2002 is 5,000 yen and the single issue price is 2,500 yen. Subscription orders can be sent to following office.

Toho Shoten
106 NKB Azeria Buillding, 7-7 Shinogawa-cho
Shinjuku-ku, Tokyo 162-0814, Japan
Phone: +81-3-3269-2131, Fax: +81-3-3269-8655

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

JOURNAL OF

FOREST PLANNING

Vol.9, No.1 April, 2003

Japan Society of Forest Planning

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Article

Studies on the Suburban Forests in China (I) - Present Situation, Issues and Challenges in the Metropolises[*1] -

Qingwei Guan[*2], Lianshun Zou[*3], Yuji Uozumi[*4], Tatsuhito Ueki[*4] and Hexin Wang[*4]

ABSTRACT

In the past quarter century, Chinese economy has been developed at very fast pace. The rapid economic development caused many problems. One of the problems is that the urban environment is getting worse everyday. Since the living standard of people has been improved steadily due to the economic growth, the urban residents have growing demand for varieties of amenities. In order to gain better understanding of the present situation of suburban forests at the national level, and identify the challenges that Chinese government and foresters may face in dealing with issues on suburban forests, 8 Chinese metropolises including Beijing were studied. The results showed a growing trend of urban sprawl that suburban forests were converted to urban use along with the urbanization and industrialization, which also happened in other nations around the world in a similar fashion. However, the forest area and coverage have been increasing in the studied metropolises since 1979, because of pass of new laws and regulations, and large-scale plantation each year. It is very different from Japan and other developed countries. At the present time, the forest coverage still remains low. Also, artificial forest area is larger than that of natural forest. Percentages of young stands are much higher than mature stands. The distribution of age class is unbalanced. The area of timber forest is much greater than that of shelter forest and other designation of forest. Today, both of timber production and environmental services of the suburban forests are becoming critical issues. The major issues are that metropolises are not abundant in forest resources and forest quality is poor. How to match the percentage of the shelter forest and timber forest and manage young stands become big challenges for Chinese government and foresters. It is essential to increase plantation and maintain sustainable management. It is imperative to develop a policy framework to conserve the suburban forests.

Keywords: China, management, metropolis, suburban forest, urbanization

INTRODUCTION

Chinese economy has been growing at a very fast pace since the economic reform began in 1979. Meanwhile, series of environmental problems surged along with the economic development. The area of soil erosion has reached 3,670 thousand km^2, which nearly accounts for 38.2% land of China. The area of desert is around 1,560 thousand km^2, which almost equals to all the farm land of China. It also expanded at the speed of 2,100km^2 per year (Li, 1996). Another problem is the water supply, especially in the metropolises. Over half of the cities in China have encountered water supply shortage for both industrial and civilian usage, especially in the Northern metropolises. The water supply shortage has become an important factor that affects the economic growth (Qian *et al.*, 2001). On the other hand, the living standard of people has been improved gradually due to the economic development. The people have strong demand for the amenity. It has become more imperative for the suburban forests to play more important roles than it has ever been before, in dealing with the environmental issues and meeting the demand for the amenity.

The studies of suburban forests began about 10 years ago in China. But most of the researches were focused on the

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concept, content and function of the suburban forests. They are still at an early stage (Wang *et al.*, 1997). Little research on the basic information of the suburban forests nationwide has been conducted yet. It is necessary to study the present situation, issues and challenges of the suburban forests at national level in China.

OBJECTIVES AND METHODOLOGY

The objective of this paper is to gain a better understanding of the present situation of suburban forests at the national level, provide a general overview of some of the issues and identify the challenges that Chinese government and foresters may face in dealing with the issues on suburban forests in China.

With a total area of 960 million ha and a population of 1,295 million people, China is one of the largest and the most populous countries in the world. Currently, in China, there are 667 cities distributed among 32 provinces, municipalities, autonomous regions and special administrative regions (Hong Kong and Macao). According to the criteria formulated by the central government, the cities can be classified into 5 categories based on their non-agricultural population in the urban area. The 5 categories are metropolis with over 2 million non-agricultural population in the urban area, super large city with one million to 2 million, large city with 500 thousand to one million, middle scale city with 200 thousand to 500 thousand, and small scale city with below 200 thousand. Currently, there are 13 metropolises in China including Beijing, Shanghai, Tianjin, Chongqing, Shenyang, Dalian, Guangzhou and Xi'an. Beijing, Shanghai, Tianjin and Chongqing are 4 municipalities in China. Shenyang is the largest city in Northeast of China, it is the economic, cultural, political center in the Northeast. Dalian is the biggest city around the Pacific Ocean, is very famous with its high level of greenland in China. Guangzhou and Xi'an are the 2 largest cities in Southeast and Northwest respectively. They are the political, economic and cultural center in Southeastern and Northwestern regions also. Considering the economic development level, political status, cultural background, population and location of the metropolises, they were selected as study sites.

The forest cover, forest type, composition of age class and conversion of suburban forests were investigated in the 8 metropolises. The location of 8 metropolises can been seen in Fig.1.

In China, five National Forest Resources Surveys were conducted from 1973 to 1998 in every province about once every five years. By comparing the data from the 5 National Forest Resources Surveys, the present situation of suburban forests was studied. Based on the recent key documents and information collected from field survey and observation, the issues on suburban forests and challenges that government and foresters face were discussed.

Fig. 1 Study sites distribution in China

RESULTS

According to Chinese Forest Law, the forests can be divided into timber forest, shelter forest, economic forest, fuel forest and special use forest with different management purposes. The timber forest is mainly used to produce timber. The shelter forest is for combating desert and conserving water resources etc. The economic forest is used to produce fruit, vegetable oil, condiment etc. The fuel forest is mainly used to provide fuel for farmers. The special use forest is for the special purposes, such as education and conservation of cultural heritage. Based on the statistical criteria of National Forest Resources Survey, forest cover includes the area of stand, economic forest and bamboo forest. The stand consists of timber forest, shelter forest, fuel forest and special use forest, does not include economic forest.

Forest Cover

According to the 5th National Forest Resources Survey data, the total forest cover is 3,231 thousand ha in the 8 metropolises, the average forest coverage is 20.1%, which is highter than 16.6% of the national average forest coverage. The forest area per capita is only 0.036ha, which is only 28.1% of the national average. The forest stock per capita is 1.258m^3, which merely is 13.9% of the national average. The average stock per ha is 34.7m^3, which only accounts for 48.9% of the national average level. Besides the forest quality in the 8 metropolises is very poor. The average rate of artificial forest is 72.1% in the 8 metropolises, which is higher than the national average level shown on Table 1.

Table 1. The present situation of forest resources in the metropolises

District	Area (1,000 ha)	Population (1,000 person)	Forest area (1,000 ha)	Forest coverage (%)	Potential forest coverage (%)	Forest area per capita (ha)
China	9,602,700	1,241,730	158,940	16.6	27.4	0.128
Beijing	1,780	12,500	337	18.9	52.2	0.027
Shanghai	596	10,900	22	3.7	3.9	0.002
Tianjin	1,150	9,533	86	7.5	11.6	0.009
Chongqing	8,230	30,597	1,550	18.8	40.1	0.051
Shenyang	1,290	6,749	134	10.4	14.7	0.020
Dalian	1,300	5,432	431	33.2	41.2	0.079
Guangzhou	750	6,741	294	39.3	41.8	0.044
Xi'an	1,000	6,682	377	37.8	50.5	0.056
Urban average	16,096	89,135	3,231	20.1	27.5	0.036

Sources: SFAC.,1994-1998, Forest Resources Survey.

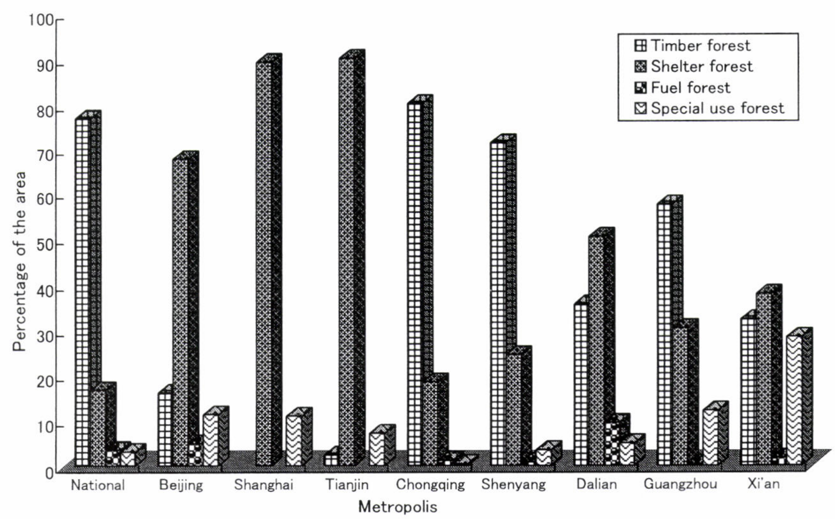

Fig. 2 The percentage of stand area between forest type in the metropolises
Source: SFAC., 2000, Forest Resources Survey (1994-1998)

Forest Type

The 5th National Forest Resources Survey showed that total stand area reached 2,467 thousand ha including 1,492 thousand ha of timber forest in the 8 metropolises, which was greater than the other forest types. It made up 60.5% of the total stand area, which was lower than 76.9% of the national average level. Shelter forest area reached 756 thousand ha. It covered 30.7% of the total stand area in the metropolitan area, which was greater than the national average level shown in the Fig 2. The ratios of the fuel forest and special use forest were low compared to the shelter forest and timber forest. However, it also can be seen that the ratios of the forest type are different in the different city. In Beijing, Shanghai, Tianjin and Dalian, the ratios of the shelter forest are higher than the other cities.

Forest Age

The results of the 5th National Forest Resources Survey showed that area and volume of the stand were 2,467 thousand ha and 112.1 million m^3 including 844 thousand ha and 14.0 million m^3 of 1-10 year class, which made up 34.2% and 12.5% of the stand in the 8 metropolises. The area and volume of 11-20 year class were 898 thousand ha and 35.5 million m^3, which accounted for 36.4% and 31.7% of the stand respectively. The area and volume of the 21-30 year were 379 thousand ha and 27.8 million m^3, making up 15.4% and 24.8% of the stand respectively. Both the 31-40 and 41-50 year classes showed much lower percentage of area and volume than the 21-30 and younger classes, as shown in Fig 3.

DISCUSSION

Forest Cover and Sustainable Management

Based on the data of the Forest Resources Surveys from 1977 to 1998, the forest area and forest coverage in the metropolises have been increasing (Table. 2), since the rapid Chinese economic development began. It is very different from Japan and other developed countries in which decreasing trend of forest area could be seen clearly due to the rapid economic development. It is because the forest coverage was very low in China decades ago. Another reason is that the plantation has been done at large scale each year compared to the developed countries.

Although the forest area and coverage have been increasing in the metropolises in recent years, they are still at a low level. According to the National Ecological Development Plan passed by the Chinese State Council in 1998, the projecting national forest coverage is 27%. The current forest coverage in the 8 metropolises is only 20.1%, which is much lower than the national target, though it is highter than 16.6% of national average level. However, there are about 1.6 million ha of land need to be planted in the 8 studied metropolises (State Forestry Administration of China (SFAC), 2000). Speeding up the plantation seems to be the only possible solution to increase the forest area. On the other hand, forest stock is very low and artificial forest ratio is high in the 8 metropolises. Therefore, the number one issue is the low quantity of forest resources and poor forest quality. How to increase forest coverage and improve forest quality becomes a major challenge for Chinese foresters and the government.

Another issue is that the ratios of the forest type were unbalanced. Based on the data of Forest Resources Survey, the ratio of timber forests is much higher than that of shelter forest, and the ratios of fuel forest and special use forest are very low. In recent years, the more and more publics began to believe that the forest could improve the environmental quality, especially in the metropolises. Residents have strong demand of forest for the water resources conservation, air

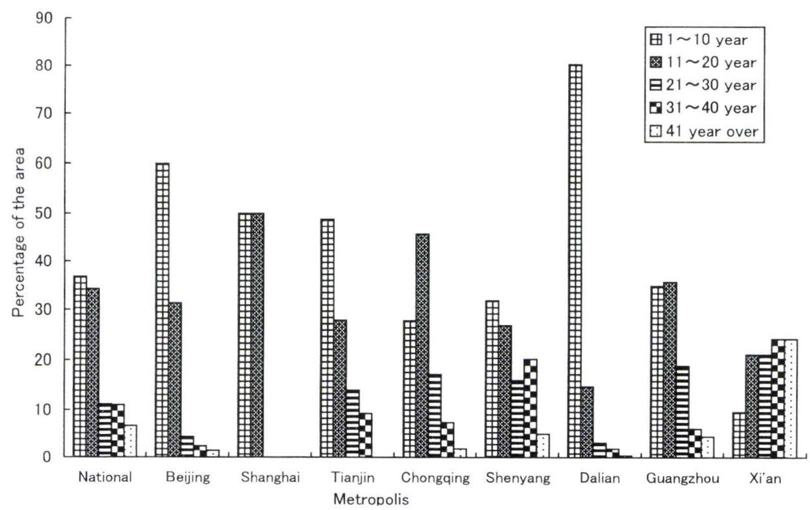

Fig. 3 The percentage of stand area between age class in the metropolises
Source: SFAC., 2000, Forest Resources Survey (1994-1998)

Table 2. The change of forest area and coverage in the metropolises

(Unit: 10 thousand ha, %)

Period	Beijing			Shanghai			Tianjin		
	City area	Fores area	Forest coverage	City area	Forest area	Forest coverage	City area	Forest area	Forest coverage
1977-1981	178	14.4	8.1	60	0.8	1.3	115	3.0	2.6
1984-1988	178	21.5	12.1	60	0.9	1.5	115	6.2	5.4
1989-1993	178	26.7	15.0	60	1.5	2.5	115	8.6	7.5
1994-1998	178	33.7	18.9	60	2.2	3.7	115	8.6	7.5

Source: SFAC., 1977-1998, Forest Resources Survey purification and recreation. The shelter forest area was expected to increase intensively. On the other hand, the total wood consumption increased from 196 million m^3 to 260 million m^3 in 1992, along with the rapid growth of the GDP. It is predictable that wood consumption will keep the increasing trend caused by the economic development (LI, 1996). However, as a developing country, it was impossible for the government to spend so much money on wood imports to meet the national demand. How to match the percentage of shelter forest and timber forest will become another big challenge for the government and foresters.

Because the area and stock of young stand are much higher than mature forest, the forest resources can't fully maintain their environmental services at current capacity. The third issue is the unbalance of composition of forest age. How to maintain sustainable management of young stand is becoming another major challenge for Chinese government and foresters.

Urbanization and Forest Conversion

In the past several decades, a tremendous amount of attention has been paid to the environmental endangerment caused by the conversion of forestland to urban use, especially in the developed countries. According to the National Agricultural Land Study of U.S.A., between 1967 and 1975, 650,000ha of forestland, about 81,250ha per year, were converted to urban, transportation, or water uses (GORDON, 1984). A typical example of sprawl is Atlanta, GA in the United States. The Land Satellite images of the Atlanta region clearly showed the changes in land cover from 1972 to 1993 and demonstrated the rapid sprawling growth of Atlanta Metro Region over the past 25 years. The sprawl not only occurred on the edges of large metropolitan area, but also occurred on the edges of small towns and communities experiencing growth around the Southeast. The studies had showed that a 1% increase in population growth resulted in a 10% to 20% growth in land consumption (AMERICAN FORESTS ATLANTA, GA. Data Service, 1993). In Japan, during the 1960's and 1970's rapid economic development, many forestlands were converted into industrial lands, recreational lands. In Yokohama city, 3,700ha of the forestlands were urbanized during that period (UOZUMI, 1995).

In recent years, the GDP of China had been increased approximately from 42.6 billion USD in 1978 to 963.7 billion USD in 1999 (Fig.4). The GDP per capita had increased about 20 times over the past 20 years, and household consumption increased 4 times from 1978 to 1999. The average rate of economic growth was over 7% in each year, which is very high in the world (NATIONAL BUREAU OF STATISTICS OF CHINA (NBSC), 2000). However, the rapid economic development also caused many problems. One problem was urbanization, which caused forest conversion, similar to other countries in the world.

Urbanization in China, the largest developing country in the world, has been observed for the last 20 years. First of all, the total amount of cities has been increasing. In 1978, there were only 193 cities in China. By 1991 and 2000, the total amount of cities reached 479 and 667 respectively. Among the cities, 37 cities with the non-agricultural population over 1 million mainly located in the eastern region around the Pacific Ocean. There are 365 cities with non-agricultural population less than 200,000, which are increasing rapidly (NBSC. 2000). Secondly, the urban population proportion of China has been increasing continuously from 17.9% in 1978 to 30.9% in 1999. On the contrary, the rural population proportion has been decreasing from 82.1% in 1978 to 60.1% in 1999 (Fig.5). Thirdly, the urban population density increased from 262 persons/km^2

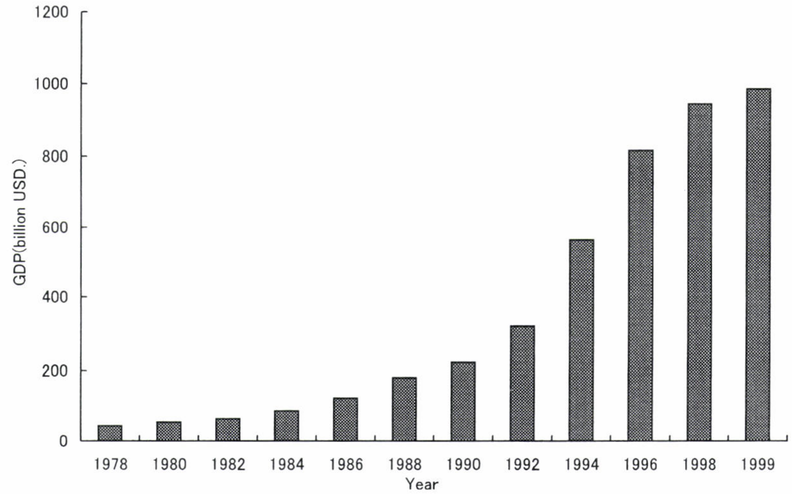

Fig. 4 The change of GDP in China
Source: NBSC.,2000, China Statistical Yearbook

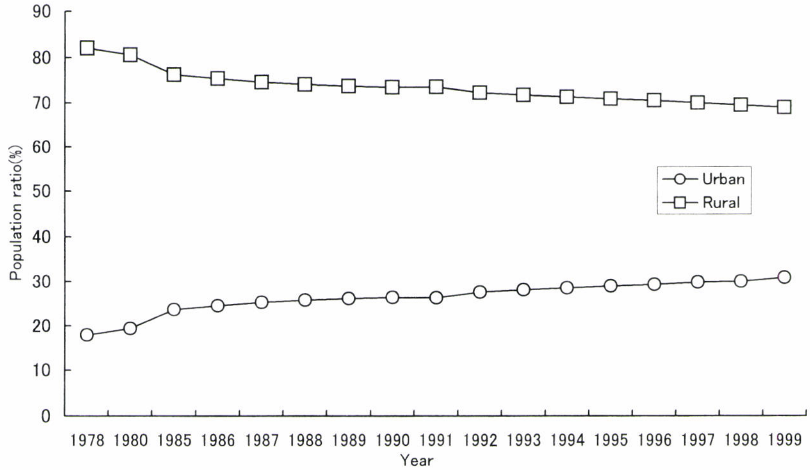

Fig. 5 The change of ratio between urban and rural population
Source: NBSC., 2000,Chinese Statistical Yearbook

in 1985 to 462 persons/km^2 in 1999 (NBSC. 2000).

According to the Third National Forest Resources Survey (1984-1988), 23.3 million ha of forestland had been converted to non-forest land from 1981 to 1988 while Chinese economy had been developed at fast pace. It averaged 2.9 million ha per year, 6 times more compared with the conversion area of farmland in the same period. The forestland has been changing into other uses every year as shown in Table 3. In recent years, the converting trend was controlled at some extent, because the Chinese government took a series of measure.

Urbanization is an inevitable phenomenon accompanying with rapid economic growth in the world. It causes the conversion of forests in the suburban district and some other negative impacts. Therefore the urbanization is a serious threat to the suburban forests. How to alleviate the conversion of suburban forests is another challenge for Chinese government and foresters.

Table 3. The conversion area of forest in the metropolises

(Unit: ha)

District	1994	1995	1996	1997	1998
China	73,778.9	49,995.1	30,454.7	7,144.0	7,929.3
Beijing	166.3	105.7	78.6	9.9	1.0
Shanghai	8.7	0.2	1.6	0.7	0.0
Tianjin	4.2	67	33.3	14.7	3.6
Chongqing	-	-	-	135.2	54.3

Source: SFAC.,1995 – 2000,Chinese Forestry Yearbook

Laws and Regulations

In order to increase and preserve the forest resource in the suburban area, a lot of laws and regulations (Table 4) have been drafted in China since 1979.

For controlling the conversion of the suburban land, the Land Expropriation Regulation was passed in 1982 by the State Council of China. According to the regulation, saving land is the national fundamental policy. The land expropriation should be controlled strictly. During the construction, the environment should be protected completely. If the forestland was taken for development, the compensation should be paid immediately, and the site-inspection is mandatory. If the required forestland was over 30 ha, it needs to be approved by the State Council of China.

The Standing Committee of the National People's Congress promulgated the Forest Law (draft) in 1979. Then, it was amended in 1998 for coping with the new situation. Based on the Forest Law, forest resources belong to the country and public. The government has encouraged forest planting and limited wood production. Forest cutting has to be approved by the government. Shelter forest and special use forest cannot be managed by clear- cutting.

To meet the needs of the forest recreation for the civilian, State Forestry Administration of China drafted the Forest Park Regulation in 1994. According to the regulation, any construction in a forest park must harmonize with landscape. Construction is not permitted to make in the central part of landscape. Expropriation of the forestland must get the approval from the State Forestry Administration.

In order to increase the green area in urban and suburban districts, the Chinese State Council created the City Green-Land Code in 1992. Based on the Code, the green land construction should be brought into line with the state plan. The green area must be well matched with the population and urban area where the real estate is planned to build. It is not permitted to convert green-land to other use. Any kind of tree cutting has to be approved by the city government.

Table 4. Laws and regulations related to the suburban forest

Year	Law and regulation	Drawn up by
1979	Forest Law (draft)	SCNPC.
1981	Regulation of Conserving and Developing Forest	SCC.
1982	Land Expropriation Regulation	SCC.
1984	Forest Law	SCNPC.
1985	Regulation of Forest Cutting (draft)	SFAC.
1987	Forest Regeneration Code	SCC.
1988	Wild Animal Conservation Code	SCNPC.
1991	Soil and Water Conservation Code	SCNPC.
1992	City Green-Land Code	SCC.
1994	Forest Park Regulation	SFAC.
1995	Regulation of Forest Cutting	SFAC.
1996	Forest Classified Management Code	SFAC.
1998	Forest Law (amendment)	SCNPC.
1999	Regulation of Natural Forest Conservation	SFAC.
2001	Desert Controlling Law	SCNPC.

Note: SCNPC.: The Standing Committee of the National People' Congress
SCC.: State Council of the China
SFAC.: State Forestry Administration of the China

Although a lot of new laws and regulations have been passed to protect the suburban forest, some suburban forests still have been converted to the other use in some region because of the regional economic development and other local interests. It is necessary to develop a policy framework to conserve the suburban forests.

CONCLUSION

Accompanying the economic development and urbanization, urban sprawl is growing in the studied metropolises. Some suburban forests were converted for other uses. It is important to set up certain laws and regulations to prevent conversion of the suburban forest. Although the forest area has been increasing since 1980's due to the large-scale plantation every year, the forest coverage still remains low currently. Also, artificial forest area is greater than that of natural forest. Imbalance of the distribution of age class and forest type needs to be adjusted in the studied metropolises. Based on the current situation, national economic development trend, and diversity of the people's needs with regard to suburban forests, it is essential to increase the plantation and to maintain sustainable management, especially for the young stand.

ACKNOWLEDGEMENTS

The authors gratefully thank Mr. Liguo Li of Liaoning Forestry Department, China for his support of the data collection.

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*The titles are tentative translations from original Chinese and Japanese titles by the authors of this paper

(Received 26 February 2002)
(Accepted 14 November 2002)

Article

Studies on the Suburban Forests in China (II) - A Case Study of Forest for Water Conservation in Shenyang*1 -

Qingwei Guan*2, Liguo Li*3, Qinglin Zhong*4, Yuji Uozumi*5, Tatsuhito Ueki*5 and Hexin Wang*5

ABSTRACT

China, as one of the biggest developing country in the world, is facing many environmental problems accompanying with the rapid economic development and increasing population. The water supply shortage is one of the most serious problems. The total water resource is about 2,800 billion m^3, and water resource per capita is 2,200m^3 in China. It only makes up a quarter of the world average level and half of the Japan. Water problems in the urban areas are more serious than in the rural areas. Now, two thirds of the cities are experiencing moderate to high water shortage. The water resources that can be used have become less and worse than before. The quantity and quality of water resources have become key factors that affect the economic development and people's life in China, especially in the urban areas in recent years. To control flood and provide water for the industry, agriculture and residents, a lot of dams and water conservation projects have been built in China in past several decades. However, the water problems have not been put to an end yet. To increase quantity and improve the quality of the water resources, plantation, as a major measure, has been done in the watersheds of China since 1980's. Up to now, there are many researches about forest for water conservation in large valleys. However, there is a little research about forest for water conservation in metropolises. The goal of this paper is to gain a better understanding of the present situation and issues of the forest for water conservation in metropolises. Shenyang, one of the biggest cities in northeastern China, was investigated. The results showed that the percentage of forest for water conservation is only 7.7%, lower than the percentage of timber forest in Hunhe watershed, which provides surface water resources for the city of Shenyang, which is much lower than the percentage of forest for water conservation in Japan. Its forest age is very young. 85% of the stand area of forest for water conservation is below 40 years old. Also, its stand volume is low. In order to increase the forest area for water conservation and improve its quality, transferring the timber forest into the forest for water conservation by management of the long-term cutting was recommended. It was suggested that the approach of Closing Mountain to Regenerate Forest, which has low cost and better effect, should be popularized in the Hunhe watershed.
Keywords: China, forest for water conservation, Hunhe watershed, metropolis

INTRODUCTION

The comprehensive assessment of the freshwater resources of the world shows that about one third of the world population lives in countries that are experiencing moderate-to-high water stress and by the year 2025 as much as two thirds of the world's population could be living under similar level of water stress. The implications for developing countries are evident from the fact that three quarters of the population living under conditions of moderate-to high water stress amounting to 26% of the total world population is located in low to lower middle income countries (Secretary General of United Nations, 1998).

*1 Portions of this paper were presented at the 113th Annual Meeting of the Japanese Forestry Society.
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China, as one of the biggest developing countries in the world, is experiencing serious water stress now. According to the assessment of the water resources in China, the total water resource is about 2,800 billion m^3, and water resources per capita are 2,200m^3. It only makes up a quarter of the average level of the world, half of the Japan. (QIAN and ZHANG, 2001). The quality of the surface water and underground water are very poor, because of the various degrees of pollution. The silt in the Huanghe River is the highest in the world. (MINISTRY OF WATER RESOURCES OF CHINA, 2001).

Water problems in the urban areas are more serious than the rural areas in China. Two thirds of the cities are facing water supply shortage. The United Nation recognized Shanghai, the biggest city in China, as one of the most serious water supply shortage cities in the world. In Beijing, water resources per capita are only 300m^3. Water crisis has occurred several times since 1980's (WATER RESOURCES DEPARTMENT OF BEIJING, 2001). The quantity and quality of water resources have become key factors that affect economic development and people's living in China.

A lot of dams and other water conservation projects have been built to increase water resources in the past decades, such as Sanxia Dam and the Project of Transferring Southern Water to North, which are giant projects in China and will take hundreds billion RMB (Chinese Yuan). However, at present, accompanying with the rapid economic and population growth, the water resources that can be used have become less and worse than before (QIAN and ZHANG, 2001). Also, it has been recognized that water problems cannot be put to an end once for all by the dam only.

In order to increase quantity and improve quality of water resources, many ecological projects that took plantation as a major measure, have been working in large watersheds in China since 1980's. Up till now, there are many researches related to the forest for water conservation in Yangtze and Huanghe watersheds etc. (YU and YU, 2001), but there is little research about water conservation forest in metropolises. This article aims to gain a better understanding of the present situation and issues of the forest for water conservation in metropolises. Shenyang, the biggest city in northeastern China, was investigated.

STUDY SITES AND METHOD

Shenyang is the capital of Liaoning province and the fifth largest city in China and it is located in northeastern China. It governs Shenhe, Heping, Tiexi, Huanggu, and Dadong 5 districts that are in the urban areas, Yuhong, Shujiatun, Dongling, and Xinchengzi 4 districts in suburban areas and Xinmin, Liaozhong, Kangping, and Faku 4 counties in rural areas. The total land area of Shenyang is 12,980 km^2 and 3,495 km^2 in urban areas. Most of its areas are plains. Mountains and hills are centered in Shujiatun, Dongling and Xinchengzi districts located in its southeastern portion. The total population in 1999 was 6.8 million including 4.8 million urban people. The annual average precipitation in Shenyang is 561mm, making it an arid or semi-arid climate zone. Liaohe River, Hunhe River and Xiushuihe River run across Shenyang. The Dahuofang dam that supplies over 50% of water resources to Shenyang is in the upper reaches of Hunhe watershed. It is 55km away to the east of Shenyang, located in Fushun city of Liaoning province (Fig. 1).

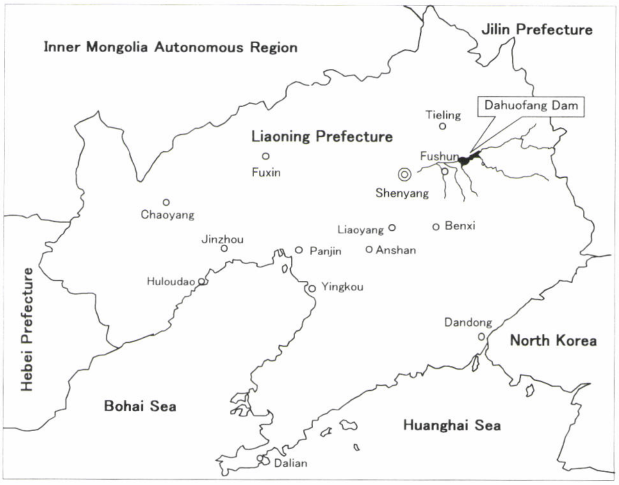

Fig. 1 The map of the investigation site

According to the Construction Planning of the Forest for Water Conservation in Liaoning province, the construction content of the forest for water conservation includes 32 districts (counties) of 7 cities. However, the content of forest for water conservation for Shenyang city was not designated in the planning. Considering that the surface water resources of Shenyang mainly come from Dahuofang dam, the content of the forest for water conservation of Shenyang should include Shuncheng, Fushun, Xinbin, and Qingyuan 4 counties (district) of Fushun city that are located in the upper reaches of Hunhe watershed, and Shujiatun, Dongling, and Xinchengzi 3 districts of Shenyang city.

Based on the Forest Resources Survey data and development planning of forest for water conservation in Liaoning province, the present situation of forest for water conservation in Shenyang was analyzed. Considering the water consumption in Shenyang and economic status of the counties (districts) in the watershed, low cost and effective management of forest for water conservation were discussed.

RESULTS AND DISCUSSION

A Short History of Forest for Water Conservation

The construction of forest for water conservation in Shenyang began in 1980's followed by the construction of shelter forest in the northeastern, northwestern, and north of

China. Because water crisis occurred in the city group where Shenyang was taken as center in 1986, the government took more attention to the construction of forest for water conservation than before. Since 1987, 20 million RMB was invested by the government for plantation at large scale in eastern Liaoning province. In the following projects, Complex Forest Development in the Eastern Mountain of Shenyang in 1989, Comprehensive Agricultural Development in the Eastern Mountain of Liaoning Province in 1990, the Project of Shelter Forest in the Liaohe Watershed in 1994, and the Ecological Demonstration Region Establishment in Sujiatun district and Xinbin county, which are located in the Hunhe watershed in 1995, the forest for water conservation has been planted. Up to now, the forest area for water conservation has reached 55 thousand ha in Hunhe watershed (Forestry Department of Liaoning Province, 1997; Forest Bureau of Shenyang, 1998).

Current Situation and Issues of the Forest for Water Conservation

According to the statistical criteria of National Forest Resources Survey, forest area includes the area of stand, economic forest and bamboo forest. The stand consists of timber forest, shelter forest, fuel forest and special use forest, does not include economic forest and bamboo forest.

In China, shelter forests refer to those that protect crops, combat desert, conserve water etc. The shelter forests in Hunhe watershed only serve the purpose of water conservation, thus they are considered as forests for water conservation.

Based on the Forest Resources Survey data of Liaoning province in 1998, the total forest area was 714 thousand ha including 608 thousand stand area, and the forest coverage reached 52.2% in Hunhe watershed. The stand area for water conservation was 55 thousand ha, including 21 thousand ha of artificial forest and 34 thousand ha of secondary forest. All of the artificial forest was pure even-aged stand, and the stand volume amounted to 105m^3/ha. It was only one third of the average volume of Japanese larch timber forest aged at 30 years old located at middle productivity class in Nagano province, Japan. The stand volume of secondary forest was 67m^3/ha. It was close to the standard of poor forest. The stand area for water conservation was only 7.7% of all forest area in Hunhe watershed. It is much lower than the 25% of forest for water conservation in Japan. Therefore the first issue is that the ratio of forest for water conservation is very low in Hunhe watershed, and its stand volume is low also. The basic information of 7 districts (counties) in Hunhe watershed can been seen in Table 1.

The Forest Resources Survey data also showed that the stand area reached 608 thousand ha including 519 thousand ha of timber forest. It accounted for 85.4% of the total stand area. The shelter forest area was only 55 thousand ha, and 9.1% of all stand area in Hunhe watershed. The reason that the ratio of timber forest is very high is that Hunhe watershed was assigned to the timber productivity base of Liaoning province 30 years ago. The annual output of wood amounted to 550 thousand m^3, which accounts for one third of the province (Forestry Department of Liaoning Province, 2001). How to balance the proportion between the timber forest and forest for water conservation becomes another important issue (Fig. 2).

The third issue is the imbalance of the distribution of age classes. The results of Forest Resources Survey showed that the stand area with forest age below 20 and between 21 and 30 years old were 36.9% and 48.5% of all stand area respectively. It is obvious that the forest age is very young in Hunhe watershed (Fig. 3).

Based on the current situation of the forest for water conservation, its proportion is very low and the forest age is very young with low stand volume. It is not favorable for the forest to conserve water and improve water quality. In

Table. 1 The basic information in the Hunhe watershed

District (County)	Land area	Population	Forest area	Forest ratio	Stand area for water conservation			Stand volume for water conservation			Ratio of forest for water conservation
					Artificial	Secondary	Subtotal	Artificial	Secondary	Subtotal	
	(ha)	(10,000 people)	(ha)	(%)	(ha)	(ha)		(10,000 m^3)	(10,000 m^3)		(%)
Total	1,366,383	246	713,852	52.2	21,122	34,148	55,270	222.6	229.2	451.8	7.7
Shenyang	252,450	117	30,114	11.9	3,070	2,507	5,577	22.6	16.9	39.5	18.5
Shujiatun	76,200	42	8,183	10.7	384	29	413	2.6	0.1	2.7	5.0
Dongling	88,587	45	8,234	9.3	197	110	307	2.9	0.9	3.8	3.7
Xinchengzi	87,663	30	13,697	15.6	2,489	2,368	4,857	17.1	15.9	33.0	35.5
Fushun	1,113,933	129	683,738	61.4	18,052	31,641	49,693	200.0	212.3	412.3	7.3
Shuncheng	56,810	38	16,193	28.5	154	28	182	0.5	0.1	0.6	1.1
Funshun	220,638	24	108,930	49.4	6,292	3,377	9,669	101.3	23.2	124.5	8.9
Xinbin	443,190	32	263,174	59.4	2,909	17,662	20,571	23.8	115.5	139.3	7.8
Qingyuan	393,295	35	295,441	75.1	8,697	10,574	19,271	74.4	73.5	147.9	6.5

Sources: Forestry Department of Liaonig Prefecture, 1998, the statistics of forest resources of Liaoning prefecture

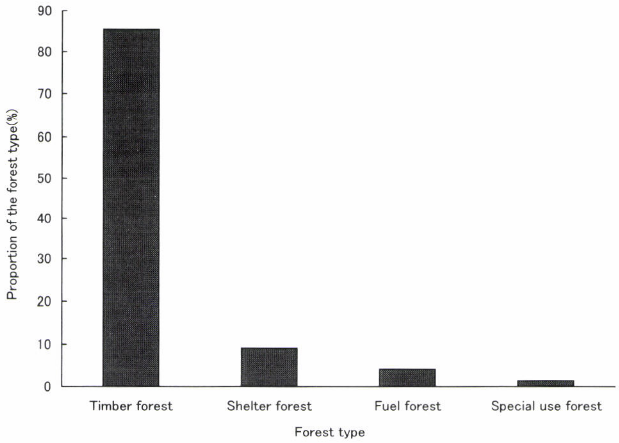

Fig. 2 The composition of forest type in the Hunhe watershed
Sources: FORESTRY DEPARTMENT of LIAONING PREFECTURE, 1998, the statistics of forest resources of Liaoning prefecture

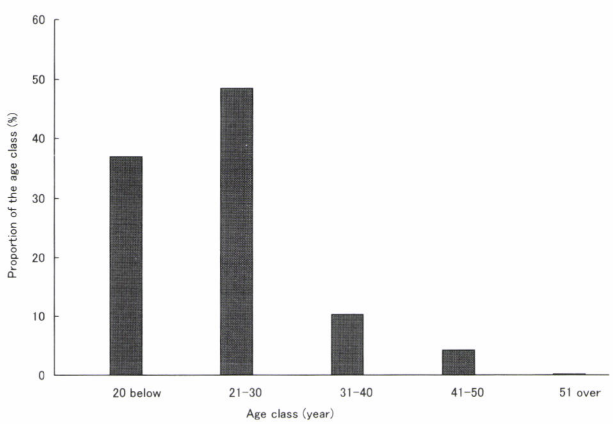

Fig. 3 The distribution of age class of forest for water conservation in the Hunhe watershed
Sources: Forestry Department of Liaoning Prefecture, 1998, the statistics of forest resources of Liaoning prefecture

Shenyang, the water consumption was 2.3 billion m^3 in 2001. It has been predicted that the water consumption will reach 3 billion m^3 and 3.5 billion m^3 respectively by 2010 and 2020 (WATER RESOURCES DEPARTMENT OF SHENYANG, 2001). However, the supply of underwater cannot be increased anymore because of over-exploitation in the past years. It is strongly expected to increase water supply from surface water. The forest for water conservation, which can increase the supply of surface water, becomes more important than before. How to enlarge the area of forest for water conservation and improve its quality are big challenges for the government and foresters.

The Management of Forest for Water Conservation

The forest for water conservation in Hunhe watershed decreased greatly. Its quality became worse than before because of the war and illegal cutting hundreds of years ago. The forest type was changed from Korea pine (*Pinus koraiensis* Sieb. Et Zucc.) broadleaf virgin forest into the poor secondary forest and barren hill (EDITORIAL BOARD OF LIAONING FOREST, 1990). Accompanying the plantation at large scale since 1950, the forest was recovered gradually.

The Management of Artificial Forest

Japanese larch (*Larix leptolepis* Gord.), which was introduced from Japan hundreds of years ago, is taken as one of the major species to be planted at scale of 10 thousand ha in a year (WANG, 1992; WANG, 2001). The plantation sites where the thickness of soil is over 50cm with rich humus are selected. The bush and weeds are cleared, and then the pits with size of 40cm by 30cm are dug before plantation. The densities of plantation vary with the purposes of management, site index and demands of the wood etc. If the purpose of management is to produce large diameter wood that Diameter at Breast Height (DBH) is over 24cm, the density of plantation will be low. On the other hand, if the purpose is to produce small diameter wood that DBH is below 14cm, the density will be high. Generally speaking, they vary from 1,330 trees/ha to 4,050 trees/ha. The cost of plantation is about 1,800 RMB/ha in Hunhe watershed, and it will increase with the increase of the density (TIAN, 1995).

The thinning will be done when the canopy become closed after 10 years old for the Japanese larch artificial forest. The thinning ratio varies from 10% to 30% with plantation density and forest age. The Table 2 showed that the thinning ratios increase with the increase of the plantation densities, and their variation with the forest ages. However, if the stand density of Japanese larch forest in Hunhe watershed is compared with larch stand in Nagano province of Japan, when the forest age is below 50 years old, the stand densities of Japanese larch forest in Hunhe watershed are much higher than that of Nagano at approximate productivity class and same age. For example, when the forest age is 30 years old,

Table. 2 The change of thinning ratios with different plantation density and stand age (Unit: %)

Plantation density (trees/ha)	10 year	17 year	24 year	31 year
4,050	15	20	30	20
3,330	10	15	25	20
2,490	0	10	15	20
2,000	0	0	15	15
1,330	0	0	0	0

Sources: Tian, Z., 1995, the silviculture of Japanese larch

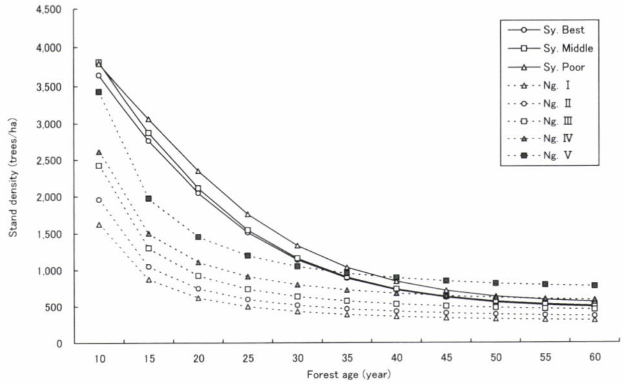

Fig. 4 The comparison of larch stand density between Shenyang and Nagano at different productivity class
Sources: Tian, 1995, the silviculture of Japanese larch
Forestry Department of Nagano Prefecture, 1991, the handbook of long-term management of Japanese larch artificial forest
Note: Sy.=Shenyang, Ng.=Nagano

Table. 3 The final cutting age of Japanese larch stand at different management purpose Unit: year

Management purpose	Poor productivity class	Better productuvity class
	Site index at 18 below	Site index at 20 over
Small diameter wood (DBH <14cm)	17-20	15-17
Middle diameter wood (DBH: 16-20cm)	20-13	18-20
Large diameter wood (DBH >24cm)	40-45	38-40

Sources: Tian, Z., 1995, the silviculture of Japanese larch

the stand densities vary from 1,143 trees/ha to 1,335 trees/ha at different productivity class in Hunhe watershed. But in Nagano province, they vary from 430 trees/ha to 1,051 trees/ha. When the forest age is over 50 years old, the differences of stand density between Hunhe watershed and Nagano province are diminishing (FORESTRY DEPARTMENT OF NAGANO PROVINCE, 1991; TIAN, 1995). The change of stand density with forest ages can be seen clearly in Fig. 4.

The final cutting age of larch stand varies with the purpose of plantation, site index and others. In terms of low site index, if the purpose of plantation is to produce small diameter wood such as pulp and rafter, the final cutting age is around 17-20 years old. If the purpose is to produce large diameter wood such as beam and log, the final cutting age is around 40-45 years old. In terms of high site index, the final cutting ages of small diameter and large diameter wood are around 15-17 and 38-40 years old respectively. No matter what the purpose of the management and how site index they are in Hunhe watershed, all of the final cutting ages are below 45 years old. It is obvious that the management of Japanese larch artificial forest is characterized with a short-term cutting (Table. 3).

Based on the above investigation, the ratio of forest for conservation is very low compared with that of timber forest. The forest quality is poor. The stand density is very high with the character of short-term cutting in Hunhe watershed. It has been pointed out that it was necessary to transfer timber forest into forest for water conservation (FORESTRY DEPARTMENT OF LIAONING PROVINCE, 1996). However, how to realize the transformation has not been solved yet.

In Japan, there are many researches about the management of forest for water conservation (WATANABE, 1982; TSUKAMOTO and OTA, 1984; TAKESHITA, 1990; OTA, 1991; HATTORI *et al.*, 2001). These researches showed that the best forest types for water conservation are the large diameter forest, mixed forest, broadleaf forest and multi-storied forest. The forest for water conservation has been changing from pure even-aged artificial forest to large diameter forest, mixed forest and multi-storied forest through the long-term management etc., and a lot of model forests for water conservation have been formed in Kanagawa province and Tama watershed (FORESTRY DEPARTMENT OF KANAGAWA PROVINCE, 1994; WATERWORKS BUREAU OF TOKYO CITY, 2001).

In order to search for the possibility of management of long-term cutting in Hunhe watershed, 3 plots were investigated. Plot A was located in Qingyuan county, its forest age was 62 years old, stand density was 394 trees/ha. Plot B and C were located in Xinbin county, their forest ages were 60 and 86 years old respectively, the stand densities were 455 and 536 trees/ha respectively. The dominant species of 3 plots was Japanese larch. The results showed that the average stand height of 3 plots was over 28m, and the average DBH was over 30cm. The average stand stock amounted to 540m^3/ha, which was 5 times as much as the average stand volume of 105m^3 /ha in Hunhe watershed. The average volume of singletree reached over 1.2m^3, and the stock of the trees that DBH was over 30cm was over 90% of all stock. (WANG, 2002). The details of the investigation can be seen in Fig. 5. The results also showed that the broadleaf trees that invaded into plots amounted to 1,200 trees/ha, and the major species were Manchurian linden (*Tilia mandshurica* Rupr. Et Maxim.), Chestnut (*Quercus mongolica* Fisch.), and Ussurian pear (*Pyrus ussuriensis* Maxim.) etc.

Therefore, it seems possible to produce large diameter wood by the management of long-term cutting, which implicates that it is possible to transfer timber forest into the forest for water conservation by the management of long-term cutting in Hunhe watershed. However, the issues like what thinning ratio is the best at different age class and when thinning is to be done for the management of large diameter wood still need more researches in Hunhe watershed.

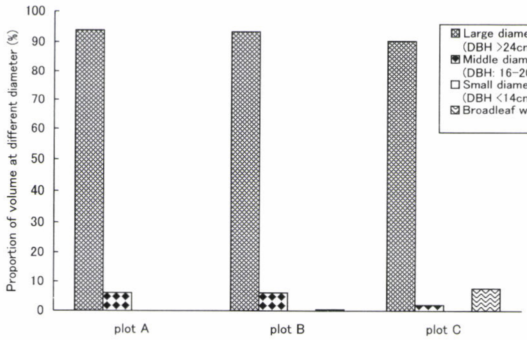

Fig. 5 The composition of volume at different diameter in the old age larch stand
Source: Wang, H., 2002, the possibility of management of long-term cutting of Japanese larch in China, Transactions of the Japanese Forestry Society

The Closing Mountain to Regenerate Forest

Because the economic statuses of the districts (counties) are at low level in Hunhe watershed, the study on how to increase forest resources with low cost and better effect has become necessary. The Closing Mountain to Regenerate Forest (CMRF) is one approach to increases forest resources in China. The natural regeneration is mainly utilized to recover forest during the process of closing mountain. It has two implications. First, any activity that is unfavorable for the regeneration of forest is forbidden during closing the mountain, such as putting out to pasture and gathering firewood etc. Second, appropriate human management will be carried out according to the growth of the young tree such as plantation, pruning and selective cutting etc. (Xu and Zheng, 1994). The area of the CMRF varies from several ha to hundreds of ha, depended on the actual situation of the stand.

According to the Forest Management Codes of Liaoning province (Technological Standard Department of Liaoning Province, 1993), the following objects could use the CMRF approach to recover forest in Hunhe watershed.

(1). Japanese larch below 10 years old, Korea pine below 13 years old and Black locust (*Robinia Pseudoacacia L.*) below 3 years old.

(2). The bush, sparse woods and cut-over area where some mother trees exist and natural regeneration can be realized. The poor secondary forest where a few good trees still exist.

(3). The poor secondary forest and young stand that located in the forest parks, natural conservation zones, around the dams and rivers or in a deep and precipitous mountains.

After the poor secondary forest and young stand are assigned as the zone of CMRF, some measures should be taken into effect, such as some people will be designated to keep watch over the region to prevent the man-made interference, such as putting out to pasture etc. Duration of CMRF is about 10 years generally. After some young trees are regenerated by naturally seeding, a series of steps will be taken to promote the growth of the young trees. In Hunhe watershed, the following techniques are often utilized.

(1). Planting coniferous trees under the canopy after selective cutting.

This technique is suitable for the poor secondary forest. First of all, the species and quantities of young trees should be investigated. Then weeds, bush and others should be got rid of. Also, other types of trees should be cleaned up by selectively cutting. Only the good middle and small diameter designated trees should be kept. Additionally, the Korea pine, Manchurian fir (*Abies holophylla* Maxim.), and Yeddo spruce (*Picae jezoensis* Carr.), which are tolerant trees, should be planted to promote the growth of mixed forest of coniferous and broadleaf trees.

(2). Planting coniferous trees by row to form mixed forest.

This is for the sites where enough mother trees and young trees both present, and evenly distributed. The amount of the young trees regenerated by natural seeding should be controlled. Any weeds and bush that affect the growth of young trees should be got rid of. Based on the row spacing of 3-5m, the tolerant trees such as Korea pine and Manchurian fir should be planted. In order to form mixed forest earlier, eliminating the weeds and adjusting the proportion of the coniferous and broadleaf trees are very necessary after 2-3 years of plantation.

(3). Planting the coniferous trees by group to form mixed forest.

This is suitable for the location where quantities of young trees regenerated by naturally seeding are not a lot, and unevenly distributed. Because of the uneven distribution of the young trees, the tolerant trees such as Korea pine and Manchurian fir are planted by 3-7 coniferous tree group where there are no young trees regenerated. The area of each group is about $5m^2$. After plantation, in order to balance the proportion between coniferous and broadleaf trees, it is necessary to clean up poor trees and non-designated trees.

Considered as the effect of CMRF, if the mountain could be closed indeed, the forest should be recovered by natural regeneration and the stand structure would be very similar to natural forest. There are many successful cases of CMRF in China. The Laoshigou forestry farm, which locates in Hunhe watershed, is a typical case of CMRF.

The total area of the forestry farm is 983 ha which includes 410 ha of the stand governed by the Committee of Communist Party of Shenyang. In order to keep its important documents, the forestry farm has been closed since 1960's. Now, the forest has grown up to the stable mixed forest. The biological species are abundant. The majority are middle-aged and matured forests. According to the survey of Forestry Bureau of Shenyang, the area of the stand below 20 years old is 29 ha, which consists of 7.1% of all stand area. The

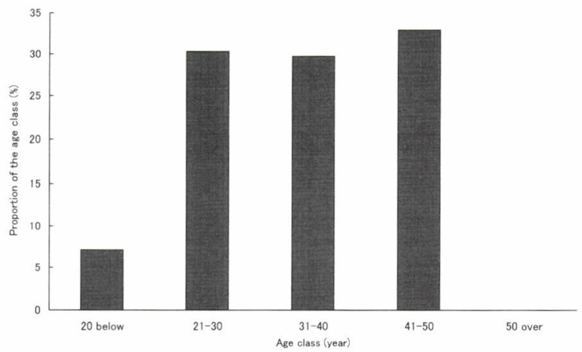

Fig. 6 The distribution of age class in Laoshiguo forestry farm
Sources: Forestry department of Liaoning prefecture, 1998, the statistics of forest resources of Liaoning prefecture

Table. 4 The comparison of cost between plantation and CMRF

Area	CMRF (RMB/ha)	Plantation (RMB/ha)	CMRF/Plantation (%)
Chaoyang city, Liaoning prefecture	196	978	20.0
Panshi county, Jilin prefecture	226	1,419	15.9
Qingyuan county, Liaoning prefecture	161	1,483	10.9

Sources: Zhao, R., 1995, silviculture in the semi-arid area

Table. 5 The cost of CMRF in the watershed of Shenyang Unit: RMB/ha

Category of expense	Cost
Total	228
Keeping watch over the forest	15
Training for forester	5
Purchasing the fire protection tools	76
Purchasing the communication tools	8
Conducting propagangda among citizen	5
Controll of diseases and pest	14
Monitoring of the forest	5
Thinning and plantation	60
Construction of the forest road and bridge	30
Others	10

Sources: Forestry Bureau of Fusun, 2001, data service

percentage is much lower than 36.9% in the watershed at same age class. The area of stand between 31 and 40 years old is 124 ha, which accounts for 30.3% of all stand area, lower than 48.5% in the watershed at same age class. However, the stand area aged over 41 years old is 256 ha, about 62.6% of all stand area. It is much higher than 14.6% in Hunhe watershed at same age class. The different ratio of each age class of Laoshigou forestry farm can be seen in Fig. 6.

Because less or no seedlings were planted during CMRF in comparison with plantation, there is less or no expense on the management of seedling. The cost of CMRF is much less than that of plantation, but it varies in different regions. Many researches showed that the cost of CMRF was about one fourth of the plantation in general (Yu and Yu, 2001; Zhao, 1995; Xu and Zheng, 1994). It was showed in Table 4. In Hunhe watershed, the cost of plantation is about 1800 RMB/ha in recent years, and the cost of CMRF is about 228 RMB/ha, which accounts for 12.7% of the plantation. The details of the cost of CMRF were showed in the Table 5.

The above study showed that the forest could be recovered effectively by CMRF, which cost is much lower than plantation. This indicates that CMRF should be applied at large scale in the future.

CONCLUSION

Shenyang, as the biggest city in northeastern China, is involved in serious water stress. There are 2 approaches to solve the problem. One is through the increase of water supply, and another is through saving water strategy. However, followed by the rapid economic development and improvement of the people's living standard, the demand for water consumption will be increased, digging more underwater to meet the needs of water consumption is not possible in Shenyang because of over-exploitation in the past. To increase the supply of surface water is imperative now. Therefore, the forest for water conservation becomes more important than before.

Many researches showed that the best forest types for water conservation are the large diameter forest introduced by long-term management and natural forest etc. Unfortunately, in Hunhe watershed, because of the war and illegal cutting, the virgin forests do not exist anymore, and the young artificial forest with high density aimed at producing timber primarily and the secondary forest with poor quality are the major forest types. The proportion of the forest for water conservation is very low. It does not match the growing needs of increasing water supply and improving water quality. It is necessary to expand forest area and improve its quality for water conservation in Hunhe watershed.

To transfer the timber forest into the forest for water conservation by the management of long-term cutting is possible in Hunhe watershed. Not only can the forest area for water conservation be increased, but also the conflict between economic and environmental benefit could be minimized or even solved.

CMRF is one of the effective approach to increase forest area and improve the forest quality in Hunhe watershed. This approach is proved to be less costly and suitable for Shenyang to recover forest. It should be popularized furthermore in the future. However, the mountain must be closed reliably during the closing mountain. It is here, challenges remain for the government, foresters and local people, such as how to deal with the issues that local people used to gather firewood and put out to pasture in the region of CMRF, after mountain is closed. The available policies and techniques should be drawn up in the future.

ACKNOWLEDGEMENT

The authors gratefully thank professor Robert W. MILLER of the University of Wisconsin who provided very helpful comments on the manuscript.

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*The titles are tentative translations from original Chinese and Japanese by the authors of this paper

(Received 4 June 2002)
(Accepted 1 March 2003)

Article

Woodfuel Consumption Rates and Flow in Kampong Thom Province, Cambodia

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ABSTRACT

Woodfuel consumption rates and flow were estimated based on an interview survey of 155 households conducted in Kampong Thom Province in December 2000 and January 2001 combining with National Population Census 1998. We found that per capita woodfuel consumption rates varied in places according to household sizes and woodfuel prices. For each district, the per capita consumption rate obtained from the samples was normalized based on an average household size of the National Population Census. Per capita woodfuel consumption rate per year of the province was 183 and 134kg for firewood and charcoal, respectively, with a mean of 131kg oven dry wood (ODW) equivalent. This study revealed a total woodfuel consumption of 76,139 tonnes ODW equivalent for the province, of which 94.3% represented by household sector, 3.2% by industrial and service sectors and 2.6% transported to Phnom Penh. These results indicate that the household sector strongly affects woodfuel flow within the whole province. Low per capita incomes and slow economic development suggest that Kampong Thom will not move towards using modern sources of energy (kerosene, gas, or electricity) in the near future. Woodfuels will therefore maintain its important role as a provider of energy.

Keywords: firewood, charcoal, woodfuel consumption, woodfuel price, household size

INTRODUCTION

Woodfuels are the primary source of cooking energy and plays a vital part in the energy supplies of developing countries (Heltberg *et al.*, 2000; Chen *et al.*, 1998; World Bank, 1987). Almost 50% of the worldwide annual wood cut is used as fuel (Kersten *et al.*, 1998). Firewood consumption is increasing in absolute terms, even when its share of national energy consumption is decreasing (Chaturvedi, 1999; Regional Wood Energy Development Program in Asia (RWEDP), 1997). Substantial increases in population as well as decreasing forest areas have led to woodfuel shortage being reported in many countries (Abbot and Lowore, 1999; Montalembert and Clement, 1983). With mounting concern for the firewood sector, many international agencies, including FAO, CIDA, OECD, WECD, have funded wood energy studies. Many of these studies concentrated on the consumption/demand side as a means to obtain site information necessary for planning, as well as a basis for further research and possible technological application (Mahapatra and Mitchell, 1999).

Previous studies showed that per capita woodfuel consumption rate varies with ecological and socioeconomic factors (e.g., Kersten *et al.*, 1998; Kituyi *et al.*, 2001b; Marufu *et al.*, 1999; Mahapatra and Mitchell, 1999). In particular, it is known that household size affects the woodfuel consumption rate. However, there have been only few studies taking household size into account in order to estimate total woodfuel consumption in states or countries (Marufu *et al.*, 1999; Kituyi *et al.*, 2001a).

As in other parts of the developing world, the Cambodian people have been heavily dependent upon forest resources in order to meet household energy needs. The National Population Census conducted in 1998 by National Institute of Statistics (NIS, 1999) indicated that over 95% of both urban and rural inhabitants in Cambodia are dependent on firewood

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and charcoal for cooking. This indicates the vital role of forests in meeting woodfuel needs in this country and offers an interesting environment in which to investigate the dynamics of the collection and consumption of woodfuels. RWEDP (1998) investigated woodfuel flow and consumption rate in Phnom Penh, the largest city of Cambodia. However, there has been no study on woodfuel consumption in other areas of Cambodia. The objectives of this study are to (1) estimate per capita woodfuel consumption rates in Kampong Thom, 168 km north of Phnom Penh, taking into account the effects of household sizes and the regional differences and (2) estimate total woodfuel flow in the province.

STUDY SITE

Kampong Thom Province is situated in central Cambodia, with a total land area of 12,447 km^2 (Department of Forestry and Wildlife (DFW), 1999), and consists of 8 districts, 81 communes and 737 villages. The climate is tropical with a bi-annual change of monsoonal wind systems, the rainy season (May～October) and the dry season (November～April). Mean annual rainfall and temperature over the last five years (1996-2000) have been 1,700mm and 28°C, respectively.

The province is covered by over 0.63 million ha of forests (DFW, 1999) representing about 50.9% of the provincial area (Table 1). Three dominant forest types, i.e., deciduous, mixed/semi-deciduous and evergreen, mostly cover in the northern and northeastern province representing 3.8%, 4.3% and 64.9%, respectively, of total forestland. The remaining 26.9% are inundated forest and regrowth forest. Forest areas fall under different management regimes, but have the same legal status, being government owned.

Kampong Thom is an economically poor province with low living standards for the majority of the population (MRD/GTZ, 1995). The 1998 population was 569,060, of which about 88.5% lived in rural areas (NIS, 1999). The annual population growth was 2.49% with an average population density of 46 per/km^2. The total number of households in the province was 106,908, with an average household size of 5.32 (Table 1). Population distribution and settlement pattern is determined by the means of transport used. Most villages are situated along the major roads. Others follow rivers and a few fishing villages are found on the shores of Tonle Sap Lake. Stoeng Sen District includes the provincial town, with the highest population density (144 per/km^2) and the lowest forest cover ratio (0.9%), whereas Sandan District is situated in the remote area with the lowest population density (13 per/km^2) and highest forest cover ratio (89.5%).

MATERIALS AND METHODS

Woodfuel Consumption Rates

A survey by interview was conducted in the province during December 2000 and January 2001. It encompassed 155 households, including 103 firewood users and 52 charcoal users, distributed over 8 geo-political districts throughout the province (Fig 1, Table 2). The interview was based on questionnaires and carried out by discussion with the head of each household concerning the amount of woodfuels consumed per month and household size. Per capita woodfuel consumption per year was calculated for each household and each district.

As mentioned above, woodfuel consumption rate is known to vary with household size. In this study, the average sample household size (Table 2) is consistently larger than the district and provincial averages obtained from the National Population Census 1998 (NIS, 1999) (Table 1). For each district, therefore, per capita consumption rate of the sample was normalized to the average household size, obtained from the National Population Census, using methods developed by Marufu *et al.* (1999). First, the relationship between per capita

Table 1 Basic information for each district in Kampong Thom

District	Forest Land*1		Population*2		Household*2		Woodfuel Users*2	
	Area (ha)	Ratio to total area (%)	Number	Density (per /km^2)	Number	Size (per/hh*)	Firewood (per)	Charcoal (per)
Baray	11,291	8.6	159,586	122	30,839	5.17	150,980	2,016
Kampong Svay	33,215	24.0	74,834	54	13,586	5.51	68,511	298
Stoeng Sen	419	0.9	66,014	144	12,295	5.37	58,469	5,370
Prasat Balangk	70,116	50.8	40,516	29	7,533	5.38	38,897	48
Prasat Sambo	29,548	38.9	36,983	49	6,870	5.38	36,213	81
Sandan	260,798	89.5	38,574	13	7,113	5.42	36,905	472
Santuk	165,757	66.3	58,434	23	10,713	5.45	55,939	398
Stoung	62,754	36.0	94,119	54	17,959	5.24	91,066	707
Total/Province	633,898	50.9	569,060	46	106,908	5.32	536,979	9,390

*hh = household

Source: *1 DFW (1999)

*2 NIS (1999)

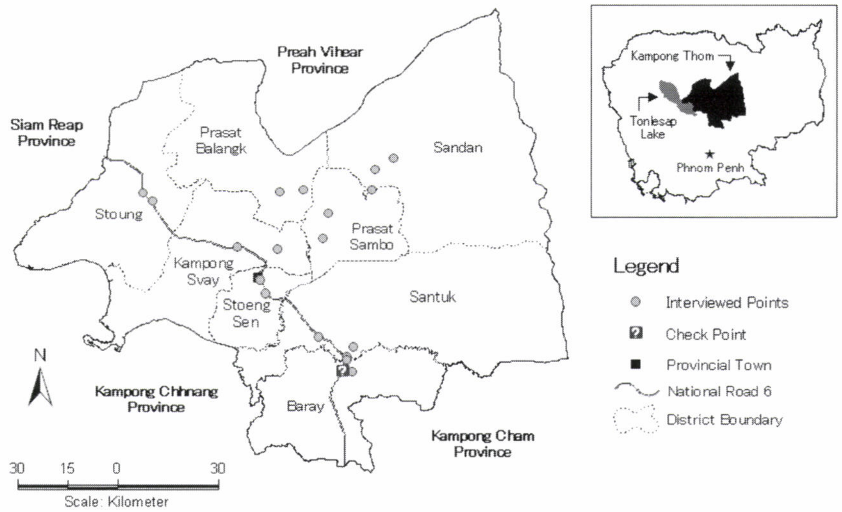

Fig. 1 Kampong Thom Province, Main road map and interviewed points

Table 2 Distribution of samples for study

District	Firewood			Charcoal			Total sample
	Sample (hh*)	User (per)	Average size (per/hh)	Sample (hh*)	User (per)	Average size (per/hh)	
Baray	9	75	8.33	6	36	6.00	15
Kampong Svay	14	107	7.64	6	40	6.67	20
Stoeng Sen	15	108	7.20	10	62	6.20	25
Prasat Balangk	14	99	7.07	6	41	6.83	20
Prasat Sambo	14	89	6.36	6	46	7.67	20
Sandan	14	97	6.93	6	39	6.50	20
Santuk	9	63	7.00	6	36	6.00	15
Stoung	14	106	7.57	6	39	6.50	20
Total/Province	103	744	7.22	52	339	6.52	155

*hh = household

woodfuel consumption and household size was described by an equation of the form

$$C = C_0 + ae^{-bs} \quad (1)$$

where C is the consumption rate (kg/capita/year), C_0 is a constant representing the baseline per capita woodfuel consumption rate (consumption rate for a very large household). S is the household size, while a and b are constant describing the intercept and curvature of the function, respectively. The Levenberg-Marquardt curve-fitting algorithm of DeltaGraph (version 4.5, SPSS Inc.) was used for the curve-fitting. Second, the following equation was used for the normalization.

$$C_{normalized} = \frac{C_0 + ae^{-bs_{district}}}{C_0 + ae^{-bs_{sample}}} \times C_{sample} \quad (2)$$

where $S_{district}$, S_{sample} and C_{sample} are average household size obtained from the National Population Census (NIS, 1999), the average sample household size and per capita woodfuel consumption rate of the samples, respectively, for each district.

In the vicinity of the studied areas, we further interviewed some woodfuel sellers or retailers about the price of firewood and charcoal. We then examined the relationship between the normalized per capita woodfuel consumption rate and average woodfuel price of each district. Due to the small sample size (n=8), Spearman's rank correlation coefficient was used to test for significant correlations between them. During the survey, the currency exchange rate was USD 1 = 3,800 riel, Cambodian currency.

Woodfuel Flow

Total woodfuel consumption refers to end-use analysis of the gross amount of firewood and charcoal only devoted to a specific use category (household, industrial and service sectors) including transport to other destinations outside the province. There are three main roads connecting Kampong Thom to other provinces (Rout 64 to Preah Vihear Province in the north, the National Rout 6 to the northwest and southeast). According to Provincial Forestry Office (PFO), no woodfuel is transported to the north or the northwest destinations, except the southeast direction. In order to collect data on woodfuel transportation, a 3-day observation was conducted by the study team in cooperate with provincial forest officials at the Checkpoint in the Kampong Thma Commune (Fig. 1).

Woodfuel consumption in the household sector was calculated using the normalized per capita consumption rate and the number of firewood and charcoal users obtained from the National Population Census 1998 (NIS, 1999) for each district. Data on woodfuel consumption in industrial and service sectors was obtained from the Department of Industry (DOI) and PFO. Attempts have been made to identify as many different institutions using woodfuels as possible. However, in the industrial sector, only brick/tile making, bakeries and fish smoking were taken into account. Other entities were negligible because the amount of firewood consumed was relatively low. In the service sector, only big and medium size restaurants were considered.

Units and Conversion

In terms of woodfuels, only firewood and charcoal are commonly used in the province and referred to in this study. Domestic consumption units are stere ($1 \times 1 \times 1$m of stacked wood, 360kg) for firewood and kilogram or sack (55kg) for charcoal. In order to estimate total woodfuel flow, firewood and charcoal weight were also estimated using average weight at oven dry wood (ODW) equivalent (around 12% moisture content).

The conversion factor between oven dry and air-dry weight was estimated as 0.71 (using 20 firewood samples from 10 tree species). Using these results, one stere firewood was 255kg ODW equivalent. Based on the study conducted by RWEDP (1998), one-ton charcoal was 7.3 stere firewood on average, and therefore one-tonnes charcoal was 1.862tonnes ODW equivalent.

RESULTS AND DISCUSSION

Woodfuel Consumption Rates

Based on the sample average as described in Table 3, per capita firewood consumption in each district ranged from 134 to 208kg per year, with the highest being the remote Sandan (208kg) and the lowest being the populous Stoeng Sen District (134kg). With respect to charcoal, per capita consumption in each district ranged from 101 to 133kg per year, with the highest being Stoeng Sen (133kg) and the lowest being Sandan District (101kg).

Fig. 2 and 3 show the relationships between per capita consumption rates and household size for firewood and charcoal, respectively, pooling survey data from all districts. In these relationships, we can assume that the effects of the regional differences between districts on the per capita consumption rates, as mentioned above, are negligible because no significant differences in mean household size of the samples were found among different districts (ANOVA, p=0.8922 for firewood and p=0.9770 for charcoal). Fitting equation (1) to the survey data yielded the following functions.

$$C_{firewood} = 150.8052 + 462.2669e^{-0.489972s} (r^2 = 0.353) \quad (3)$$

$$C_{charcoal} = 94.9708 + 109.9742e^{-0.215918s} (r^2 = 0.447) \quad (4)$$

These indicate that per capita consumption rates decrease exponentially up to a household size of about eight persons. Thus, households of smaller family sizes tend to consume

Table 3 Annual per capita woodfuel consumption rates by district

District	Firewood consumption rate (kg/per/year)		Charcoal consumption rate (kg/per/year)	
	Sample average	Normalized	Sample average	Normalized
Baray	143	169	125	131
Kampong Svay	149	168	120	127
Stoeng Sen	134	150	133	140
Prasat Balangk	201	224	105	113
Prasat Sambo	170	182	123	137
Sandan	208	229	101	107
Santuk	136	149	128	132
Stoung	192	221	117	125
Average/Province	168	183	120	134

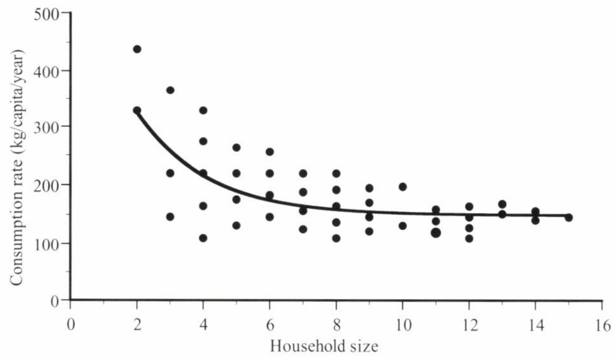

Fig. 2 Variations in the rate of firewood consumption with household size

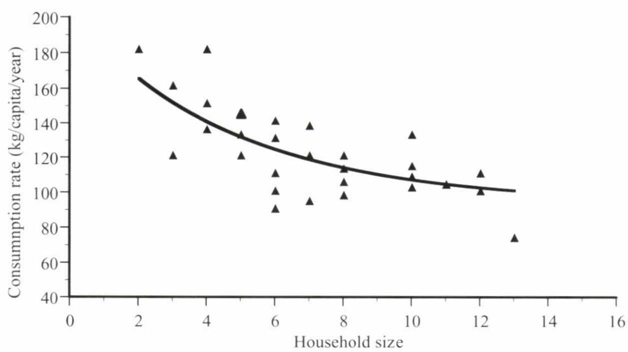

Fig. 3 Variations in the rate of charcoal consumption with household size

Table 4 Price distributions of firewood and charcoal by district

District	Firewood		Charcoal	
	riel/stere	riel/kg	riel/sack	riel/kg
Baray	7,000	19	11,000	200
Kampong Svay	5,500	15	8,800	160
Stoeng Sen	17,000	47	16,500	300
Prasat Balangk	4,500	13	7,700	140
Prasat Sambo	5,000	14	7,700	140
Sandan	3,500	10	5,500	100
Santuk	7,000	19	8,800	160
Stoung	4,500	13	7,700	140

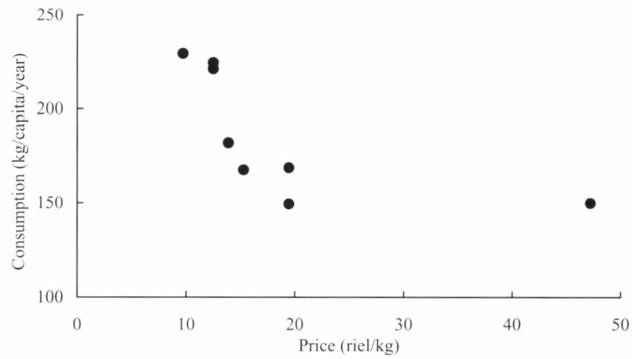

Fig. 4 Firewood consumption rates and prices

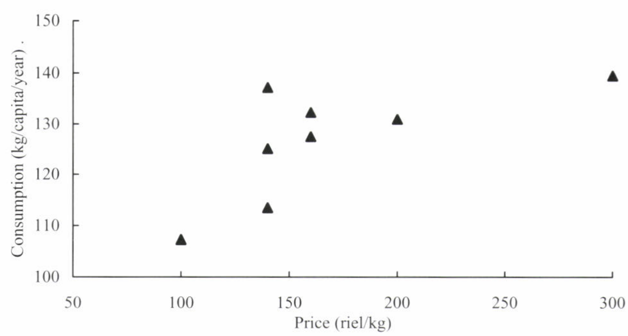

Fig. 5 Charcoal consumption rates and prices

more fuel per capita, in comparison with those of larger family size, agreeing with the findings of KITUYI *et al.* (2001a), HOSIER (1985) in Kenya, MARUFU *et al.* (1999) in Zimbabwe, MAHAPATRA and MITCHELL (1999) in India and KERSTEN *et al.* (1998) in Nigeria. This means that larger households are more efficient users of fuel than smaller ones. Therefore, collective cooking for several individuals tends to require less fuel.

Table 3 also includes per capital woodfuel consumption rates normalized using equations (2), (3) and (4), showing similar regional differences to the sample averages. We found that these regional differences in the normalized per capita woodfuel consumption rate were closely related to the average prices in each district (Table 4, Fig. 4 and 5). Firewood consumption is negatively correlated to price ($r=-0.893$, $p=0.0182$, $n=8$); as price increases, consumption decreases (Fig. 4). In the case of charcoal, consumption tends to increases as price increases ($r=0.720$, $p=0.0567$, $n=8$) (Fig. 5). These relations may be explained by woodfuel availability and household income. In rural areas with higher firewood availability such as Sandan District (89.5% of area is covered by forest, and the population density is low as 13 persons/km^2), firewood could be obtained more cheaply or free. This leads to a wasteful use of firewood (higher consumption rate) with less attempt at fuel saving or conservation in contrast to fuel-stressed areas. These findings agree with HOSIER (1985) and KITUYI *et al.* (2001a) studies in Kenya.

Using the normalized per capita woodfuel consumption rate (Table 3) and the number of woodfuel users (Table 1) of each district, the per capita consumption rate of the province was 183 and 134kg for firewood and charcoal, respectively. In Table 5, our estimates on woodfuel consumption rate are compared with those from other studies. The per capita charcoal consumption rate estimated in this study (134kg) is

Table 5 Firewood consumption rates reported in literature

Source	Consumption Rate (tonnes/capita/year)		Country
	Firewood	Charcoal	
This study	0.18 (0.13 ODW)	0.13 (0.25 ODW)	Cambodia (Kg. Thom)
RWEDP, 1998	0.12	0.13	Cambodia (Phnom Penh)
KITUYI *et al.*, 2001b	0.64	0.1	Kenya
MAHAPATRA and MITCHELL, 1999	0.46	-	India
MARUFU *et al.*, 1999	0.99	-	Zimbabwe
AMOO-GOTTFRIED and HALL, 1999	0.72	-	Sierra Leone
KERSTEN *et al.*, 1998	0.39	-	Nigeria

similar to the result (130kg) conducted in Phnom Penh by RWEDP (1998). However, our study estimates a higher per capita firewood consumption rate in comparison with the latter study (183 and 122kg for Kampong Thom and Phnom Penh, respectively). This difference may be due to low firewood availability (only 3.0% of the total area covered with forest) and high population density (3,448 people/km^2) in Phnom Penh.

Compared with results in other countries, our data on per capita firewood consumption rates are at the lower end (Table 5). In Zimbabwe (MARUFU *et al.*, 1999) and Kenya (KITUYI *et al.*, 2001b), firewood is used not only for cooking but also for space heating. In the case of Kampong Thom, no woodfuel is burnt for space heating due to the warm climate throughout the year. This could be explained as a factor causing the lower consumption rate in this province. Other factors, e.g. number of meals per day, substitutes and firewood species characteristics, may also cause the different results among countries or regions. In case of charcoal, the per capita consumption rate in Kenya (103kg, KITUYI *et al.* 2001b) is slightly lower than our result (134kg), even though charcoal is also used for space heating in Kenya. This may imply that charcoal users in this country utilize other fuels (e.g. kerosene, gas) as substitutes, being different from our study targeted to only the pure charcoal user.

Woodfuel Flow

Based on estimates made by PFO, approximately 70% of total woodfuel consumption in Kampong Thom was from forest land, with the remaining portion sourced from non-forest land (agricultural land, agro-forestry systems, waste-land, line trees, domestic gardens, etc.). Based on estimates produced by SO (2000), 17% of the total households purchased woodfuels from local markets for cooking, and the rest collected their own.

Using the normalized per capita consumption rate (Table 3) and the number of woodfuel users (Table 1) of each district, the total woodfuel consumption within the household sector was 98,045tonnes or 69,448tonnes ODW equivalent for firewood and 1,260tonnes or 2,345tonnes ODW equivalent for charcoal, totaling (firewood and charcoal) 71,749tonnes ODW equivalent.

Table 6 Charcoal transported to Phnom Penh over a 3-day period

Observed day	Total charcoal transported	
	Number (sack/day)	Quantity (kg/day)
1st	45	2,475
2nd	58	3,190
3rd	53	2,915
Average	52	2,860

Based on DOI and PFO, within the industrial sector, 42 brick/tile kilns, 6 bread and candy bakeries and 10 fish smoking houses were operating in the province, giving a total firewood consumption of 2,937tonnes or 2,080tonnes ODW equivalent per year. In the service sector, 27 big and medium size restaurants operated in the province, giving a total firewood consumption of 454tonnes or 321tonnes ODW equivalent per year. Therefore, total firewood consumption in industrial and service sectors was 3,390tonnes or 2,402tonnes ODW equivalent per year.

The 3-day observation at the Checkpoint in the Kampong Thma Commune showed that the majority of woodfuel transported was charcoal, mostly targeted at Phnom Penh rather than other provinces. Firewood was also transported, but was negligible, the volume transported being relatively low. Approximately 52 sacks of charcoal or 2,860kg were transported daily to Phnom Penh (Table 6), with total transportation of 1,044tonnes or 1,944tonnes ODW equivalent per year.

Fig. 6 shows woodfuel flow in Kampong Thom based on results described above as expressed in ODW equivalent. Total woodfuels (firewood and charcoal) purchased by the household sector was 12,205tonnes ODW equivalent or 16% of total woodfuel flow (based on 17% of total households obtaining their woodfuel from traded sources as estimated by SO, 2000). Approximately 70% of total woodfuel demand from

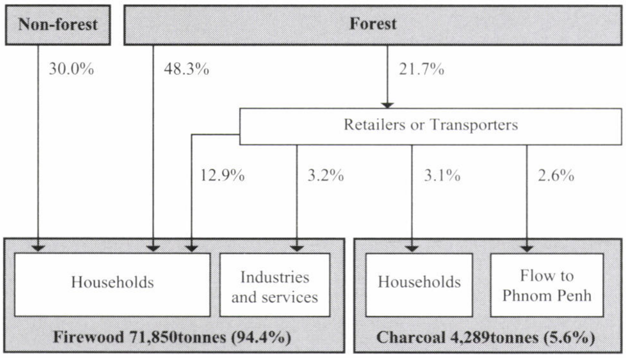

Fig. 6 Woodfuel flow chart based on oven dry weight equivalent

forests was made up of 48.3% collected by household members and 21.7% purchased from local markets. Total woodfuels extracted from forest and non-forest sources for the three sectors studied (household, industry and service) including transport to Phnom Penh, was approximately 76,139tonnes ODW equivalent in 1998.

From Fig. 6, it can be seen that the household sector contributes the highest percentage of all woodfuel consumers in the province. It represented up to 94.3% of the total woodfuel flow, while industrial and service sectors were 3.2%, and charcoal transported to Phnom Penh only 2.6%. These results reveal that the household sector is the largest woodfuel consumer in the province.

CONCLUSION

Woodfuels were consumed at an average rate of 183 and 134kg for firewood and charcoal, respectively, giving a mean per capita consumption rate of 131kg ODW equivalent for the Kampong Thom Province. The per capita consumption rates vary in places according to household size and woodfuel price. Households of larger family sizes tend to require less fuel per capita, in comparison with those of smaller family size. People tended to utilize more firewood and less charcoal in areas of lower price. This study revealed a total woodfuel consumption of 76,139tonnes ODW equivalent for the province, of which 94.3% represented households, 3.2% industrial and service sectors and 2.6% transported to Phnom Penh. These results indicate that the household sector strongly affects woodfuel flow within the whole province. The relatively favorable price of firewood and charcoal, in comparison to substitutes, such as kerosene, gas and electricity, may be the major reason for a high demand for woodfuels.

It is generally held that people move to modern energies with a rise in economic condition (e.g. KITUYI *et al.*, 2001b). Slow economic development suggests that Kampong Thom will not change to more modern sources of energy in the near future. Woodfuels will therefore maintain its important role as an energy resource. It has not been shown whether woodfuel consumption causes ecological and forest degradation. However, efforts should be made to reduce woodfuel consumption. This could be achieved if improved cooking stoves with low woodfuel consumption and high efficiency were available. Development of cheaper substitutes for firewood and charcoal will be crucial in reducing pressure on forest resources. In addition, renewable energy sources (e.g., hydro power, solar, wind, geothermal, as well as biofuels) should be introduced.

ACKNOWLEDGEMENTS

We are grateful to Prof. TOSHIO NAKAO of Miyazaki University, Mr. TY SOKUN, General Director, and Mr. OUK SYPHAN, Deputy Director, of the Department of Forestry and Wildlife, for providing assistance on a wide range of issues. The data was obtained with the generous cooperation and assistance of Mr. SO THAN, Mr. VONG SARUN, Ms. LIM SOPHEAP, and Mr. NUP CHAYA, to whom we express our sincere gratitude. We also extend our appreciation to Ms. SARAH BURGESS, Project Advisor of GTZ/Cambodian German Forestry Project, and Mr. CONRADO HARUELA, Wood Energy Planning of RWEDP, for making available valuable documentation. Financial support for this study was partially provided through a Grant-in-Aid for University and Society Collaboration from the Ministry of Education, Culture, Sports, Science and Technology of Japan (11794030).

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(Received 29 May 2002)
(Accepted 14 November 2002)

Article

Spatial Scheduling of Forest Management Activities using a Dynamic Deterministic Harvest Block Aggregation Process

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ABSTRACT

A dynamic, deterministic process for aggregating individual forest management units into larger harvest blocks was developed to allow a simulation of management behavior in support of the development of reasonable portrayals of forest policies in western Oregon, USA. The method described here dynamically aggregates individual management units into harvest blocks (a tactical goal), and the blocks are then fit to a variable (user-defined) clearcut size distribution (a strategic goal). One important objective with this work is that management behavior (the method for aggregation and the size distribution of recent clearcuts) is modeled or simulated, not optimized, for policy analysis purposes. Management units are selected for clearcut harvest and included in harvest blocks based on a valuation of the timber resource, and a determination of whether the size of the block is consistent with a clearcut size distribution. A close representation of management behavior facilitates a process whereby policy makers and landowners can evaluate alternatives to current policies, and begin to "think through" forest polices prior to implementing them.

Keywords: forest planning, forest policy analysis, simulation, harvest scheduling, area restriction model

INTRODUCTION

Forest policy analysis is increasingly relying on quantitative forest planning to provide an estimate of the spatial distribution of harvest activities over time under different policies, particularly to help understand the implications of different levels of forest management on the protection of biodiversity. A large-scale project to simulate the ecological, economic, and social aspects of forests of the Coast Range of Oregon (Coastal Landscape Analysis and Modeling Study 2002) for the next 100 years was developed with this policy process in mind. It requires a projection of the spatial nature of harvest activity. Future harvests in the Coast Range will likely occur largely through clearcutting of industrial and non-industrial private lands. To simulate the forest harvesting activities, the analysis process relies on a definition of individual land management units of similar characteristics as the building blocks for stand growth and yield. These, in turn, are aggregated into larger harvest blocks to emulate current management behavior. A dynamic, deterministic process for aggregating management units into these larger blocks, guided by a specified clearcut size distribution, was developed to facilitate this process. This process is part of the LAMPS (Bettinger and Lennette, 2002) simulation model. While Bettinger and Lennette (2002) provide a description of how to use LAMPS, they do not provide a detailed description of how newly developed processes within LAMPS, such as this, actually operate. Therefore the focus of this paper is on the description of a process (a dynamic, deterministic process for aggregating individual forest management units into larger harvest blocks) used to assist in the analysis of management behavior across broad areas and long time frames.

Strategic planning is generally characterized by processes that examine impacts and production over long time frames and large areas, with few spatial considerations recognized. Tactical planning is generally characterized by processes that examine impacts and production over short time frames and smaller areas, and addresses the spatial challenges involved in the development of a plan of activities. Public policy analysis is increasingly seeking a recognition of the characteristics of both approaches. As computer technology advances, the reasons for utilizing two separate approaches diminish, and as forest policy debates evolve, policy makers increasingly want

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to see impacts of proposed strategic policies depicted on maps of the landscape. The policy analysis example we use throughout this paper relates to the examination of forest policies across large areas, multiple ownerships, and long time frames. One group of landowners (industrial) have indicated that emulating their management behavior is important in the policy analysis debate. One behavioral aspect we emphasize with this paper is that the blocking process used by industrial landowners is not necessarily optimal. While they tend to center harvest blocks on high valued timber stands, they may also harvest nearby adjacent stands of lower value, in an effort to minimize the costs associated with harvesting the lower valued stands. Another behavioral aspect is that land managers install on the landscape clearcuts of a variety of sizes, and (either consciously or unconsciously) may avoid making all clearcuts as large as the maximum size allowed. These two aspects of their behavior are important if one were to adequately evaluate, over time and space, the policies (regulatory and organizational) currently in place. Thus an important objective of the research presented here is that management behavior is being *modeled*, or *simulated*, not *optimized*.

Our intent throughout this research has been to merge strategic and tactical considerations into a simulation model designed for public policy analysis. Modeling the objectives of long-range strategic plans and the important characteristics associated with tactical planning efforts can facilitate various facets of policy analysis, since the placement of management activities on a landscape affects where future activities can be located, which may in turn affect commodity production values, cumulative watershed effects, wildlife habitat arrangements, and aesthetics (JONES *et al.*, 1991; SNYDER and REVELLE, 1997).

One particular characteristic associated with tactical planning is the physical location of timber harvests. The size of clearcuts is increasingly becoming controlled by state or organizational policy, leaving forest managers to design clearcuts within a range of sizes. Early efforts in tactical planning centered on maintaining separation between individual management unit harvests, which are assumed to be internally homogenous and spatially stable over time (HOLMGREN and THURESSON, 1997). However, since individual management units are usually smaller (e.g., 15-20ha) than the maximum size defined in a policy (e.g. 50ha), such separation may come with a loss of flexibility in planning (SESSIONS and SESSIONS, 1991). Building harvest blocks within a forest planning process by aggregating adjacent management units, would alleviate some of this loss of flexibility, and allow the process to emulate actual management behavior.

The goal of the process described in this paper is similar to goals described by others (CLEMENTS *et al.*, 1990; LOCKWOOD and MOORE, 1993; WIGHTMAN and BASKENT, 1994), yet is different in several respects. First, previous efforts (CLEMENTS *et al.*, 1990; WIGHTMAN and BASKENT, 1994) defined harvest blocks *a priori*, whereas the process we describe allows block sizes to be changed as the harvest-scheduling considerations change. Second, CLEMENTS *et al.* (1990) chose the blocks for harvest randomly; our process uses a deterministic method for both building the blocks and scheduling harvest. ANDISON and MARSHALL (1999) described a blocking process by which disturbance theory is used to randomly choose pixels (25-m grid cells) in the development of blocks of various shapes, sizes, and frequencies. This is similar, in theory, to our approach, except that the method by which pieces of land are chosen for inclusion in larger blocks is random (ours is deterministic), and the treatment of management units as continuous variables (ours are integer variables). LOCKWOOD and MOORE (1993) employed an approach to recursively examine changes in harvest block size and membership with integer variables, effectively creating and modifying (building upon, splitting, or reducing the size of) blocks during a binary-search process. In contrast to their approach of iteratively modifying harvest blocks, our process builds blocks to certain specifications, then leaves them alone. If the binary-search parameters are changed, all blocks are effectively eliminated and the process begins anew.

Still another approach is that developed by HOLMGREN and THURESSON (1997), which assigns priorities to raster grid cells, based on harvest entry costs and sub-optimality losses, for units that could be added to or removed from harvest blocks. This value-driven approach differs from most other approaches, which emphasize spatial constraints as the main reason for adding or removing units from harvest blocks. Our approach is also value-driven, but it is based on potential revenue, not cost. Another difference is that our approach treats management units as integer variables, whereas HOLMGREN and THURESSON (1997) disaggregate management units into smaller pieces (grid cells), which may lead to the development of unharvested pieces of management units that cannot be efficiently harvested in the future.

The work presented here is relevant for three reasons. First, the geographic location of activities is important for biologists and economists who collaborate in strategic planning and policy analysis efforts, and desire to associate ecological or socio-economic models (which typically use spatial information) with the projected landscape conditions to estimate the effects of current and alternative policies. Second, replicating a historical distribution of patch sizes is important to closely represent the management behavior of certain landowners when simulating management activities, a goal of the Coastal Landscape Analysis and Modeling Study (2002). Finally, the results of policies which attempt to emulate management behavior have meaning for the stakeholders who evaluate the products (maps) of planning efforts and policy analyses. A close representation of actual management behavior facilitates a process whereby policy makers and landowners alike can "think through" current and alternative policies prior to implementing them. The more closely actual management behaviors are modeled, the more realistic the results may be perceived.

METHODS

Management units, spatially-defined pieces of land perhaps with different age class structures and tended at different times with various methods, are typically aggregated when final harvests (clearcuts) are scheduled on forest industry land in western Oregon. Although there is a variety of ownerships (federal, state, forest industry, non-industrial private) in western Oregon, this research only pertains to the management behavior of forest industry landowners. The reasons for aggregating management units are heavily influenced by regulations and organizational policies regarding the maximum size permissible for harvested areas, economies of scale regarding logging systems, and the need to convert low-valued forestland to higher-valued plantations.

The pattern of clearcut harvesting sizes in western Oregon over the past decade indicates that the contiguous area covered by these harvests tends to approach the maximum permissible by State law (48ha), yet not in all cases (Table 1). It was determined, based on several discussions with managers of industrial land in the region, that modeling this historical distribution in any type of policy analysis (current and alternative policies) was important. In addition, these managers noted that blocking management units for harvest was more reflective of their actual day-to-day decisions based on the reasons noted above. Therefore it should be clear that what we will soon describe, the application of a blocking algorithm to model management behavior across long time frames and large areas, is to simulate the management behavior of forest industry landowners. While the industrial forest landowners communicate the desire to be modeled as if they manage land under a net revenue maximization objective, in reality a mixture of stand types are blocked together in an effort to spread the costs associated with road building, and moving equipment to lower-valued management units over a broader revenue base.

Table 1. Distribution of clearcut harvest-block sizes in the central Coast Range of Oregon, 1991-1995.[1)]

Block size (ha)	Percent of total clearcut area (%)
1-16	16.7
16.1-24	14.3
24.1-32	15.2
32.1-40	17.3
40.1-48	36.5

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To set the context for the forthcoming discussion, the problem we are addressing is one where we are evaluating the activities on forest industry landowners in a 560,000 ha area of western Oregon. A binary search technique, embedded within a forest landscape planning model (LAMPS, described in BETTINGER and LENNETTE, 2002), is used to develop a schedule of activities over time. Binary search requires an initial harvest target level, a harvest level to use as an adjustment to the target level, and stopping criteria. For example, assume that the initial target level was 1,000,000 units per time period over a planning horizon, and that the adjustment factor was 100,000 units. If 1,000,000 units were successfully scheduled in each time period within a planning horizon, the target harvest level would be adjusted upward to 1,100,000 units. The binary search process would then clear from memory the schedule of activities, and attempt to meet the new volume target. If the target was not successfully met in any one time period, the target volume level is adjusted downward by the size of the adjustment factor (to 900,000 units), the binary search process would clear from memory the schedule of activities, and attempt to meet the new volume target. In addition, the adjustment factor is halved after each use. At some point, the adjustment factor will become quite small, and commonly a rule is used to stop the binary search process after it falls below some threshold value. In addition to the binary search process, the LAMPS model treats the scheduling of activities as an integer programming problem, thus the response surface is most likely irregular. Binary search may require some refinements to work efficiently under these conditions, an area of investigation we leave for future endeavors.

The LAMPS model allows users to modify a large number of parameters related to forest policy scenarios. To illustrate the harvest blocking process, we designed a LAMPS scenario to utilize some very basic assumptions: the time frame is 100 years (twenty 5-yr. time periods); the goal is to achieve the highest even-flow of timber harvest volume possible; harvest blocks will be designed to emulate a clearcut size distribution; and a minimum clearcut harvest age requirement (45 years) is imposed.

The ultimate objective of the scheduling process in LAMPS is to minimize the deviations of actual harvest levels from a target harvest level set during an iteration of binary search.

Minimize:

$$\sum_{t=1}^{T}\left[\sum_{i=1}^{I}\sum_{k=1}^{K}\left(x_{it}v_i V_{ikt}\right)-\text{targetvolume level}_t\right]$$

Where:

t = a time period
T=total number of time periods
i =a management unit
I =total number of management units
k =a forest product
K=total number of forest products
x_{it}=binary variable indicating whether (x_{it}= 1) or not (x_{it}= 0) management unit i is harvested in period t
V_i=area of unit i
V_{ikt} =Volume (per unit area) of product k during time period t in unit i

LAMPS, however, is a simulation model, and takes a slightly different approach to meeting this objective: the goals (target volume level$_t$) are defined for each time period during a binary search iteration. The scheduling of activities during a time period continues until the targets have been exceeded, or no other units are available for harvest. The resulting harvest levels are therefore usually slightly above (less than 0.01%) the target volume levels, unless the harvest levels cannot be achieved. In this latter case, the harvest levels are adjusted and the binary search process continues.

The minimum harvest age constraint allows a management unit to be considered for clearcut harvest in a particular time period:

$$\text{If Age}_{it} \geq \text{minimum harvest age} \qquad x_{it} \in \{0,1\}$$
$$\textit{Else} \qquad x_{it} = 0$$

Where:

Age_{it} = average age of the trees in unit i during time period t

The remainder of this discussion of methods relates to the harvest block size constraint. Management units are selected for harvest based on their "value", and perhaps blocked together for simultaneous treatment. Harvest blocks of various sizes are created, and an attempt is made to fit the distribution of acres by block size to a historical distribution to emulate the current management behavior.

There are two general approaches to applying spatial restrictions in forest planning efforts. First, the application of a technique called the "Unit Restriction Model" (URM) makes it possible to restrict harvest activity in units neighboring a unit scheduled for clearcutting, disallowing neighboring units from being treated in the same time period (or near-time periods). The technique would be invoked, for example, to prevent clearcut harvest of two adjacent management units in the same time period.

Constraints such as

$$x_{it} + x_{jt} \leq 1 \quad \forall i,t,j \in Ni$$

where

N_i = set of all management units adjacent to unit i

can be used to control URM problems (MURRAY, 1999). Management units are typically smaller than the maximum clearcut size restriction, and thus it may be important to schedule adjacent units for harvest to produce a feasible management plan containing "harvest blocks." In such cases, a second technique, called the "Area Restriction Model" (ARM), can be used to assign simultaneous treatments to adjacent planning units, as long as the total contiguous area does not exceed the maximum area limit (MURRAY, 1999). Here, we use the ARM technique to build harvest blocks to fit a clearcut size distribution. Recursive functions are generally used to evaluate the resulting spatially sprawling block of management units. To evaluate ARM problems, constraints such as

$$x_{it}v_i + \sum_{j \in N_i \cup S_i} x_{jt}v_j \leq A$$

where

S_i=subset of the total number of harvested units that contains all units adjacent to the neighbors of unit i plus all units adjacent to the neighbors of the neighbors, etc.
A= maximum permissible area of harvest block

are used. The blocking process we report here uses an ARM technique to evaluate the size of harvest blocks, and a URM technique to prevent two clearcut harvest blocks from merging together if they are being developed for clearcut during the same time period.

Defining Harvest Block Size Goals

Harvest block size goals come in many forms, such as a simple maximum size (e.g., in Oregon it is 48ha), a minimum size, or perhaps a range of sizes. In this research we had the goal of matching, or fitting, a historical range of harvest block sizes. To do so, the land area of forest to be clearcut in each period is first estimated. This estimate is made by determining how much clearcut area would be required to meet the binary search harvest volume target if one were to harvest the highest valued management units first, with no regard to the spatial positioning of the harvests. Then maximum area limits are used to define each harvest block size strata. For this study, the percentages of clearcut area in certain size classes (the strata) over the period 1991-1995 were estimated (Table 1). The area represented by each block size stratum is then calculated by multiplying the estimated total clearcut area by these percentages. We then know that for each stratum (e.g., 1-16ha), only a certain amount of area should be clearcut (e.g., Table 2, clearcut 167ha using 1- to 16-ha blocks).

Since exact achievement of these goals may be difficult, given the infinite number of potential combinations of harvest blocks and the desire to achieve an even-flow of timber harvest volume over time, minor deviations from these goals are allowed. The harvest-scheduling process builds the blocks and continuously sums the amount of area in each block-size stratum. In each binary search iteration, the largest block-size goal not yet met is the current maximum block size for blocks being built. Once the clearcut area for the largest block size has been surpassed, the next size available (that does not already comprise more area than is desired) becomes the maximum block-size goal.

Defining How Individual Management Units will be Chosen

Scheduling management units for harvest typically involves stand-level or forest-level optimization based on the contribution of the unit (e.g., net present value, timber volume, habitat characteristic) to the overall goals of the plan. To determine which management units to add to a harvest block, the units must be evaluated based on some shared attribute, and function of their current (and projected) condition. For example, "valuing" might mean the per-hectare timber value for each unit, minus logging and transportation costs. Valuing could, however, be based on other criteria, such as an ecological value (e.g., a habitat suitability index, or number of snags per hectare) or a socioeconomic value (e.g., recreation opportunity value), depending on the forest goals being addressed. For example, an ecological value (high or low) may be used to rank individual management units if we were to use this process to build habitat blocks.

Value, for this study, is represented in each time period t of an analysis by the net revenue, per unit area, from potential clearcut harvests:

$$\left[\frac{\sum_{k=1}^{k}\left(x_{it}v_{ikt}\left(p_{kt}-c_{kt}\right)\right)}{v_i}\right] \qquad \forall i;t$$

where

p_{kt} = Stumpage price for product k during time period t

c_{kt} = Logging and transportation costs for product k during time period t

This is a value per unit area, not a total net revenue. Negative or non-positively valued management units are not included in the blocking process. These units may include young plantations or other sparsely-stocked management units where the cost of harvesting outweighs the revenues that might be obtained. Therefore, the current version of the blocking algorithm only allows positively-valued units to be included in a clearcut harvest block.

Build and Schedule Harvest Blocks

Most scheduling techniques (particularly heuristics) typically use 1-opt or 2-opt moves to schedule harvest of either management units or pre-defined harvest blocks. 1-opt moves examine a change in a single characteristic of a single management unit to the objective function value of a forest plan. 2-opt moves examine a swap of a single characteristic among two management units (perhaps the clearcut harvest timing). The effect of these changes on a forest plan are subsequently assessed, and if some goals are violated, generally only the last change to the solution is reversed. In addition, these methods can consider changes to a forest plan across all time periods simultaneously. In contrast, a binary search technique generally schedules activities period-by-period, with no opportunity to simultaneously schedule activities across all time periods. With each change in binary-search harvest-scheduling criteria, all schedules for management units are removed from memory, harvest goals change, and new harvest blocks are formed. As mentioned earlier, an ARM technique is used to control the sizes of clearcut harvest blocks, and URM technique is used to prevent blocks from merging together. Our application of these spatial considerations differs from previous research in that (1) blocks are not defined *a priori*; (2) once blocks are formed, they are not adjusted incrementally; (3) blocks may change in size and shape from one time period to another; and (4) maximum block sizes may be adjusted as each successive block is built.

To schedule activities, net values are calculated for each management unit in each time period (Fig. 1). Harvest blocks

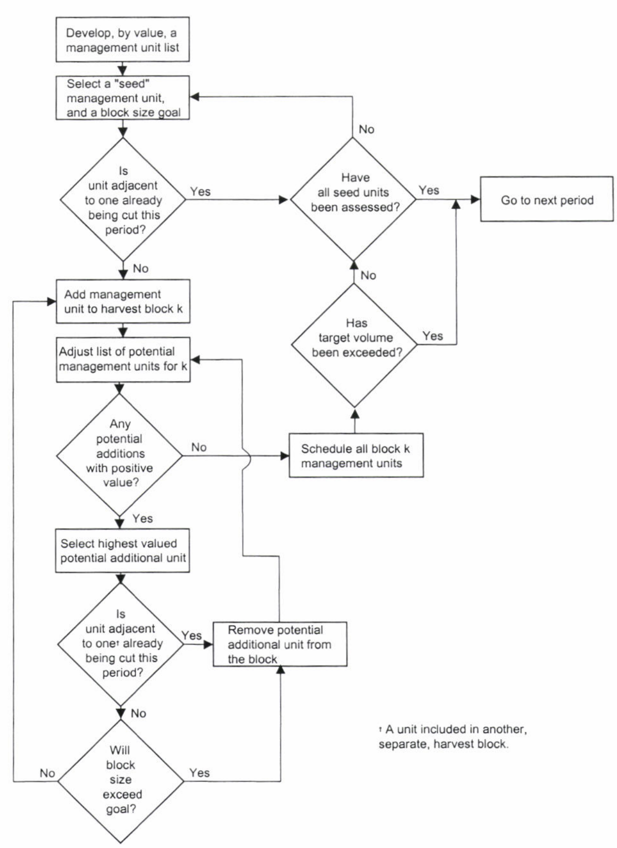

Fig. 1. A flow chart of the management unit blocking process.

were then built one at a time. The highest valued available management unit becomes the "seed" around which harvest blocks are developed. Other management units adjacent to the selected unit are then added to the harvest block until a size is reached where the total area does not exceed the maximum-size goal. Even if the block being developed closely approaches the block size goal, the blocking process continues to check all possible other additions (with a positive value) to see whether any more can be added to the block. It is only when all possible additions have been checked that the block is scheduled. Any additions that are added (temporarily) to the block and subsequently result in the block exceeding the size goal, are removed from the block, and removed from the list of additions. Then, the process proceeds to the next highest valued available management unit, not adjacent to a harvest block, and repeats.

A short example may help illustrate the process. Suppose we select a management unit (number 8 in Fig. 2(a)) as a seed. We then develop a list of adjacent units from which we select the highest valued (13) and add it to the block. Unit 13 can be added because the total block size remains under our maximum size, and the unit is not touching any other unit being cut this period (Fig. 2(b)). The list of adjacent units is then expanded to include those adjacent to unit 13. The highest-valued unit from the expanded list of adjacent units is then selected (number 18 in Fig. 2(c)), and so on, until the harvest block has been created. Units 3, 5, 11, 14, 17, and 18 are selected and rejected either because they touch another unit being clearcut during the current time period or because their addition to the block would make the block too large. No other adjacent unit to those in the block (2, 7, 9, 10, 16) has positive value, so the harvest block (units 6, 8, 12, and 13 in Fig. 2(d)) is scheduled for harvest.

This process continues, and harvest blocks are developed and scheduled, until predetermined criteria are met. In our case, the criterion is whether the target even-flow volume for the current period has been exceeded. If it has, we move to the next period and begin building harvest blocks for that period. If the target even-flow volume has not been met, we select another "seed" unit and begin a new harvest block. If the binary-search harvest-scheduling model changes the target even-flow volume, all harvest blocks are removed from memory, and the blocking process begins as if no blocks have been scheduled.

An additional level of complexity to the process is added when clearcut size distributions are considered. Fig. 1 alludes to the notion that a block size goal is selected before each harvest block is developed. Clearcut size distributions were described in an earlier section of this paper. The block size goal is a maximum size that an individual harvest block can become as each block is being developed. Areas clearcut for each block size strata (such as those noted in Table 2) are accumulated as each block is developed. The largest block size stratum where the area accumulated has not exceeded its projected total becomes the maximum size goal. Once the accumulated area for a clearcut block size stratum has exceeded its goal, the next smallest block size with accumulated area below its goal becomes the maximum size goal, and so on. Obviously, as harvest blocks are being developed, the resulting harvest block size may be less than the maximum size goal, due to the constraints involved in aggregating management units for harvest. While the blocking algorithm attempts to make the harvest blocks as large as the goal allows, the resulting harvest blocks may actually contribute area to smaller block size strata. At some point, the smaller block size strata may actually exceed their projected totals as a result of this process. As we will see, the block size goals serve as guides to the achievement of clearcut size distributions. The maximum area (A) of an individual block is constrained, yet the total area of clearcuts within a block size strata may not match exactly the areas projected for each strata.

Table 2. Projected amount of clearcut area, and potential number of blocks in different sizes, assuming 1,000 hectares will be clearcut in a planning period.

Block size (ha)	Area in clearcuts (ha)	Number of blocks[a] (#)
1-16	167	8
16.1-24	143	3
24.1-32	152	2
32.1-40	173	2
40.1-48	365	3

[a](Area in clearcuts / mid-point of block size range), rounded up or down to the nearest whole block.

Application to a Landscape

The landscape over which the harvest blocking process was applied is 560,000ha on the Coast Range of Oregon, of which about 206,000ha is in forest industry ownership and described by 20,544 individual forest industry management units. Each management unit is described by a set of tree lists derived from remote sensing (Ohmann and Gregory, 2002), and geographic information system databases describing the ownership pattern, the stream system, and other spatial features were used to characterize the landscape (see Coastal Landscape Analysis and Modeling Study 2002). Within the planning system, timber volumes are projected for over 2,600 hardwood, mixed hardwood and conifer, and conifer management prescriptions typical for the major landowners in the Coast Range of Oregon. The binary-search harvest-scheduling model (Bettinger and Lennette, 2002) is programmed in the C programming language and operated on a Pentium III 500 MHz computer with 2 Gb of RAM.

Fig. 2. An example of individual units being blocked together to create harvest blocks, from initial selection of the seed unit (a), to adding (b) and rejecting (c) potential additions to the block, to final harvest block configuration (d).

Included in block   Rejected from block

RESULTS AND DISCUSSION

When used in conjunction with a binary-search scheduling routine, which is driven by a goal of even-flow of timber harvest volume, the blocking algorithm consistently formed harvest blocks that resembled recent historical data (Fig. 3). The average length of time it took to develop harvest blocks for a single time period was approximately 3 seconds. The dynamic nature of the algorithm can be seen in the location of harvest blocks over a 100-year period for a sample of the landscape (Fig. 4). Here, we can see that the location of clearcut harvests, hence the harvest blocks, changes during each time period of the binary search harvest scheduling process. The members of each harvest block change in response to the constraints involved in the blocking process, and to a lesser extent, the volume goals of the binary search scheduling process. The harvest blocking process is thus dynamic, since block sizes and membership are not fixed in a spatial manner through time, as with other harvest scheduling processes (e.g. CLEMENTS *et al.*, 1990; WIGHTMAN and BASKENT, 1994).

For the results shown, no single block-size category exceeded its target by more than 12 percent. The modeled percentages do not exactly match the target percentages for two major reasons. First, harvest-block formulation is sensitive to the spatial arrangement of forest conditions (WIGHTMAN and BASKENT, 1994), as well as the temporal availability of a suitable condition (or value). Second, the maximum block size constraint equaled the largest block size that was available. As a result, smaller blocks were scheduled for harvest regardless of whether the maximum block size could be achieved. This, in turn, placed more area in the smaller block-size classes than the target allowed. As we mentioned earlier, once a block-size goal was achieved, the next available smaller block-size goal was evaluated; if this goal had already been achieved (and perhaps exceeded), the next smaller block-size goal was evaluated, and so on. Given the irregular shape of the management units and the fact that block-size goals could

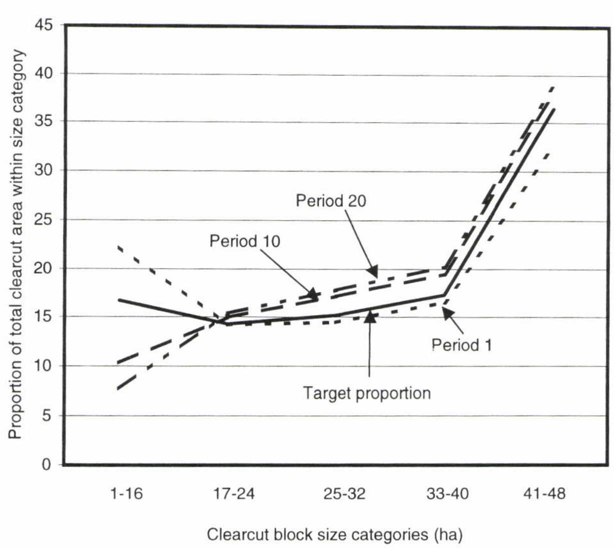

Fig. 3. Percentage of clearcut area in various clearcut size blocks when fit to a historical (target) distribution of clearcut block sizes.

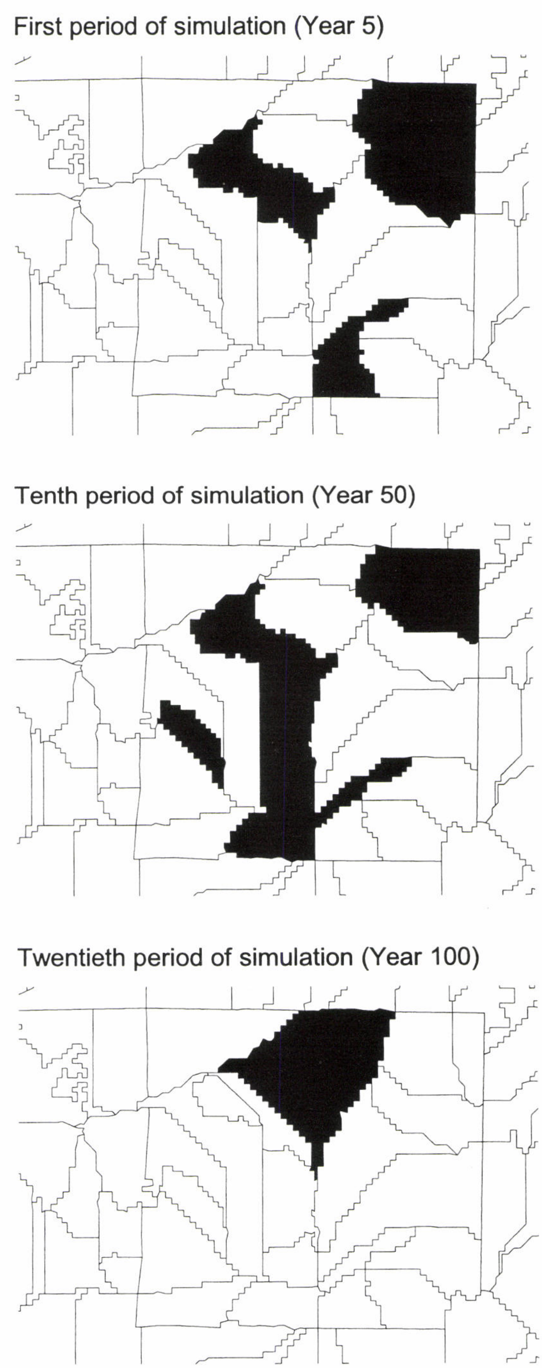

Fig. 4. Example of harvest block locations over time in a sample area of the 560,000ha landscape.

change within the binary-search harvest-scheduling routine, the process described here performed reasonably well.

One must recognize and acknowledge that utilization of these procedures results in an emulation of behavior, not an optimization of some management objectives. The solutions generated satisfy the constraints that are assumed under the quasi-objective function, within the simulation framework, to generate realistic solutions for forest managers and policymakers. To optimize harvest blocking solutions, one could define the harvesting order by comparing the value increment of a management unit to the opportunity cost of letting the unit continue to grow. An efficient solution (from an economic or ecological point of view) may also be achieved by optimizing the value of the blocks in association with the block-size goals using heuristic methods. However, a more detailed analysis of a large number of possible spatial and temporal combinations would be required. From a management behavior and policy analysis perspective, utilization of the procedures described in this paper does result in the production of realistic or acceptable solutions for the managers or policymakers (the problem currently being solved seeks to maximize even-flow subject to behavioral issues), and thus seems appropriate for strategic planning or policy analyses. Our feedback from stakeholder groups has affirmed this notion.

The discussion of management behavior, and whether it is optimal within the context of the management context in which it is applied, may cause some tension among members of stakeholder groups. Although it was not the intent of our research, some landowners may feel as if they are portrayed as sub-optimal managers. At the stand-level, management behavior probably has not been economically optimal given the forest-wide goals of each organization and the fact that human nature plays a role in the decision-making processes. In our efforts to develop reasonable alternatives to assist policy makers, our first and foremost goal was to produce results of a scenario where we assume that landowners will continue to manage their land in the future as they do today. This requires understanding how the forests are managed today. Some may argue that the purpose of planning is to find optimal ways of managing land, which may be true for individual organizations in their efforts to control costs and manage land in an efficient manner. However, how forest plans actually are implemented is what is important for public policy analysis. Thus our objective was first to model reasonably well current management behavior, then (in the future) to examine other ways of managing land that seek to benefit one or more other goals (economic, social, environmental) within the simulation framework.

A variety of planning approaches may be facilitated by the use of a blocking process such as the one described here, including the following alternatives which have arisen from discussions with stakeholder groups:

1. Use a blocking process to aggregate management units of lower value. An operable timber harvest area can be defined by a minimum harvest volume, perhaps of certain product types. Developing large blocks of lower-valued timber might provide a minimum harvest volume and sufficient revenue to exceed the costs of moving equipment in and around other logging sites. Conversion of low-valued, low-stocked forests to higher stocking might then be possible.

2. Set a single, large block-size goal. A block-size goal that is as large as possible, within regulatory and organization policies (i.e., 40-48ha), may address some of the economy of scale problems associated with smaller harvest blocks. It could also serve an ecological goal by reducing forest edge and maintaining a maximum amount of area in forest interior.

3. Develop large, yet compact blocks. Rather than using volume or economic value as the key criterion for including a management unit in a harvest block, an objective of minimizing the dispersion of management units within blocks might be useful. By minimizing the distances between the centers of the management units, the formation of long, narrow blocks would be discouraged.

4. Develop disjointed blocks. A "neighborhood" approach, rather than strict adjacency, could be used to define adjacency. In practice, units that are not physically adjacent, but that are separated by short distances, are sometimes scheduled for harvest together. Although geographic information systems (GIS) can recognize spatial distances other than strict adjacencies, doing so over large areas with varying degrees of "closeness" is difficult.

5. Build habitat blocks. This process is the inverse of the harvest-block process. Instead of developing harvest blocks of some maximum size, the algorithm could be used to identify habitat blocks of some minimum size. Similar processes have been described by BETTINGER *et al.* (1997; 1999; 2002). Examples include the development of blocks greater than some minimum size (e.g., 16ha) and containing only a preferred forest type (e.g., "older forest"), and the creation of large blocks (e.g., 160+ ha) that contain a minimum percentage of a preferred forest type and a maximum percentage of less-preferred types.

CONCLUSIONS

As public policy analysis evolves to include multiple ownerships, large areas, and long time frames, spatial and tactical models will increasingly be used simultaneously to better reflect the goals of managers and policy makers alike. One of our goals was to produce the most reasonable and realistic simulation of forest management behavior across a vast landscape (200,000 - 600,000ha). We feel that the blocking algorithm described here allows us to move ever closer to doing just that. While we did not directly compare the results from the use of this algorithm to those produce by simply scheduling activities based on maximization of economic criteria, we believe the process is beneficial because the stakeholders (industry representatives) associated with the study area have provided feedback that indicates that the process is consistent with current practice. It therefore meets our goal of emulating or simulation management behavior. In addition, the process will facilitate the evaluation of alternative policies, such as lowering (to reflect increasingly restrictive policies) or increasing (to emulate, to some extent, a natural disturbance regime) the minimum clearcut sizes.

The blocking algorithm we described is a dynamic one, in which forest harvest blocks are neither static nor defined *a priori*. The blocking algorithm is also deterministic (not stochastic) and based on a valuation of the individual management units. Other considerations (both spatial and non-spatial) are used to identify potential additions to a harvest block; these too are deterministic, not random. This blocking algorithm differs from previous work in harvest scheduling, which mainly considered adjacency restrictions among individual management units. As a result, a process such as this may be of use to forest planners and analysts who are interested in modeling realistic management goals to support forest planning and policy analyses.

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(Received 24 July 2002)
(Accepted 9 December 2002)

Article

Recognition of Spectral Pattern Characteristic of Land Cover for Assisting Visual Interpretation of Landsat ETM+ - A Forest Degradation Mapping in Tropical Rain Forest of Sabah, Malaysia -

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ABSTRACT

The study was originally designed to assess vegetation diversity in Borneo's tropical rain forest with ecological consequence that can be retrieved from Landsat ETM+. We were particularly interested in recognition of spectral pattern of land cover for developing land cover and forest degradation mapping by visual analysis of satellite imagery in Sabah, Malaysia. In addition unsupervised, supervised classification, band ratio of TM4, TM4/TM5, and TM2/TM7, and pattern decomposition analysis were tested to evaluate the interpretation. We proposed a reliable method of forest degradation mapping in Sabah from land cover map incorporated with their spectral pattern. Dense forest was found clearly discriminated from water and soil by using visual interpretation and pattern decomposition analysis, particularly in channel 3, 4, and 5. However, it was difficult to discriminate spectral pattern of non-forest through decomposition analysis. Logged-over forest was found dominant in the study area (36%), followed by plantation (21%), and only about 17% covered with natural dense forest. It is estimated that approximately 76% of the forest in Sabah, have been threatened with forest degradation.

Keywords: spectral pattern, land cover/use, Landsat ETM+, forest degradation.

INTRODUCTION

Borneo Island, next to the Amazon of Brazil, is the second largest tropical rain forest ecosystem in the world. It has the most species-rich communities known anywhere else on earth and performs important environment and landscape function (Whitemore, 1975). However, the vegetation biodiversity of Borneo tropical forest has been poorly studied and understood although it is subject to be intensive converting for timber extraction, agriculture, mining and settlement. Therefore, study of characteristic of land cover is important source for understanding the vegetation biodiversity. Availability of land cover information is a prerequisite for understanding the global change process and will enhance our capability to predict land use and vegetation pattern and global forest environment (forest fire, degradation forest etc.) for forest management strategies.

Recently, several image classification techniques have been developed to map land cover and forest degradation (Langford and Bell, 1997; Shimabukuro *et al.*, 1998). In general, methods to extract land cover/use from remotely sensed data can be summarized as: Visual Analysis (VA) (Lillesand and Kiefer, 1987; Howard, 1991), Multivariate Spectral Analysis (MSA) (Mather, 1987; Smith, 1999), Spectral Mixture Analysis (SMA) (Adam *et al.*, 1986; Thompkins *et al.*, 1997), and Data Integration (e.g. Conway, 1997). The most famous technique to extract information from satellite imagery that still preserves the highest information on vegetation is the Normalized Difference Vegetation Index (NDVI) (Jensen, 1996). However, as noted by Shimabukuro *et al.* (1998), NDVI has a drawback for monitoring land cover and

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deforestation in tropical area. As NDVI value appeared higher for re-growth forest compared to mature forest, and bare soil or pasture has low NDVI, it is very difficult to construct a simple deforestation classification using this index.

Many studies have showed problems in automatic classification for vegetation cover in tropical region such as insufficient discrimination of old and mature re-growth, early growth and plantation, pasture with trees, and dense agriculture (e.g. BOYD and RIPPLE, 1997; STEINIGER, 1996). Perhaps, as stated by KUCHLER and ZONNEVELD (1988), this problem is due mainly to the spectral diversity and complex pattern within tree layers in tropical region, as they appear in the image. For example, the natural rain forest in Sabah Malaysia, described as the ever-wet tropical forest (WHITEMORE, 1975), is subject to constant moisture and water supplies that hampers the application of automatic classification.

A relatively new technique of fraction image based on SMA was proposed to derive land cover/use map and land degradation monitoring (SHIMABUKURO *et al.*, 1991, 1998). This technique principally estimated the fractional composition of a pixel. However, as noted by THOMAS *et al.* (1996) some uncertain associates and ambiguous results were found with fractional estimation of SMA technique for large and non-homogenous area, such as in tropical region. Some misclassification was also found with this technique for discrimination between natural forest and re-growth forest in tropical region (STEININGER, 1996). Thus, application of SMA for land cover mapping in a large area like Borneo not helpful.

Data integration most often deals with application of Synthetic Aperture Radar (SAR), due to its advantage in penetrating clouds. However, application of SAR data for land cover/use mapping, particularly for heterogeneous area like the Borneo tropical forest, most often produced ambiguous result, and was also visually difficult to interpret, due to complex relationship between radar back scattering and vegetation type (CONWAY, 1997; TETUKO *et al.*, 2001).

To overcome the problems of land cover mapping in the tropical forest, visual interpretation is mainly applied (KARTERIS, 1985; LOBO *et al.*, 1998; ROY and TOMAR, 2001; SCHMITT-FÜRNTRATT, 1992). This technique is based not on the pixel, but on the characteristic of group or feature of the pixel that appears in the image, so it does not lose information on the spatial detail. Several studies have noted the difficulty in visual interpretation of satellite data to discriminate some tropical vegetation types in Amazon, such as the difference between old secondary forest and disturbed primary forest, early succession or growth forest and mixed crop (APAN, 1997; SADER *et al.*, 1990). However, these finding may be environmental specific, and only applicable in lowland environment, such as in Amazon tropical forest, rather than in Borneo tropical rain forest that is ecologically different in land use type, soil, and altitude.

So far, land cover/use of tropical Amazon forest of northern Brazil has been well studied (e.g. BATISTA *et al.*, 1997; MALINGRREAU and TUCKER, 1990; STEINIGER, 1996). However, a few studies are available on the land cover/use and forest degradation in Borneo tropical rain forest by using high-resolution satellite imagery, in particular from ecological aspect. Therefore, study of the potential Landsat Enhanced Thematic Mapper plus (ETM^+) for deriving land cover/use information and forest degradation mapping incorporating with the understanding the spectral pattern is essential.

OBJECTIVE OF STUDY

This study was originally designed to assess vegetation diversity of tropical forest in Borneo with ecological consequences that can be retrieved from Landsat Enhanced Thematic Mapper plus (ETM^+). At present we are particularly interested in developing land cover/use type and forest degradation mapping by visual delineation of satellite imagery. Our objectives were, (1) to characterize the land cover/use type that can be accurately retrieved with visual analysis from high resolution remotely sensed image, and (2) to map degradation forest and discriminate natural forest from other land cover/use, as this data is considered to be important for forest fire hazard model (DARMAWAN *et al.*, 2001) and ecological study (KITAYAMA *et al.*, 2001).

STUDY AREA

The test site was located in Sabah Malaysia (northern part of Borneo island). the area lies within 115°8' to 118°6' E and 4°1' to 7°4' N (Fig. 1). The study area represents montane, highland and lowland rain forest ecoregions. The montane and highland forests are mainly along the western and central part of the study area, with altitude ranging from 1,500 to 4,000m. Dominant vegetation in this region is composed of the Indo-Malaysian (e.g. *Dipterocarpacea*), East Asian (e.g. *Fagacea*), and Australian (e.g. *Dacrycarpus* sp. and *Leptospermum* sp.) flora (MUI HOW, 2002). On the lower slope of montane forest (between 1,000 to 1,500m), dominance of *Dipterocarpacea* is replaced with Oak (*Quercus* and *Lithocarpus* spp.) and chestnut (*Castanopsis* spp.) (WWF-full report). Swamp and mangrove forest are dominant in lowland regions mainly spread along eastern to northern part of coastline. Shifting cultivation looks dominant in the hill area, as well as logging and plantation in the central region. The northern part of the area, timber species (*Acacia mangium*) was planted by the Sabah Forest Department in former grassland to eliminate forest fire hazard (JALIN, 1999).

Climate is typically rainy, with hot and rainy season through out the year. Mean air temperature normally is around 30°C in lowland area and decreases as a function of elevation, with minimum temperature between 9.7°C and 18.4°C at the top of Kinabalu. The annual rainfall can reach approximately 3,230 mm (WHITEMORE, 1975).

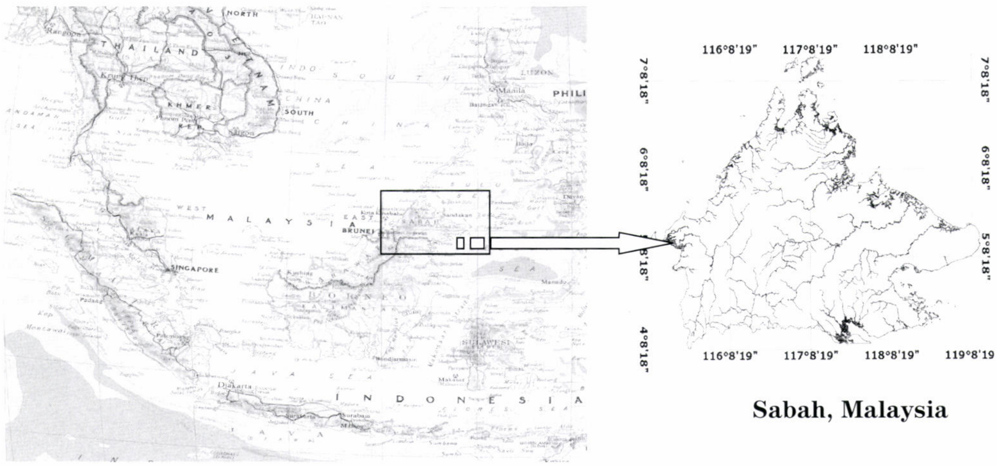


Fig. 1 Study site

MATERIAL AND METHODS

Conventional methods based on the multivariate classification of pixel (e.g. MATHER, 1987) often produce inadequate results to resolve forest discrimination such as between dense forest and mangrove or secondary forest cover in tropical region, particularly when working with high resolution imagery such as Landsat ETM$^+$ (Fig. 2). We choose Landsat ETM$^+$ due to its advantages over other remotely sensed data in spatial and temporal resolution.

Seven Landsat ETM$^+$ images for Sabah (Fig. 3) along with other reference map were used in the present study (Table 1). These images were carefully selected from moderate to fairly clear data, mostly during the wet season. Since we could not get data of the same date, initial attention was on finding the relation vegetation cover in each Landsat ETM$^+$ channel. We found no significant change in land cover type within the image. Standard geometric correction were applied to Landsat ETM$^+$ and showed residual less than 1 pixel. Band rationing of TM4, TM4/TM5, and TM2/TM7, as recommended by SCHMITT-FÜRNTRATT (1992), were also used for interpretation.

The normalized stretching (SMITH, 1999) was previously applied to Landsat ETM$^+$ images to enhance visual discrimination between land cover/use. An interpretation was carried out based on the basic element of interpretation, proposed by HOWARD (1991) and LILLISAN and KIEFER (1987) for aerial photo interpretation, such as texture, tone/color, shadow, pattern, site and association. This element was supported by recognition of vegetation distribution and physiographic of the study area, during thematic map revision in East, West, and Central Kalimantan-Borneo (DARMAWAN *et al.*, 1996), and ecological study in Sabah, Malaysia (KITAYAMA *et al.*, 2001).

Once delineation was done, it was scanned by Scanplus III Calcomp device and converted to vector for further analysis.

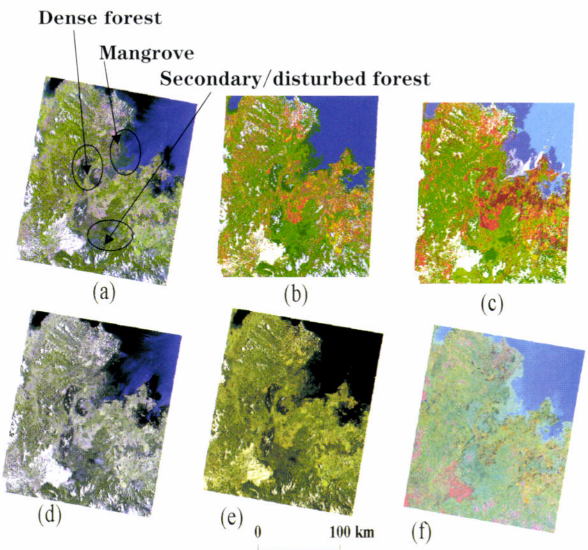


Fig 2. Image channel 543 (a), Unsupervised (b), Supervised (c), Decomposition image of bare-soil, dense forest, and water (d), decomposition image of bare-soil, dense forest, and mangrove (e), ratio of TM4, TM4/TM5, and TM2/TM7 displayed in red green blue respectively (f). Dense forest is clearly distinguished from mangrove in image (a), (c), (e), and (f) but not clearly seen in image (b) and (d). In image (e) and (f) dense forest is difficult discriminated from secondary forest or log-over forest as is clearly separated by image (a) and (c)

With this method we can precisely delineate on the edge boundary of land cover/use. However, this procedure has a critical drawback, as the result may include pseudo error (e.g. sliver polygon and dangle/ undershoot line) within vector data that required editing, until it was verified that the delineation boundary adequately represented different objects. The last

Table 1. Data used in the present study

	Landsat ETM+		Reference map		
No	Path/Row	Date Acquisition	Theme	Data Source	source
1	116/56	18 September 1999	Natural and Plantation Forest map	Sabah Forestry Department 1989	Aerial photo and data compilation
2	116/57	7 November 2000			
3	117/55	9 September 1999			
4	117/56	9 September 1999	Land cover map	Kitayama et al. (2001)	1992-1993 MESSR-MOS* data
5	117/57	9 September 1999			
6	118/56	2 October 1999			
7	118/57	21 December 1999			

*the Japanese Marine Observation Satellite

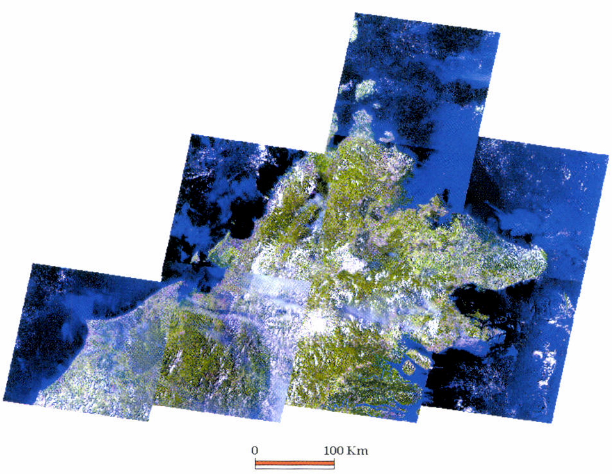


Fig. 3. Mosaic of Northern Part Borneo Island from landsat ETM+ displayed in band 543 for red green and blue respectively. Data is acquired during rainy season of 1999. Dark green indicates densed forest, and pinkish to light red is mainly sparse vegetation or plantaion

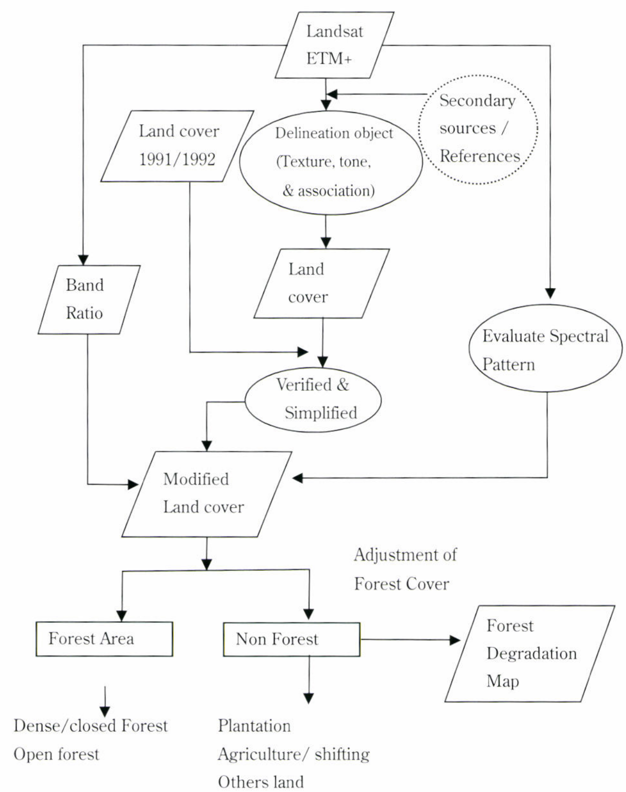


Fig. 4. Flow chart of the protocol followed in this study

step was deriving deforested map by separating forest with other land cover type with reference to FAO classification (1973), which was employed for forest inventories in tropical area.

In addition unsupervised and supervised classification and Pattern Decomposition Analysis (PDA) was tested to evaluate the interpretation. The PDA technique is slightly different from the SMA technique. In PDA, the pure pixel of water, soil, and vegetation were initially extracted from all Landsat ETM+ channel. This pixel is called as end member. Since our interest is on forest cover, pure pixel of water, soil and dense forest and open forest were selected as end member from their homogenous area in the image. This pattern was used to separate land cover of forest and non-forest. More details of unsupervised and supervised classification methods are given in Smith (1999) and PDA in Fujiwara *et al.* (1996). All the analysis was done with TNTmips ver. 6.6 software packages. The protocol followed is shown in Fig. 4.

RESULT AND DISCUSSION

Characteristic of Land Cover in the Study Area by Visual Interpretation

Several combinations of "pseudo natural color image" (ERDAS, 1997) were obtained for Landsat ETM+. A Combination of TM5, TM4, and TM3 for red green and blue were selected for the baseline delineation of land cover. This composite enhanced the visual discrimination between natural forests and others land cover categories (Fig. 2(a)). In combination of TM4, TM4/TM5, TM2/TM7 displayed for red, green, and blue, the dense/closed forest was clearly depicted in purple to blue, mangrove in light blue and soil in brown color contrast to other land cover (Fig. 2(f)).

It is not surprising that a few classes of land cover/use did not coincide appropriately with class of the reference map as shown in Table 2. This finding does not mean "mis-interpretation" as we questioned before, but rather depicts to the association of land cover map. The difference perhaps is due, mainly to the recovery process or intensive conversion in the study area during the year of 1992 to 1999, as well as the fact that Landsat ETM+ provides better spectral and radiometric resolution than MOSS data.

As the interpretation mainly depends on the experience of the interpreter, the recognition of plantation distribution and physiographic data were useful to support interpretation. Even though, it showed that the boundary of vegetation cover as delineated on the Landsat ETM+ may include combinations of land cover (vegetation crown, shadows, plantation, soil etc.). Through interactive editing it was observed that the large portion of homogenous vegetation cover was found in the land cover classes.

Five elements of photo interpretation were found useful for discrimination of land cover: texture, tone, color, site and association. Other elements such as size and shape were not clearly depicted in land cover class. Based on visual analysis of

Table 2. Association between land cover classes derived from Landsat ETM+ and the reference map

Land cover/use map from Landsat ETM+	Natural & Plantation Map of Sadah Forestry Department	Land cover/use map from MOS
Ultrabasic	Virgin jungle, Park/ protected area	Ultrabasic
Montane forest	Virgin jungle, Park/ protected area	Ultrabasic forest
Lower montane forest	Virgin jungle, Park/ protected area	Dense/ closed forest
Secondary forest	Protection forest reserve, Plantation	Logged over forest
Mangrove forest	Mangrove	wetland
Swamp mix forest	Protection forest reserve	wetland
Log over forest	Protection forest reserve	Dense/closed forest
Sparse vegetation	Plantation, domestic forest reserve	shifting cultivation
Agriculture area	Other land use	Shifting cultivation
Shifting cultivation	Plantation, Protection forest reserve	logged over forest
Plantation	Protection forest reserve Plantation	Plantation
Urban area	Other land use	Shifting cultivation

mosaic Landsat ETM$^+$ (Fig. 3) the actual land cover was derived. The mosaic image gave the consistency delineation within boundary of land cover and detail forest environment. Land cover/use of Sabah was classified into nine classes, which was derived with ecologically meaningful legends: natural dense/closed forest (consist of ultrabasic, montane, lower montane), secondary forest, lowland forest (mangrove forest and swamp forest), logged-over forest, sparse vegetation, agriculture low land (paddy), shifting cultivation, plantation, and urban. Ultrabasic and montane forest, have similar tone and texture and they are mainly separated with elevation in the image. These natural forests resemble moist evergreen forest referred by SCHMITT-FÜRNTRATT (1992) for tropical forest inventory. Natural dense/closed forest, mangrove and swamp forests appeared different in texture, tone and association.

The texture of dense/closed forest was found coarse in the image. Coarse texture represents the lower montane forest, while fine texture represents ultrabasic and montane forest. The discrimination between secondary forest and the lower montane forest is quite difficult with visual interpretation, as also reported by SADER *et al.* (1990) and APAN (1997). However, secondary forest showed bright to red green color with magenta tinge, while the lower montane forest has dark green color, thus tone and color appropriate for distinguishing these land cover.

Open forest (e.g. logged-over forest) showed medium to light green tone with coarse texture. This is true because the rain forest structure in Borneo is generally composed of three to five layers of vegetation growth (WHITEMORE, 1975), and many of the smaller trees grow in the shade of the larger one, usually dense and not fully exposed to the sunlight. On these complex structures many shadows will exist between vegetation layers, and might result dark and fine texture. However, human intervention on the natural forest in tropical region has resulted in large change of vegetation composition (e.g. ROY and TOMAR, 2001) and exposed soil surface. The presence of soil might give brighter green color and coarse texture. Shifting cultivation mainly exists in the lower montane forest, because this forest is confined to a less complex terrain, while the montane forests are less utilized for shifting cultivation. Plantation is mainly spread in the lowland area towards mangrove. Detail visual description of each land cover is shown in Table 3.

Characteristic of Spectral Pattern of Land Cover/Use in Study Area.

Similar with spectral mixture analysis, in PDA it is assumed that spectral reflectance from a land surface, or a pixel, is liner combination of the spectral reflectance from varied component, mainly composed as water, soil and vegetation, thus the proportion of each component type, theoretically, can be estimated. PDA involves measurement of reference spectral or end member value from the field or laboratory work. Several number of end member would be possible to select, but a finite number of spectral references should not excite the number of available band plus one (THOMPKINS *et al.*, 1997).

In present study, the reference spectral pattern of forest and non-forest were selected from their homogenous area in the image. The proportion of end members were calculated based on the distance between minimum pixel value of Landsat ETM$^+$ for channel 1, 2, 3, 4, 5, and 7 and mean pixel value of the end member spectral pattern. Decomposed image that consist only three component of water, soil and forest or non-forest cover was derived for assisting visual interpretation. The discrimination of land cover by visual interpretation from several methods is shown in Table 4.

Spectral pattern of forest and plantation showed a typical healthy vegetation reflectance. In general, their reflectances are low in channel 1, 2, and 3 (visible channel) and channel 7 (infrared channel). A little increase sees in channel 2 and maximum increase sees in channel 4 and 5 (Fig. 5). Since all Landsat ETM$^+$ data are acquired during rainy season, the presence of water and well-managed plantation might result in healthy plantation trees, which has reflectance similar with dense forest. Log-over forest, ultrabasic and secondary forests were found similar in spectral reflectance, and their spectral reflectance cannot be discriminated with the PDA technique. However it was possible to separate between these forest covers and mangrove or montane forest.

It is quite easy to discriminate water and soil from forest cover because of their different response, particularly in channel 3 (red) and channel 4 and 5 (mid to near infrared). However, it was difficult to discriminate between soil and non-forest cover type such as paddy, shifting cultivation, urban and sparse vegetation. The reflectance of soil commonly is higher than soil covered with vegetation such as sparse vegetation or paddy soil, but the presence of water in the soil during rainy season has decreased the reflectance of soil. Thus their spectral reflectance was similar, which tends to have increase from the visible to mid and near infrared channel. The spectral pattern of forest and non-forest cover is shown in Fig. 5.

Forest Degradation Map

Deforestation is a major issue in tropical countries, leading to the destruction of tropical rainforest, which is a valuable resource. Currently there is no single standard definition of forest degradation although there has been a long history of forest degradation. The term forest degradation used in this study is, the interrupted or exploitation forest area including cultivated area, except for settlement, as concluded from DARMAWAN *et a*l. (2001). This degradation mainly results from the interaction of human, natural hazard (e.g. forest fire) and agriculture-related.

The proportion of forest degradation area in Sabah is

Table 3. Characteristic of land cover/use in study area

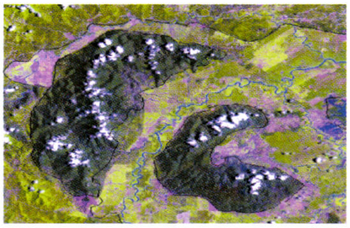
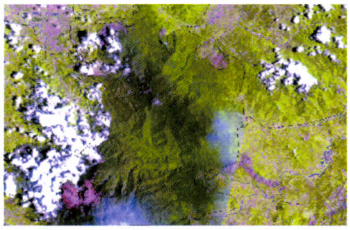
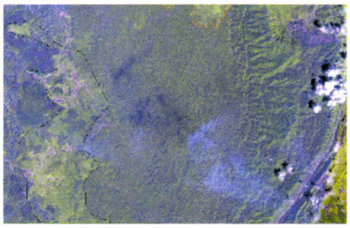
Land cover/use	Tone & Color	Texture and Pattern	Association	Image
Ultra basic Forest	Dark green	Fine Irregular	On steep and high slope, mostly in accessible area, and shadow	
Montane Forest	Dark green	Fine Irregular	On steep and high slope, mostly in accessible area, and shadow	
Lower Montane Forest	Dark green with magenta tinge	Coarse Irregular	Mainly at lower elevation of montane forest	
Secondary forest	Light to red green	Coarse Irregular	Gentle elevation, close to urban area	
Mangrove forest	Dark green with bluish tinge	Fine Irregular	Low elevation and along the coast line	
Swamp mix forest	Bright and dark green	Medium coarse Irregular	Low elevation between big river, mainly along the backside of mangrove areas	

Table 3. Characteristic of land cover/use in study area (continue)

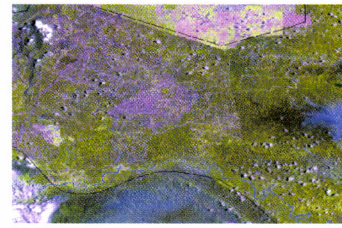
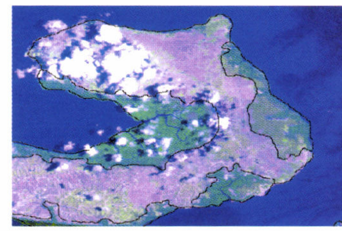
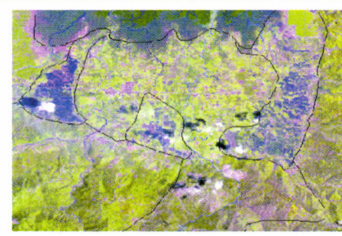
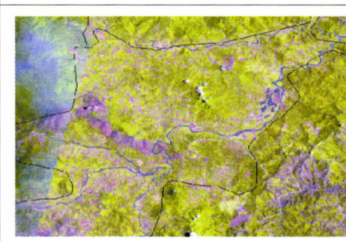
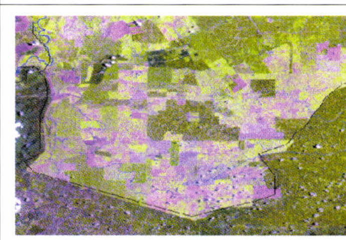
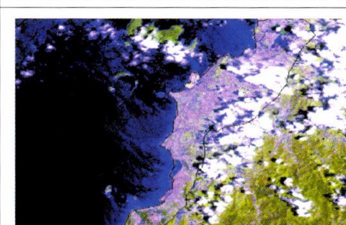
Logged-over forest	Medium to Light green	Coarse Irregular	Logging activities.	
Sparse vegetation	Pinkish to light red	Coarse Irregular	At gentle to steep slope, most often is abandoned Plantation.	
Agriculture area/paddy	Bluish green	Coarse Irregular	Low elevation close to settlement	
Shifting cultivation	Light blue green	Coarse Irregular	Distributed sporadically on moderate to steep slope. It seems to be mosaic of small open-land or clearance.	
Plantation	Light to red green	Medium Regular	Low elevation and road network	
Urban area	Red to white	Medium Regular	Road network or other human communication	

Table 4. The spectral pattern of land cover/use as seen in the image
(Visible (+), difficult (-), and doubtful (*))

Land cover/use class	Visual RGB		Unsupervised	Supervised	Pattern Decomposition Analysis
	ETM+ band 5, 4, 3	Ratio image of 4, 4/5, 2/7			
Ultrabasic	+	-	-	-	*
Montane forest	+	+	+	*	+
Lower forest	*	-	-	+	*
Mangrove	+	+	+	+	+
Swamp forest	+	+	+	+	+
Secondary forest	*	+	+	+	*
Logged over forest	+	-	-	*	*
Plantation	+	+	-	*	+
Agriculture/ paddy	+	-	+	*	+
Shifting cultivation	+	-	-	-	-
Sparse vegetation	+	-	-	-	-
Urban area	+	-	-	+	*
water	+	+	+	+	+
Soil	+	+	+	+	+

Table 5. Classification of land cover in study area

I. Forest Area
I.1. Natural dense/closed forest: Non cultivated area, more than 70% of the ground as seen in the image was covered by the crown of medium to larges trees
a. Ultrabasic
b. Montante
c. Lower montane
d. mangrove
e. Swamp mix forest
I.2. Open forest: Interrupted or exploitation forest
a. Secondary forest
b. Logged over forest
II. Non forest: Cultivated area
a. Plantation
b. Agriculture
c. Grassland
d. Shifting cultivation
e. Sparse vegetation
III Urban area: settlement

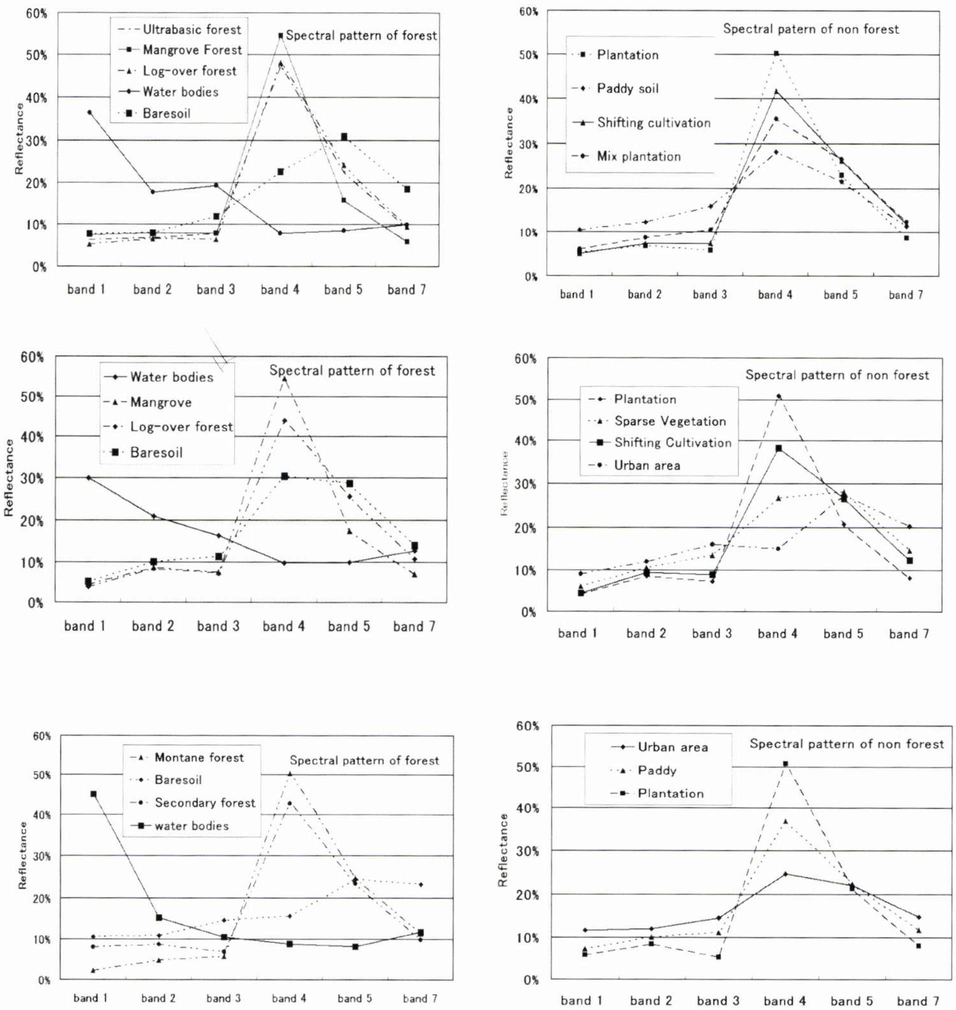


Fig. 5. Spectral pattern of forest and non forest

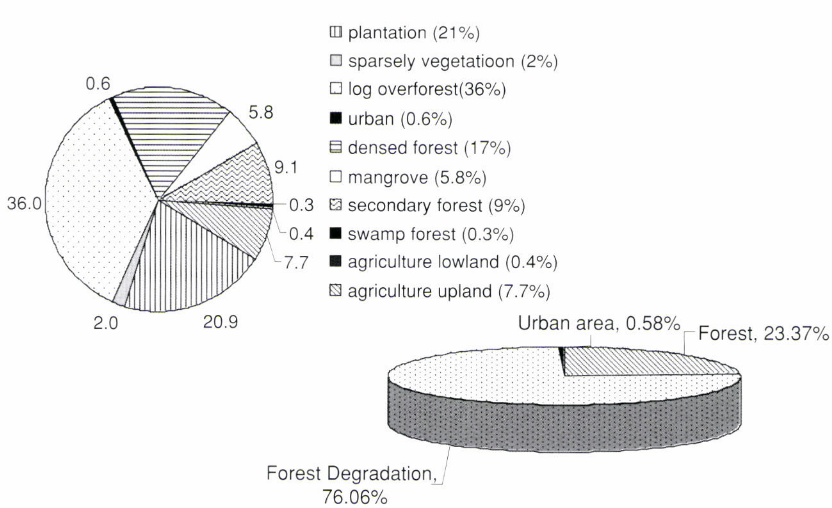


Fig. 6. Percentage of land cover/use and forest degradation in Sabah in 1999

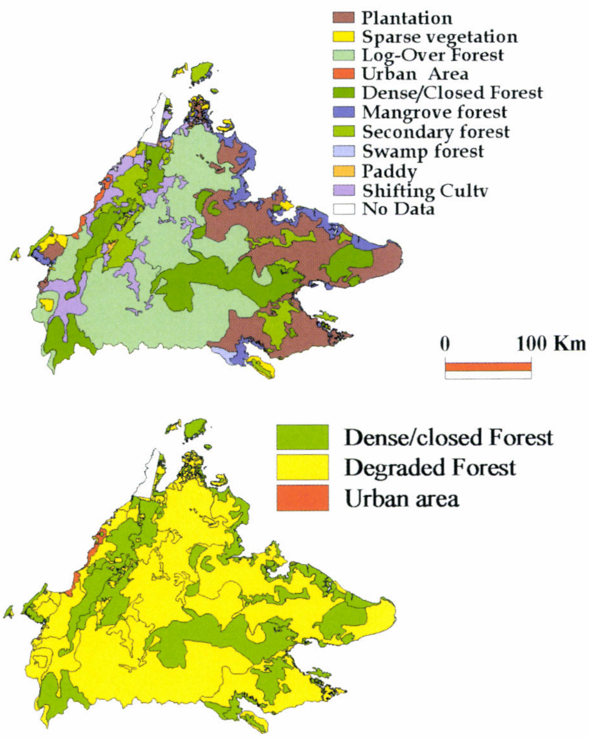


Fig. 7. Land conver/use of Sabah, Malaysia derived from Landsat ETM+(a), Forest degradation map derived from land cover (b)

calculated from total number of open forest (I.2) and non-forest (II) (Table 5), except for urban area. It is estimated that around 76% of Sabah area was actually categorized as forest degradation area, and only 23% is considered as natural forest (Fig. 6). The final map of land cover/use and forest degradation is shown in Fig. 7. The proportion of land cover/use area in degradation area is dominated by Logged-over forest (36%), followed by plantation (21%), and shifting cultivation (8%). It is estimated that only 17% of the natural forest actually is covered by dense/closed forest (Fig. 6).

CONCLUSION

This study shows that visual analysis of Landsat ETM+ supported with recognition of spectral pattern can derive land cover/use map and forest degradation area of tropical region, which would be difficult by single automatic classification. An image texture is a fundamental element for discriminating natural forest in tropical forest. Tone and color is useful to determine natural forest with disturbed forest, and association is useful for recognizing human made object.

Although visual analysis can derive land cover in tropical rain forest region, it is labor intensive and often subjective as well as difficult to estimate the accuracy for huge area. Since land cover/use is a dynamic process it is also difficult to provide land cover map following rapid changes on the ground by visual analysis. On the other hand, remote sensing focused on the development of coarse scale vegetation dynamics is a promising tool for evaluating the characteristic of ecological structure and vegetation dynamic process including land cover change detection. Such technique applied to global data set (e.g. SPOT Vegetation, MODIS) will be useful for land cover and forest degradation mapping of the major regions of Borneo Island.

ACKNOWLEDGMENTS

Mulyanto Darmawan is grateful to the Centre for Ecological Research, Kyoto University and Forestry and Forest Products Research Institute, Ibaraki, for the assistantship for data synthesis. We are sincerely thanks to Dr. Osamu Nakakita, Forestry and Forest Products Research Institute, Ibaraki, Japan for invaluable insight, helpful and used of remote sensing facilities. We are also highly thankful to Dr. Neelam Ramaiah (Tokyo University) for comment and editing the manuscript.

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(Received 19 August 2002)
(Accepted 28 January 2003)

Article

Changes in Land Use Practices of Indigenous People in the Chittagong Hill Tracts of Bangladesh - An Analysis of Political-Economy Perspective -

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ABSTRACT

The Chittagong Hill Tracts (CHT) of Bangladesh is the home of a half million of indigenous people. Land rights of these people are based on customs and traditions that dates backs to many centuries. Their land use systems also differ from other parts of the country. They have been living on shifting cultivation locally known as *jhum* for centuries and the relationship between the indigenous people and this subsistence cultivation enriched their cultural identities through ages. But this old-aged land use practices are seriously affected by the development programs carried out by the governments in different periods of time. The development programs were little regard for their impact on the indigenous people and their way of life; many of the programs became inconsistent regard for the indigenous people, their value systems and traditional life. The traditional subsistence land use systems have gradually been changed to market oriented land use practices. The life styles of the indigenous people have also been changed to closer link with market economy. Many indigenous people, now-a-days, have become wage labor losing their resource base to the outsiders or to the government agencies. With the failure of government intervention in the resource management in the CHT, it is suggested that participatory approach of resource management where the local people should be included and their indigenous knowledge should be the basis for designing such intervention of resource management.

Keywords: land rights, land use, indigenous people, Chittagong Hill Tracts, Bangladesh

INTRODUCTION

The principle of sustainability has appeared in the development theory in the last few decades since there were mounting evidences of negative impact of environmental degradation on economic development and thus, growing concern about human livelihood. The issues of natural resource management in the mountainous areas of many tropical and sub-tropical countries have been an important priority in recent years. The indigenous peoples of those mountainous areas have been managing the resources with their traditional knowledge and customs. The traditional economy of themselves is called as subsistence economy which is completely need oriented, which means that production aims—and therefore the overall level of production—are geared to fulfilling the totality of individual and communal needs. But many of the indigenous communities today find themselves confronted with conditions which have seriously disrupted their economies and social systems and do not allow them to continue with their traditional resource use practices any more. Many of the encroachments on indigenous territories happen in the name of 'development', are projects and programs which pretend to be guided by the aim to make a more rational use of respective land and resources (ERNI, 1995). When communities traditionally have managed resources in sustainable manner, government claims may destroy any incentive to continue to do so (LYNCH and ALCON, 1994). In many cases these development programs did not bring any positive sign in

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resource management rather became the root causes of the conflicts between the stakeholders. The indigenous people of the many areas of the world were seriously affected by the government policies, lost their resource base and became marginalized. The ongoing conflicts over land and resources in many indigenous areas are the result of the failure of government intervention in resource management. The World Commission on Environment and Development considers the marginalization of indigenous peoples as a clear indicator of a misguided development:

"In terms of sheer members, these isolated, vulnerable groups are small, but their marginalization is a symptom of a style of development that tend to neglect both human and environmental considerations. Hence, a more careful and sensitive consideration of their interests is a touchstone of sustainable development policy" (World Commission on Environment And Development, 1987).

Like other indigenous territories in the world, various policies and programs have been implemented from the time of the first colonial power—the British—to the present national administration, in the Chittagong Hill Tracts (CHT) of Bangladesh. Sometimes the policies and programs contributed towards political and economic chaos in the region frequently stained by bloodshed. Many of these programs have become inconsistent regarding the indigenous people and their value systems and traditional knowledge. Adverse impact created by the implementation of development programs and rising political and social insecurity among the hill people following non-recognition by the constitution resulted in an armed insurrection insurgency in the CHT for long two decades (Dutta and Rahman, 1999). The Peace Accord(1) signed in December 1997 has put an end to insurgency in the CHT.

Prior to the Peace Accord, the CHT had practically remained inaccessible for research and empirical exploration for long two decades. The last few years, however, there is an increase in the literature on the CHT. International aid agencies have commissioned a number of explanatory surveys mainly to assess the local needs and development potential of the indigenous people in the CHT (e.g., Danida, 2000; ADB, 2000; AusAid, 2000). Gain (2000) provides an introductory overview of the ecology and living conditions in the CHT. Amin (2000) compiled a useful summary of the major public legislation regarding governance of the CHT. Roy (2000) offers a detailed account of the politics of land rights in the CHT, focusing on such issues of land laws, role of selected international conventions and institutions. Van Schendel *et al.* (2000) introduce the life and livelihoods of the people of the CHT. Chakarborty (2001) has compiled some historical records on the shifting cultivations in the CHT. A number of international observers have assessed the political and human rights situation in the CHT such as CHT Commission (1991) and Tebtebba Foundation (2000). Ali and Tsuchiya (2002) provide a historical analysis of policy issues on indigenous land rights of the CHT.

The last few years, the CHT has attracted attention of both academics and development activists. There have been seen something of an upsurge in the study on the CHT in many academic institutions in home and abroad. Notwithstanding the enthusiasm, however, basic in-depth studies on indigenous land rights and land use practices are conspicuous by their absence or very limited presence. No study has been found dealt adequately using filed level data particularly examining the impact of developing programs on resource use practices in the CHT. This article attempts to examine the impacts of the development programs on indigenous land rights and how it affected the resource use system and way of life style of indigenous people. The goal of this article is to explore the changes in land use practices in relation to the impacts of development programs on the indigenous land rights in the CHT. The following attempts were done to achieve the goal of the study:

1. Analyzing the current land use practices in the study area;
2. Comparing the changes in land use practices and land rights in the different villages of the study area; and
3. Evaluating the effects of different government policies on the indigenous land rights and land use practices in the CHT.

METHODOLOGICAL CONSIDERATION

The fieldwork for the study was carried out in April and May of 2002. The field work methodology mainly consisted of observation, oral history analysis and informal interviews with a cross section of the people of the CHT. No formal questionnaire was administered; instead we had a simple check-list of possible discussion topic and a field diary where virtually any observed phenomenon of interest was noted. During the course of discussions many issues emerged spontaneously—some were quite relevant, some were not. Though it was difficult to keep pace with the varied issues and responses, which were cropping up during the meetings, we tried our best to make note of as many issues as possible. While talking to the respondents, particular attention was given to their land rights and changing pattern of land use system.

Prior to the fieldwork, secondary data were collected through reviewing literatures from different sources. The first author visited the three districts of the CHT two times in December 2000 and in June 2001 for the purpose of selecting the study sites and interviewed the key persons of the areas. The criteria for the selection of the study sites were as follows. First, we selected one village where there is no development program was implemented nearby, and we selected other villages where different development programs were implemented. Second, accessibility in the villages was considered. Third, security situation was kept in mind to visit the villages because the CHT is still not totally secured to visit anywhere of its villages.

At the time of collecting data from every village or para,[2] the village *karbari*[3] was interviewed to collect the general data on the village. As key informant, *mauza*[4] headman[5] provided data on para, households, and *jhum* cultivators. The selection of respondents was purposive, only the head of the family was selected as respondent. The issue of neutrality and objectivity were responded in three ways: by being aware of and acknowledging the situation, by cross-checking the information gathered from observation and interviews, and by relating our findings with other regional studies.

THE CHT AND THE STUDY SITES

The CHT is the south-eastern part of Bangladesh, bordering the Arakan and Chin State of Myanmar, and Tripura and Mizoram States of India (Fig. 1). From the time immemorial, the CHT have been the home of about half a million of indigenous people divided into 13 individual groups. They are of Sino-Tibetan decent belonging to the Mongoloid race and closely resemble the people of north-east India, Myanmar and Thailand rather than the Bengali population of Bangladesh who are a mixed [race] comprising proto-Austroloid, Mongoloid, Caucasoid and Dravidian strains (AHMED, 1993). The region now includes three administrative

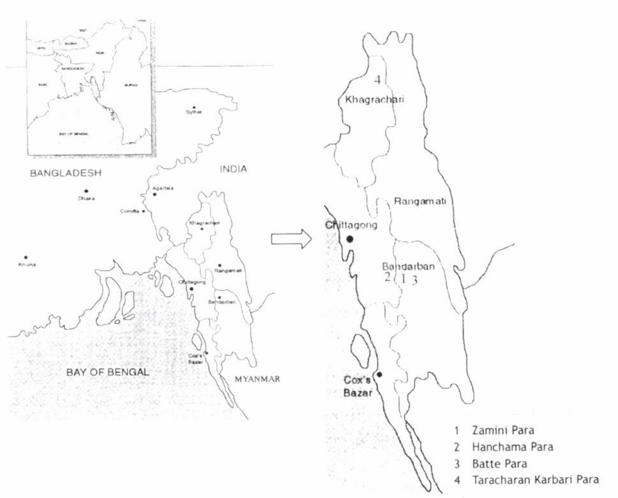

Fig. 1 The CHT of Bangladesh and the locations of the study sites

districts namely, Rangamati, Khagrachari and Bandarban covering an area of 13,295 square kilometer in extent or about 10% of the surface of Bangladesh (ROY 1998). The area of the CHT is roughly the size of Iwate Prefecture of Japan. While most of Bangladesh is flat, the CHT, a unique territory with mountains, is completely different in physical features, landscapes, agricultural practices and soil condition from the rest of Bangladesh (GAIN, 2000).

The CHT has forest of 83.8% of its total area. All the forests owned by the national government are divided into Reserved Forests and Unclassified State Forests (USF) (Table 1). Reserved Forests are managed by the Bangladesh Forest Department (FD) and the USFs are under the control of local district authorities. Population-wise the CHT have the lowest density in the country of 96 persons per square kilometer compared to the national average density of 827 persons per square kilometer (GAIN, 2000).

We selected three villages from Bandarban and one village from Khagrachari districts as our study sites (Fig. 1). The selected villages or paras are situated around 8 to 20 km from their nearest town (Table 2). Zamini Para is a Mru village about 16 km away from Bandarban town. This is a village where there is no significant impact of development program was found. The Batte Para is situated in comparatively remote area. It is about 20 km away from Bandarban. Up to 2000, there were 41 families in this village but additional 14 families came to this village from Ashur Para, which is now completely occupied by Bangladesh Army. Now there are 55 families in this village. Batte Para is a village, which is directly impacted by the militarization. Hanchama Para is about 8 km away from Bandarban inhabited by Marma people. There is a very big afforestation project of FD near the village. Taracharan

Table 1 Land Utilization of CHT and Bangladesh
(in thousand hectare)

	CHT	%	Bangladesh	%
Total Area	1,335	100.0	14,906	100.0
Forest*	1,120	83.8	2,265	15.2
Reserved Forest	280**	25.0	1,375	60.7
USF	840	75.0	733	32.4

Source: Bangladesh Bureau of Statistics, 1999
Note: *Forest indicates not only forest cover but forest land as well.
**Reserved forest in the CHT includes protected forest which is about 1% of total forest.

Table 2 The study sites, the respondents and their ethnic identities

Name of village	District	Distance from town	Ethnic identity	Total households	Respondents	% of Total households
Zamini Para	Bandarban	16km	Mru	31	10	32
Hanchama Para	Bandarban	8 km	Marma	80	8	10
Batte Para	Bandarban	20km	Mru	55	11	20
Taracharan Karbari Para	Khagrachari	20km	Chakma	36	10	28

Karbari Para is a Chakma village of Khagrachari district. The villagers came here from Rangamati district in 1962 being uprooted by the creation of Kapati dam, which submerged their hearths and homes. Near the village, there is a village of Bengali settlers namely Rashik Nagor.

MAJOR POLICIES AND PROGRAMS IMPLEMENTED IN THE CHT

During pre-colonial era in the CHT, lands of this region were communally owned and cultivated communally. Lands, outside the cultivated areas, were not owned by anyone or any community. All members had free access to lands, forests, rivers, and other natural resources. There was no private property in the CHT (DEWAN, 1990). The CHT was first ceded to the British East India Company in 1760 and following the Soldiers Uprising of 1857, the British took over the direct administration of the Indian colonies from the East India Company. (MOHSIN, 2002; GAIN and MOROL, 1995). Two hundred years of British colonial rule in India came to an end August 1947 with the emergence of two independent and sovereign countries Pakistan and India. Bangladesh emerged as an independent state in 1971 from what was then East Pakistan after the turmoil of a bloody civil war. British followed a policy of non-interference, as far as possible, in the internal affairs of the CHT. But the post partition period and Bangladesh period have had horrendous implications for the indigenous people particularly in the areas of land dispossession and disturbance to their economic and cultural life (ALI and TSUCHIYA, 2002).

A good number of development programs were carried out during the period of 1960s and the signing of Peace Accord in 1997. Many of these programs are playing in the loss of indigenous peoples' self-determination, the subsequent degradation of natural resources and changes of resource use practices. Brief descriptions of major policies and programs are given below.

Creation of Hydro-electric Project

A hydroelectric power plant was constructed in the CHT in 1962 with the funding of USAID. The Karnaphuli river was dammed and the reservoir it created occupied a huge area of 66,300 hectare. It had the distinction of being one of the largest man-made lakes in the world at the time (ROY, 2000). The immediate fallout of the project was that an artificial reservoir (known as Kaptai Lake) submerged dwelling houses of 18,000 indigenous families as displacing approximately 100,000 people from their hearths and homes many of whom migrated to Mizoram, Tripura, Assam and Arunachal Pradesh of India (GAIN, 2000). This artificial reservoir also submerged 21,950 hectare of arable lands, which were about 40% of the total cultivable land of the region. Besides, the reservoir submerged many establishments like schools, markets, hospitals and about 68900 hectare of forests (BANGLADESH DISTRICT GAZETTEER, 1975). With these outright effects the project generated discontent and anger among indigenous people in the CHT.

Militarization in the CHT

The hill people were dissatisfied with the adverse impact created by the Kaptai dam. Again the non-recognition of their separate identity by the Constitution of independent Bangladesh in 1972, the cleavages in relation between the indigenous people and the central government became sharpened. The conflicts at last resulted in armed insurrection and insurgency in the CHT. As a counter insurgency measure, there are a large number of armed personnel in the CHT since 1975. The insurgency was identified as 'national security' problem, and a large number of armed personnel were deployed in the region. The CHT underwent a full-scale militarization in the later part of 1975 (MOHSIN, 2002). The involvement, and the influence, of the armed forces is to confined to security matters, but extends to socio-economic issues (CHT COMMISSION, 1991). The situation has not changed till date. Despite assurance to the contrary from the government of Bangladesh, the CHT still remains under de facto military rule (ROY, 2000). The application of this counter-insurgency strategy in the CHT has been a major factor in the problem of land dispossession of the indigenous people as a result of the policy.

Population Transfer Program

Side by side with militarization, the central government adopted another counter insurgency strategy with can be termed as government sponsored transmigration program. The program was designated to change the demographic composition in the CHT so that the Bengalis could outnumber the hill people and dominate them and thereby help diffuse insurgency. This program was started in 1979 and continued to 1984. Within this time period, about 400,000 landless persons from plain districts were settled in the CHT (ROY, 2000). The settlement of Bengali people became an issue it created another conflicts in the area, it was a constant threat to maintaining the separate identity of the indigenous peoples and their area. Because the traditional land rights of the indigenous people began to erode as the settlers started grabbing hill people' s lands. In the backdrop of already existing problems in the CHT, the settlers had to dispossess the indigenous people of their lands.

Afforestation Projects of FD

In 1980 the government of Bangladesh undertook a scheme of commercial plantation in the CHT to make the region commercially profitable. Accordingly the FD occupied many USFs and started plantation. The afforestation policy implemented in the CHT highlights a systematic pattern of violations of traditional land and resource rights of indigenous people. Once an area acquired by the FD for plantation, the indigenous people lose access to such land. Thus there has been a considerable decrease in area of land remaining open and accessible to indigenous people to eke out of living. The FD's plantation projects have encroached upon the lands of indigenous people. As a consequence, they are struggling hard to preserve their traditional life style and cultural values centering round forests.

CURRENT LAND USE PRACTICES IN DIFFERENT VILLAGES OF STUDY SITES

Jhum Cultivation: Traditional Land Use

Jhum, a traditional swidden cultivation, is the predominant and subsistence farming practiced by all the indigenous people in the CHT. This cultivation system is carried out predominantly on the steep slopes of the high hills. Under this system, a cultivator selects a convenient piece of land in the months of January and February. Then the *jhum* cultivators cut all the secondary vegetation except the large tress. The cut plant materials then spread uniformly through out the field for drying. Usually these are dried for one month to ensure good burning. Burning of the dried plant materials is done within the middle of March to the beginning of April. After burning the *jhum* field in the spring, the farmers start planting seeds with the one set of the rains in the early monsoon (April/May). They mix seeds of different crops—rice, cotton, melon, pumpkin, millet, beans, gourds, maize, oil seeds, ginger, sesame etc. and plant them in small holes at fairly even intervals. Undesired weeds are pulled out by hand in the month of May and June. As *jhum* cultivation is a multi-crops production system, harvesting is done as and when a particular crop is ripened. The maize ripens about in the middle of July; melon, vegetables and rice are harvested in September and October; and cotton and sesame in November and December. The schedule of cultivation work during a year is shown in Table 3. The cutting, burning and planting operation is done in a collective way. Generally 4~5 people make a group (locally known as *trukut* activity) mutually help one another in cutting, burning and planting. The whole family might get engaged in *jhum* cultivation, which requires hard labor and incessant care.

Land Use in Zamini Para

Zamini Para is typical village of the CHT where all the inhabitants are *jhum* cultivators. The village is about 16 km far from its nearest town. It consists of 31 households, all of them belong to Mru ethnic community. The village *karbari* informed us that they have been practicing jhum cultivation for generations, they are *jhum* cultivators by born. The villagers maintained fallow period of 10~12 years in the past and produced 70~80 *haris* of rice. *Hari* is the local unit of measurement to denote both land area and crop. The population of this village has increased during the last 30 years (from 12 families to 31 families) but total land area available remaining constant. The respondents tell us that they maintain 5 years fallow period at present. The frequent return of the farmers to the same land has resulted in decline in yield from 70~80 to 30~35 *haris* (Table 4). According to the respondents, the production from *jhum* field cannot meet up their necessity. They started to produce some cash crops and fruits like chilly, sesame, cotton etc. The farmers started to use chemical fertilizer in their *jhum* fields, which they buy from vendors in Bandarban. The using of fertilizer was introduced in this village in the early 1990s. Now-a-days they use 4~5 kg white fertilizer in one *hari jhum* field.

Land Use in Hanchama Para

Hanchama Para is one of the nearest villages to Bandarban town and its communication is much better than other villages. The people of this village were engaged in *jhum* cultivation till 1980. The concept of private property rights became popular with its introduction in the CHT in early 1900s. The people who had ability took permanent settlement that time and became the owner of private land. All of the flat lands along with a portion of hilly lands were settled as private lands. The flats lands have been using for plough cultivation and private hilly lands, which are known as grove[6] lands, have been using for forestation. The unsettled hilly lands nearby the village remained as USF which the villagers used as their

Table 3 A typical activity calendar of the jhum cultivators

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cleaning the forest	—	—										
Drying in the sun		—	—									
Burning			—	—								
Sowing and planting				—	—							
Weeding & protection					—	—						
Harvesting							—	—	—	—	—	—

Source: Field survey

Table 4 *Jhum* cultivation in different villages of study area

Name of villages	*Jhum* cultivators	Fallow period (years)		Production** (*hari*)***		Use of chemical fertilizer
		In past*	At present	In past	At present	
Zamini Para	100%	10~12	5	70~80	30~35	started to use chemical fertilizer since early 90s
Hanchama Para	Traditional *jhum* cultivation has been disappeared					started to use chemical fertilizer in plough lands since 80s
Batte Para	100%	10~12(OI)+ 7~8(NI++)	7(OI) 3(NI)	70~80	45~50(OI) 25~30(NI)	NI started to use chemical fertilizer since 90s
Taracharan Karbari Para	30%	9~10	3~5	60~70	15~20	started to use chemical fertilizer since 80s

Source: Field Survey

Note: *In past indicates the time about 3 decade ago

**Production means how much rice (in *hari*) is produced using 1 *hari* seed

****Hari* is the local unit of measurement to denote both land area and crop, (1 *hari*=approx. 10kg)

+OI=Old Inhabitants

++NI=New Inhabitants

common lands and practiced *jhum* cultivation. In 1980, the FD occupied all the *jhum* lands (approx. 125 hectare) of this village for plantation. The local people no longer use these lands for jhum cultivation as it has become the sole property of the FD only. Now there are several types of land use in the village. These are: (a) government forest, (b) forestation in privately owned grove land, (c) plough cultivation in privately owned valley land, and (d) fruits and vegetables gardening in the homestead land(7).

Land use in Batte Para

The Batte Para is another village where *jhum* cultivation is the dominant land use. This village is relatively far from the town and situated in a remote area. All of the villagers are *jhum* cultivators. Like other *jhum* cultivators in the CHT, the villagers also practice *jhum* for generations. The new inhabitants who were forced to migrate here from Ashur Para are also completely *jhum* cultivators. The old inhabitants maintained a comparatively long fallow period and their *jhum* plots were big (Table 4). After the migration of new inhabitants, the old inhabitants provided them (new inhabitants) a portion of *jhum* lands. The people of Ashur Para were very familiar with chemical fertilizer since 1990s and they used it in their *jhum* fields. The old inhabitants of Batte Para are also familiar with fertilizer but they still do not use it in their *jhum* fields. The new inhabitants use chemical fertilizer two times in a season as they used in Ashur Para. About 4~5 kg chemical fertilizer is used for one *hari jhum* field. The old inhabitants produced 70~80 *haris* of rice in the past, now their production has been reduced to 45~50 *haris* and the new inhabitants produce 25~30 *haris* only (Table 4).

Land Use in Taracharan Karbari Para

Taracharan Karbari Para was established in 1962 by the Chakma people who were uprooted from Rangamati district by the creation of Kaptai dam. The communication of this village better, which was developed since 1978 after the military camp established near the village. There are several types of land use practices in Taracharan Karbari Para. There are plough cultivation in valley lands, fruits and vegetables gardening in the homesteads and *jhum* cultivation. There is no enough common land for practicing *jhum*. A portion of the inhabitants of this village was engaged in plough cultivation in their private lands which they got as compensation of their loss in Rangamati. The maximum portion of the common lands of this village (approx. 160 acres) where they practiced *jhum* cultivation was occupied by the Bengali settlers in 1982. The settlers village namely Rashik Nagor, a cluster village, is one of the biggest settlers village in the CHT (1,200 families consist approx. 5,000 people). The Bengali settlers took maximum *jhum* lands in 1982 and since then *jhum* cultivation stared to be practiced in limited perspective with a short fallow period (Table 4). Recently the villagers produce fruits and vegetables in their homesteads and sell these products to Dighinala bazaar. All most every family of this village has homestead garden. According to the respondents, they were very familiar with chemical fertilizer since 1980s and they started to use it in their *jhum* fields, homegardens and plough lands.

Land Use Types in the Study Sites

Several types of land use practices were found in different villages of our study sites. The valley lands, all of which are privately settled, are extensively used for plough cultivation. *Jhum* cultivation is practiced where common lands are available. Many indigenous families involved in cash crop production as mixed crops with *jhum* cultivation. Fruits and vegetables production in the homestead gardens is also a current land use practice in the study sites. The people are using chemical fertilizer for producing more products even in the *jhum* fields as well.

COMPARISON OF LAND RIGHTS AND LAND USE IN DIFFERENT VILLAGES OF STUDY SITES

Land Ownership in the Study Sites

Three types of land ownership were found in the study sites—private lands, national forests and common lands. In all villages the homestead lands are occupied by the indigenous people according to their customary law and also recognized by the CHT manual[8].

Private lands are settled by the names and the owners can sell it to others. The common lands are treated as USFs or *khas*[9] lands, no one has formal right in it. The government treats this type of land as state property. The indigenous people use it for their *jhum* cultivation. In our study sites of Zamini Para and Batte Para, there is no private land, all the available lands for the villagers are common lands. The concept of private land is totally absent in Zamini Para and Batte Para. On the other hand, in Hanchama Para and Taracharan Karbari Para, there are privately owned lands. All the valley lands of the two villages are already settled as private property. The concept of private property was introduced in the later part of 19^{th} century by the colonial government with the introduction of plough cultivation in the CHT. The privately owned lands are divided into three classes—first class land (plain valley land for wet rice cultivation), second class land (land for upland dry rice cultivation) and third class grove land (hilly land for forestation). The private lands are managed by the government authority through the Deputy Commissioner[10].

The national forests both the reserves and USFs are treated as public property owned by the government. No one is allowed to practice any kind of economic activities in the reserve forests without the permission of the FD. The local people are allowed to use the USFs, the indigenous people use it as common property. Rights and interest of common lands are administered by the indigenous institutions according to customary law and include provisions for the control, use and management of the lands and its resources. The indigenous institutions are comprised of *karbari* at the village level, headman at *mauza* level and the Chief[11] at circle level.

Influencing Factor(s) of Land Use Change

According to the respondents, the people of every village of our study sites were engaged in jhum cultivation. Before the introduction of plough cultivation, private ownership of land was totally absent in the CHT. With the introduction of plough cultivation, all the available valley lands were settled as private lands. Plough cultivation was practiced in the valley lands and *jhum* cultivation was practiced in the common hilly lands. The people of Hanchama Para and Taracharan Karbari Para started to plough cultivation when this cultivation system was introduced there in 1960s. But the people did not stop practicing *jhum* rather it existed simultaneously with plough cultivation (Table 5). A portion of people of both the villages always engaged in *jhum* cultivation. The common lands of Hanchama Para was totally occupied by the FD for commercial plantation in 1980. Since then the local people have no right to

Table 5 Pre-dominant and dominant land use and influencing factor(s) of change

Village Name	Predominant Land Use	Current Dominant Land Use	Significant change in production	Influencing factor(s)	Attitude towards FD/military/settlers
Zamini Para	*Jhum* cultivation	*Jhum* cultivation	Subsistence production matches with cash crop production	Population pressure	People do not hold strong negative attitudes towards FD, military or the settlers
Hanchama Para	Chiefly *jhum* cultivation	Afforestation project, and plough cultivation	Subsistence production has completely been disappeared	The acquisition of the FD	Very strong negative opinion against FD specially those who lost their land to FD
Batte Para	*Jhum* cultivation	*Jhum* cultivation	Subsistence production still exists, people started to produce cash crops recently	The militarization	Very strong opinion against military
Taracharan Karbari Para	Chiefiy *jhum* cultivation	Home gardening and plough cultivation	Subsistence production has not been found	The militarization and Bengali settlement in the area	Very strong opinion against military and settlers. A portion of the respondents blamed the FD too

Source: Field Survey

access to that lands where they previously practiced *jhum* cultivation. In Taracharan Karbari Para, the common lands have occupied by the Bengali settlers in 1980s. Fruits and vegetables production in the homesteads is practiced in both the villages for commercial purpose for earning cash. Homesteads gardening for commercial purposes became popular in the 1970s. Different government agencies, such as Horticulture Development Board (functional since 1973) and the Chittagong Hill Tracts Development Board (operating since 1976), inspired the indigenous people to produce fruits and vegetables in their homesteads. This is also a significant change of land use in the CHT. *Jhum* cultivation in both Hanchama Para and Taracharan Karbari Para has been changed basically due to government sponsored development programs. *Jhum* cultivation still exists as dominant in other two villages (Zamini Para and Batte Para) of our study areas (Table 5). Producing cash crops and practicing fruit production is very recent activities in Zamini Para. The people of Batte Para also started to produce cash crops (e.g. banana) in their *jhum* lands. The new inhabitants of Batte Para are more active in producing cash crops. When they were in Ashur Para, they were familiar with producing cash crops with *jhum* cultivation.

Land Use Change and their Impacts on Life Style

The changes of land use brought many other changes in the life style of the indigenous people. For simplicity of analysis, the respondents of each village were grouped according to their current land use as well as their activities. According to the use pattern, the people of Zamini Para are divided into two groups (Table 6). Although both the groups are basically *jhum* cultivators, some of them produce some cash crops such as cotton, sesame, chilly etc. with rice and vegetables in *jhum* plots. Other group emphasizes to produce fruits such as banana, mango, jackfruit, orange etc. in the gardens of their homesteads. The farmers sell these products to Bengali middlemen who came to them with tracks. The indigenous people thus earn money by selling their products and spend it for maintaining their livelihood.

The people of Hanchama Para can be divided into three different groups (Table 6). The first group is the owner of both plough and grove lands and is economically better than the other two groups. They stopped *jhum* cultivation more than three decades ago, before the FD's operation in their area. The people of this group were not affected by the land acquisition of the FD. Rather they were benefited by plantation in their own grove land, the plantation method was learnt from the FD. The second group is the owner of plough lands; they cultivate their own lands and act as tenants of other landowners. This group practices *jhum* till the FD started its plantation projects in Hanchama Para. The people of the third group are landless and survive as wage-labor. They were basically *jhum* cultivators but at present there is no land left for them to practice *jhum*. When the FD decides to clear the forests making suitable for plantation, then FD allowed the local people to practice jhum for one year only. Not everybody can get this chance from FD to do so. After clearing the forests, the FD then starts plantation. This is done actually for clearing the forest before plantation. The group II and group III work with FD and earn money. In this sense, the FD opened up the villagers (both for the male and female) for cash income.

Both the old and new inhabitants of Batte Para are *jhum* cultivators. The old inhabitants still maintain relatively large *jhum* plots. Before their coming of new inhabitants in this village, the *jhum* plots of the old inhabitants were larger than that of today. They are used to maintain long fallow. In comparison, the new comers maintained short fallow in their previous village Ashur Para. Here in Batte Para, they are maintaining short fallow too (Table 4). They have not enough land to maintain long fallow. In this village no significant change of life style of the old inhabitants has been found in the short run but the problem might be occurred in the long run. The trend of the overall rotation period of the *jhum* has been going to be reduced leading the production level to downward. The new inhabitants also work as wage labor in addition to *jhum* cultivation.

In Taracharan Karbari Para, the people can be divided into three different groups—the people who are still practicing *jhum*, the people who are mainly plough cultivators, and the people who have no land to practice either *jhum* or plough cultivation (Table 6). In this village, there is *jhum* cultivation but its fallow period and productivity have significantly been reduced (Table 4). There is no family in this village completely dependent upon jhum cultivation only. *Jhum* cultivators are engaged in other types of works such as homestead gardening, wage labor etc. The plough cultivators also produce fruits in their homestead gardens. The people who have no land at all, works as day labor. The common feature of the three groups of this village is that they all produce fruits and vegetables in their homesteads. Another feature is almost common to all three groups to work as wage labor in the FD's forest reserve to collect bamboo, the raw materials of the Karnaphuli Paper Mills, situated at Chandragona of Rangamati district. Unlike the people of Zamini Para, the inhabitants of this village can sell their fruits to the nearest Dighinala bazar which about 2~3 kilometer away from the village. Income from selling those products is relatively more than that of other villages of our study sites.

Land rights of the indigenous people of the CHT are based upon customs and practices that date back to many centuries. Land being the basic factors, economic production of the region based on predominant subsistence activities. The indigenous people have been living on *jhum* cultivation for many centuries. The findings of our study indicate that the indigenous people have lost many of their common lands, which were used for *jhum* cultivation. Thus their traditional

Table 6 Changes of land use and their impacts on life style and fire-wood collection

	Group	No. of Respon -dents	Chenges in land use	Impact on life style	Impact on fire-woods collection
Zamini Para	I	6	Producing cash crops in *jhum* field along with rice and necessary products	Subsistence life style has been gradually changing to market economy	The farmers sell their products to the Bengali middlemen
	II	4	Producing fruits in their home gardens for cash income		
Hanchama Para	I	2	No visible negative impact on land use rather benefited by learning plantation in their grove land.	Sufficient income earned from plantation in the grove land	Collect fire-woods from private grove lands
	II	2	Lost their *jhum* plots, currently engaged in plough cultivation, tenant	Occasionally work in FD's project as wage labor. Female family members also earn money working with FD	Collect fire-woods from FD's projects. Some times FD dose not allow them collecting fire-woods
	III	4	Lost their *jhum* plots which were their main sources of food supply	Being landless work as wage-labor in FD's projects and other places Sometimes practice *jhum* in the FD's project with the permission of the FD. Female members work with FD	
Batte Para	I	5	The *jhum* plots became smaller as they provided a portion of their land to the new people	No significant change is visible in the short run	Collect fire-woods from forest reserve
	II	6	They practice *jhum* more intensively than old people	Sometimes works as day labor because *jhum* products cannot fulfill their needs	
Taracharan Karbari Para	I	3	Lost most of their *jhum* lands, currently cannot maintain long fallow, production has been reduced	Fruit gardening is major sources of cash income, sometimes work with FD	Everybody collects firewood from nearest forest reserve
	II	3	Common village forest has been disappeared by the FD	Plough cultivation is main occupation; fruit gardening is also practiced for cash income	
	III	4	Lost all of their *jhum* plots to settlers	Being landless work with FD and any other places as wage-labor, producing fruits in their home gardens	

Source: Field Survey

use patterns have been changed. In our study area, two interconnected factors are responsible to change the land use—one intrinsic, the other extrinsic. The intrinsic factor is the natural process of demographic growth, which accelerated the intensive use of land resources. Zamini Para is an example of this factor. The extrinsic factor is the government policies in different times and this most significant factor become the root cause of changing the land rights as well as the land use in the study sites. The people of Hanchama Para, Ashur Para and Taracharan Karbari Para lost their lands to the FD, military, and the Bengali settlers respectively. Being landless many of the indigenous people were bound to change their occupations. Many of them are engaged in day laboring to survive. Many of the indigenous people are working as day labors add to as extra cash for their subsistence. Those who are still practicing *jhum*, are trying hard to produce foods along with cash crops.

EFFECTS OF DIFFERENT GOVERNMENT POLICIES ON THE INDIGENOUS LAND RIGHTS AND LAND USE PRACTICES

The development programs devalued the subsistence practices of indigenous people. The customary rights and culture have not been considered by the government agencies. Most of them are implemented for either maximizing the economic return of the state (e.g. creation of Kaptai dam, Afforestration etc.) or for an instrument of counter insurgency policy (e.g. militarization, Bengali settlement). As a result, most of the programs have gone against the indigenous people. The indigenous people, seriously affected by these programs, lost their land and resource base. The people of different villages in our study sites expressed their negative attitudes towards development programs carried out in the CHT (Table 5). The inhabitants of Hanchama Para hold very strong negative attitude towards the FD. Although the FD's project provides some employment to the indigenous people, but the traditional role of the people has been severely affected. A policy of counter-insurgency was the initial basis for the presence of the military in the CHT. The institutionalization of this strategy provided the armed forces with a policy framework to justify their involvement in other socio-economic matter relating to the CHT, in particular land. The application of this counter-insurgency strategy in the CHT has been a major factor in the loss of traditional land rights of the indigenous people. The indigenous people of Batte Para (new comers) of lost their ancestral land to the military. Both the new and old inhabitants are affected by the militarization. They expressed their negative attitude towards military.

The settlement program implemented in the CHT also evicted the hill people from their traditional lands by grossly violating their traditional rights and affecting their lifestyles. The government claims that Bengalis have been settled on *khas* land. But what the government regards as *khas* land is essentially the traditional *jhum* land used by the indigenous people. Taracharan Karbari Para is a village affected by the military force and Bengali settlers. The major portion of *jhum* lands were occupied by the Bengali settlers and many of the hill people of this village were forced to give up *jhum* cultivation. At present there is *jhum* cultivation but it is not in original character. It is practiced by a portion of the villagers in small plots, which cannot meet up their needs. Many of the inhabitants now work as wage labors as they have no alternative.

Changes in land use in the villages where there is no direct impact of external influences are different. But what is important to note that the changes fundamentally affect the working of the self-sufficient economy. A few decades ago, distinguishing criterion could be stated simply: hill people were exclusively *jhum* cultivators. At present there are many types of land use in the study area. The predominant land use is still practicing in many places in the CHT; but everywhere the system has been changed significantly. The indigenous farmers try to increase productivity by using chemical fertilizer in their *jhum* fields. Not only that, many *jhum* cultivators are now-a-days producing marketable goods for cash income.

Generally belief that the FD's effects is relatively soft in comparison to the impacts of other agencies like military or settlement program or dam creation. What the reality is that all of the development programs in the CHT have exerted many negative impacts on land rights and land use of the indigenous people as a whole.

It is thus logical to infer that responsibility for this deteriorating condition of in the CHT goes to the shoulders of the state. The development programs in the CHT more or less failed to bring about any sort of enthusiasm in economic life of the ethnic minorities. Such development policies in the CHT undertaken without either considering the vital question of sustainability or prior ensuring the participation of the people of that area. The significance of the questions of sustainability and people's participation and involvement is more pronounced in an area like CHT where natural environment is more susceptible to any kind of development intervention than those of the rest of the country.

CONCLUSION

Concerning the land use practices in the CHT, it is clear that land use has been changed from traditional form. Although *jhum* cultivation still exists there, the system does not remain as subsistence in nature. The rotation period has been reduced; the productivity has been reduced too. The indigenous farmer has started using chemical fertilizer in their fields for producing more products. *Jhum* products cannot fulfill their needs. Now-a-days many cash crops are being produced in the *jhum* fields. These are the general changes in land use or *jhum* cultivation in the CHT where no direct external shock is found. But in the villages where government programs and policies were implemented, land use has changed being affected by those programs, the change is not natural rather induced. The policy related factors deprived the local people from their resource base where they were engaged in practicing their economic activities for generations. The people being affected by the development programs sometimes were bound to change their occupation. The hill people were totally self-sufficient a few decades ago; today their livelihoods are seriously hampered. The government perhaps did not carry out those programs with ill thinking but the ultimate effects of those programs went against the indigenous people. If it is seen in the side of indigenous people, all the development programs really went against them. The indigenous people lost their traditional land rights and thus the land use pattern has been changed, above all their life styles have been seriously hampered. The development policies in general have impeded the indigenous population of the CHT. If the present policy of converting the communally owned lands of the CHT into extraction areas for the government's sole use and enrichment continues, the economic destruction of the indigenous people is inevitable.

Resource management is not just about resources; it is about all the livings in our state of existence. The issues of socio-economic enlistment of the indigenous communities of the CHT cannot be considered in isolation from the country's wider strategic plans and actions. This will require coordinating efforts and interventions at various levels along with participation of the local people. In recent years many governments have adopted participatory approaches in resource management. But what is crucial in this collaborating management is "confidence" of local people. The government agencies should include the local people in the management of natural resources. Indigenous or existing practices and knowledge should be the basis for designing such intervention of resource management.

NOTES

(1) The Peace Accord: An accord was singed in December 2, 1997, between the government and the Jana Sangati Samiti (JSS), a political wing of the indigenous people. According to the Peace Accord, the indigenous guerillas surrendered their arms to the government.

(2) Para: The village or hamlet is known as para in the CHT. A para consists of the inhabitants of a same ethnic group.

(3) *Karbari*: Each Para has its leader called *karbari* who is responsible for all matters relating to the para.

(4) *Mauza*: A number of villages are grouped together to form a territorial unit of jurisdiction called *mauza*.

(5) Headman: Each *mauza* has a headman who is responsible for collection of revenue, preservation of peace, administration of customary laws etc.

(6) Grove lands: Grove lands are hilly lands classified as third class private lands used for forestation only.

(7) According to the customary law a hill man can occupy up to a maximum 0.30 acre of USF land for the purpose of his homestead with the permission of the *mauza* headman.

(8) The CHT Manual: The CHT Regulation 1 of 1900, popularly known as CHT Manual, was introduced by the British colonial government. The Manual laid down a detailed constitution for the administration of the CHT, showed the legitimacy of the customary rights. These rights were not created by the Manual, but acknowledged by it, in a qualified manner. Although it was amended in different times, the Manual is still valid in the CHT.

(9) *Khas*: *Khas* lands in Bangladesh are generally either alluvial accretions from the bed of big rivers or sea, not covered within the boundaries of the permanently settled areas. The government authorities make settlement these lands with different persons on periodical basis. In the CHT, *khas* lands and USFs are used interchangeably by the government authorities.

(10) The Deputy Commissioner: The Deputy Commissioner is the government official administrator of district.

(11) The Chief: The CHT is divided into three circles and each circle has an indigenous Chief. By tradition, the Chiefs are responsible for the administration of their respective territories including revenue and land claims matters.

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(Received 8 October 2002)
(Accepted 15 March 2003)

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(May, 2001)
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