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Livelihoods and Local Ecological Knowledge in Cat Tien Biosphere Reserve, Vietnam: Opportunities and Challenges for Biodiversity Conservation

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1. Introduction

Many studies have found that protected areas (PAs) have been conventionally designed based on top-down approaches by government agencies without consulting the locals (Batisse, 1997; Kelsey et al., 1995; Wells & Brandon, 1992). Consequently, experience has shown that top-down approaches to PA management are often ineffective in reaching conservation objectives (Brown, 2002). Beyond conventional PAs, biosphere reserves are found to take into account both biodiversity conservation and socioeconomic development of local populations. Local people are considered as a key element for sustainable management of biosphere reserves (Sang, 2006). They are major stakeholders who play direct and indirect roles in resource conservation. For generations, they have not only relied on forest resources but also accumulated their local ecological knowledge (LEK) of forest resource use. To conserve biodiversity as well as securing local livelihoods, sustainable use of resources in biosphere reserves is considered crucial. The sustainable use depends on ecological knowledge, flexible policy implementation and adaptive management in terms of local realities (Olsson & Folke, 2001; Ostrom, 1990, 2005).

With regard to the case of Cat Tien Biosphere Reserve (CTBR), both local livelihoods and local ecological knowledge have brought not only opportunities but also challenges for biodiversity conservation. The forest resources in the reserve have continued to be degraded owing to a lot of pressures and several species living there are threatened. About 60-80% of the populations depend mainly on forest resources for their living (CTBR, 2006). Most of the local people within and around CTBR have depended much on forest resources for generations and have caused the major loss of the reserve's natural features (Sang et al., 2009). They harvest forest resources for both subsistence and cash income. Biodiversity in CTBR is endangered mainly by encroachment of forest land, illegal logging and poaching. This results in biological invasions, endangering endemic fauna and flora.

Natural growth and immigration lead to an increasing population in the areas within and around the reserve, which increases the threats to CTBR. One of the biggest problems for the authorities of CTBR is that the areas where hamlets and lands for cultivation occur now

were previously in the core zones (CZs) before CTBR was established. The most important conservation issue of the reserve is the large human population living within its boundaries, which is an indirect source for a lot of threats. Consequently, with a growing human population and economy, the demand for agricultural land, food, forest resources for subsistence and cash income increases. For instance, most of the hills surrounding the reserve have been stripped of trees and converted into agricultural land by the local communities. As reported in Tuoi Tre Newspaper (June 9th, 2006), from January to June of 2006 a 60 ha area of forest in the CZ and a 10 ha area in the buffer zone (BZ) of the reserve were destroyed by local residents, mostly ethnic minorities.

Despite being one of the largest protected areas in Vietnam, Cat Tien continues to be stalked by illegal poachers. Poaching and wildlife trade pose perhaps the greatest threat. According to Vietnam News on July 29th, 2004, forest guards said they discover over 2,000 animal traps in the reserve every month. On April 29th, 2010 a Javan Rhino was found dead by poachers in Cat Loc Sector, a CZ of CTBR belonging to Lam Dong Province, and its horn had been removed (CTBR, 2010). While mainly birds, monkeys, wild pigs and deer are hunted for consumption, larger mammals such as the gaurs and bantengs are also poached. Furthermore, the reserve is too small for the larger species found inside it; this leads to either erosion of conservation values or to conflicts with local people as these animals move beyond the confines of the reserve (CTBR, 2010). This problem is particularly intense for the elephant population of the reserve, which is prone to wandering and is considered too small to be self sustainable (CTBR, 2010).

The aims of this paper are to identify the feature of local livelihood strategies and LEK in CTBR of Vietnam and to clarify the opportunities as well as challenges for biodiversity conservation. Recommendations are made for biodiversity conservation and socioeconomic development in the area.

2. Description of Cat Tien Biosphere Reserve

The study was conducted in CTBR where Vietnam Central Highlands give way to Southern Delta, at E107°09'05"-107°35'20", N11°20'50"-11°50'20". It covers an area of approximately 71,350 ha and consists of three sectors: South Cat Tien (39,627 ha), West Cat Tien (4,193 ha) and Cat Loc (27,539 ha) (CTBR, 2011). Its topography comprises a mosaic of landforms of both Truong Son Mountain Range and of lowland rivers, semi-plains, medium hills, relatively flat land and scattered lakes, ponds and wetland of eastern parts of the Southern Delta (Cox et al., 1995). Most of the area of CTBR lies on a bedrock of basalt and five soil types can be recognized: ferralitic soils developed on basalt stone, sandstone, old alluvium, shale and conglomerate.

The reserve lies in the tropical monsoon region with two main seasons: the rainy season from May to November, and the dry season from December to April. February and March are the driest. The mean annual rainfall is 2,435 mm, the mean annual temperature is 25.5° C and the mean relative humidity is 80%. Rain falls on an average of 150-190 days per year, mainly from July to October. During the rainy season, rainfall is about 300 mm per month. In Bao Loc City (Lam Dong), it is up to 245 mm of rain per month; while in Phuoc Long Town (Binh Phuoc) 167 mm of rainfall has been recorded in one day (Cox et al., 1995).

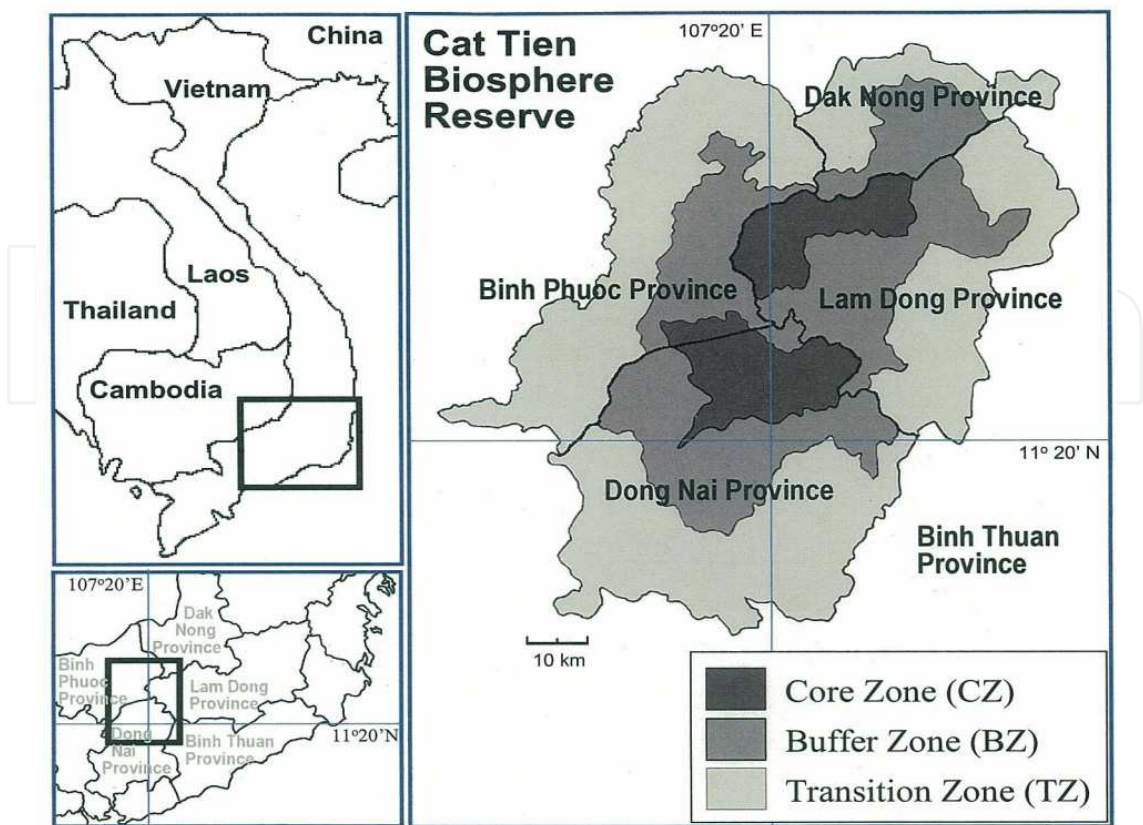


Fig. 1. Location and the map of CTBR (Source: Sang et al., 2010)

CTBR has been shown to have a high diversity of fauna and flora, especially for a relatively small area with a limited altitudinal range. The high biodiversity of the reserve stems from its location in an area between the biogeographically distinct Da Lat Plateau and eastern parts of the Southern Delta. The habitat types include primary evergreen forest (0.9%), secondary evergreen forest (23.1%), semi- evergreen forest (7%), mixed forest (bamboos and other plants, 19.3%), bamboo forest (40.1%), and wetland (2.2%). There are about 103 species of mammals, 348 species of birds, 79 species of reptiles, 159 species of fish, 49 species of amphibians, and 439 species of butterflies (table 1). The only Javan Rhino population outside of Java, Indonesia, occurs in the Cat Loc Sector. Globally endangered species found in CTBR include: *Arborophila davidi*, *Bos javanicus*, *Bubalus arenee*, *Cairina scutulata*, *Capricornis sumatraenis*, *Elephas maximus*, *Nomascus gabriellae*, *Panthera tigris corbetti*, *Pseudibis davisoni*, *Pygathrix nigripes*. So far 1,610 species of flora have been recorded on six types of habitats and belong to 724 genera, 162 families and 75 orders; 34 species are listed in the Vietnam Red Data Book; 31 are listed as rare and 23 are endemic (CTBR, 2006). The large number of plant species in CTBR has conservation as well as economic values: 38 species in 13 families for protection of genetic resources, 23 species are of indigenous endemic value, 511 species are wood trees (of which 176 species are precious timber), 550 species are medicinal plants; and hundreds of species have essential oil and special use (CTBR, 2006).

According to decision 360 / TTg of the Prime Minister on July 7th, 1978, Cat Tien National Park, the first name of Cat Tien Biosphere Reserve, was protected initially as two sectors, South Cat Tien in Dong Nai Province and West Cat Tien in Binh Phuoc Province. Then based on decision 8 / CT of the Chairman of the Council of Ministers on January 13th, 1992,

South Cat Tien was approved as a national park. Gazetted as a Rhino Reserve in 1992 upon the discovery of a Javan Rhino population, Cat Loc received the protected status from Lam Dong Province in the same year. Subsequently, decision 38-QD of February 16th, 1998 approved the integration of South Cat Tien, West Cat Tien and Cat Loc into Cat Tien National Park. On November 10th, 2001 the park was recognised by United Nations Educational, Scientific and Cultural Organisation (UNESCO) as a biosphere reserve of the world.

Taxa	Total	All species	VN Red List 2000 species		IUCN Red List 2000
		% of all species in Vietnam	Total	% of all species in Vietnam	
Amphibians	23 (49)	22	1 (2)	9 (18)	0
Birds	283 (348)	34	18 (21)	22 (26)	15 (16)
Butterflies	435 (439)	43	n.a.	n.a.	n.a.
Fresh water fish	99 (159)	21	6 (9)	18 (27)	1
Mammals	60 (103)	25	15 (32)	20 (39)	16 (26)
Reptiles	46 (60)	18	14 (17)	33 (40)	5 (8)

Note: Non-bracketed figures are confirmed records, figures in () include possible records

Table 1. Fauna species recorded in Cat Tien Biosphere Reserve (Source: CTBR, 2010)

CTBR is divided into three zones. Core zone is strictly protected; some activities and sustainable resource uses can be acceptable if they are in accordance with its conservation goals. There are two core zones in CTBR; South Cat Tien (Dong Nai Province) and West Cat Tien (Binh Phuoc Province) constitute the first CZ; and the Cat Loc Sector (Lam Dong Province) is the second CZ located in the north of the reserve. Buffer zone may provide a variety of sustainable uses which ensure the protection and conservation of the reserve, and improve the local socioeconomic conditions. Transition zone (TZ) is for sustainable socioeconomic development to reduce pressure on the reserve. At present, the board of CTBR under Vietnam Ministry of Agriculture and Rural Development has overall responsibility over the CZs. However, the socioeconomic development and management in the BZ is in the hands of many other departments and local organizations under the governance of the three provinces.

CTBR is the home of about 2,000 people in the CZs and approximately 200,000 residents in the BZ. Local people in CTBR can be categorized into three main groups - Kinh people, indigenous ethnic minorities and migrant ethnic communities. The first group includes Kinh people who lived there before 1975, Kinh households from Mekong Delta or south - east provinces of Vietnam, and many Kinh families from northern provinces of Vietnam settled under the program of development of new economic zones in 1986; the indigenous ethnic minorities comprise Chau Ma, S'Tieng, Chau Ro, and Saray who have lived there for generations; the migrant ethnic communities consist of Tay, Nung, Dao, H'Mong, Hoa from the northern provinces and a few Kho Me from Mekong Delta. Each ethnic group has different histories, various traditions, and diverse material lives. About 60-80% of the population has depended primarily on forest resources for their livelihood (CTBR, 2006). Most of them, especially ethnic minorities within and around CTBR have depended much

on forest resources for generations and have caused the major loss of biological resources (Sang et al., 2009). The locals have cultivated areas with high value industrial crops like cashew, cassava, coffee, pepper; rice and fruit such as jack-fruit, mandarin, pineapple, mango, banana, guava, papaya, custard-apple, and longan.

3. Methodologies

Field research was conducted to gain intensive understanding of people through discussions and interactions. The research reported here was carried out in 2005, 2006 and 2010. Primary data were gathered initially through household interviews based on questionnaires, Rapid Rural Appraisal (RRA), and the “walk-in-the-wood” method (Prance et al., 1987). Interviews were also carried out with community leaders, government officials, staff of CTBR and non-governmental organizations (NGOs). The data covered qualitative and quantitative information including socioeconomic status, forest resource use, LEK, crops, land holding, and cultural practices. Secondary data used in the study were mostly drawn from the author’s previous studies as well as the reports of CTBR and the local government; books, and newspapers. The Statistical Package for Social Sciences (SPSS) was used to analyze the quantitative information obtained through the questionnaire survey.

CTBR was chosen as a case study because the forest resources in the reserve continue to be degraded owing to a lot of pressures and various species of plants and animals have been threatened by the local people. To reflect the livelihoods and local ecological knowledge, the research data were gathered in sites where there were natural forests in or near the hamlets, local residents were dependent on forest resources, and the hamlets were accessible.

4. Opportunities and challenges in terms of local livelihood strategies and local ecological knowledge

The locals in CTBR have livelihood strategies combining farming, collection of non-timber forest products (NTPFs), logging, livestock raising, manufacture of handicraft, aquaculture, participation in forest management activities by government, and other employment. Many of them depend on upland cultivation, wetland rice cultivation, NTFP collection, and raising livestock. Differences in livelihood strategies reflected differences in the levels of poverty among three zones. For instance, the BZ had the highest rate of poor households (75% of the surveyed households in the zone) and the CZs the lowest (28%); the TZ had 40% (Sang et al., 2009). On an average, the poor households made up 58.3% of the total sample. Moreover, the mean family size was high in three zones (5.4 people per household). These people usually faced some months of food shortage and had low living standards. To meet the basic needs, they tended to exploit the forest resources and encroach on the forest land in the reserve. With regard to occupation, agriculture accounted for 47.7% of all population surveyed from ages six to sixty, and not including invalid or disabled persons; the distribution across the three zones was follows: the CZs 50.9%, BZ 48.2%, and TZ 44.6% (figure 2), respectively. Further more, the percentage of off-farm and non-farm jobs including wage and salary earnings, trade and handicraft was highest in the TZ (31.3%), but only 1.8% in the CZs and 6.4% in the BZ (figure 2), respectively. These showed that the closer to the biosphere reserve people were the less they were involved in off-farm and non-farm jobs. It is very easy to see at the chart that the ratio of off-farm and non-farm activities

decreased significantly from the TZ to the CZs. Likewise, the threat on the forest resources in the TZ may be less than that in two other zones.



Fig. 2. Ratio of main occupation in different zones (Data appendix used for the compilation of the graph are available from the authors)

The area of cultivated land plays a very important role in the local people’s livelihoods as it is the area in which productive activities take place. The bigger the land size is, the better opportunities for the people ensure food security. Table 2 gives an overview on land resources of households in the surveyed hamlets in the three zones. The average per capita area of cultivated land decreased significantly from the CZs to the TZ: CZs 3.8 ha (16 times larger than that in TZ), BZ 1.23 ha (5 times larger than that in TZ), TZ 0.24 ha (table 3). This may mean that the livelihood of the people in the CZs and the BZ depended much on land resource, but much less in the TZ.

The local people have got high income from upland cultivation; so many areas of natural forests in CTBR have been converted illegally into crop lands. Land conversion is the biggest threat to biodiversity conservation. The closer people lived to the core of the reserve, the more they depended on upland cultivation of cashew and cassava. For example, the residents in the CZs had the highest upland cultivation income (95.1%), and the TZ the lowest (11.1%); with the BZ with 60.7% falling in between (Sang et al., 2010). It indicates that upland cultivation in the CZs and BZ is the most important for the local livelihood strategy in terms of income generation. As a result of the practice of this livelihood strategy, forest land encroachment has been common. Certain areas in each zone, particularly both in the CZs and BZ have been converted illegally from forest into crop lands. For instance, in a 7 year period ratio of households involved in upland cultivation increased from 46.7% in the TZ through, 54.9% in the BZ to 88.9% in the CZs (Sang et al., 2009). Using Wilcoxon signed

ranks test to compare the change of the upland cultivation area per local household during a 7 year period (1998-2005), it is evident (table 2) that the increase (129.5%) in the BZ was statistically significant. The increases in the CZs and the TZ were not significant. This indicates that the demand for cultivation land has been very high in the BZ where there were 59% of very poor households and 14% of poor households in 1998 (Sang et al., 2010). According to the field survey, the poor households in the BZ encroached 98.4% (36.4 ha) of the total area of the encroached uplands. So, it is obvious that the local poverty in the BZ is the reason for the encroachment into forest areas. To avoid getting caught, locals usually use special ways to encroach forest land. “Many households who have arable land near the boundary of the forest in CTBR have encroached very small areas of natural forest land gradually, making it difficult for local officials and reserve staff to detect the area encroached”, said the officials in Phuoc Cat 2 and Bu Dang Commune. Another way is that both indigenous and migrant ethnic minorities have cleared areas deep inside the forest which the forest guards could not reach. According to Vietnam Forest Ranger (VFR), in 2010 the local people encroached 5.6 ha of natural forest in CTBR for crop upland, but in reality the lost area may be much higher. Forest conversion into agriculture land resulted in loss of habitat of many species, so conservation impact of this activity was very high. Furthermore, recently some outsiders have begun purchasing land from indigenous ethnic minorities illegally. Some local government officials believe that some outside individuals enticed indigenous ethnic people to sell their land at a low price; and the indigenous ethnic minorities then tended to give up land use rights and became wage earners. Consequently, further forest land has been encroached. In addition, a lot of indigenous ethnic minorities could not manage their livelihood strategy well; they had to sell their cashew nuts on trees for cheap prices before being ripe, and then they continued to be poor.

Zones	Z	Asym.sig. (2- Tailed)
CZ	-1.826	0.068
BZ	-5.053	0.000**
TZ	-1.604	0.109

Note: Statistic Test: Wilcoxon Signed Ranks Test (This Test is denoted by the test statistic T although the Z statistic can be reported instead, and Asym.sig. is the *P* value for the test)
 *, ** denotes significance at 0.05 and 0.001 level

Table 2. Comparison of upland area per household in a 7 year period (Data appendix used for the compilation of the table are available from the authors, a 7 year period between 1998 and 2005)

Rice, a staple food of Vietnamese, is used mostly for consumption in CTBR. Most of the areas of paddy fields in the surveyed hamlets of the BZ were used to produce rice for two or three seasons a year, whereas in the TZ paddy was mostly produced for one season only. This was based on the irrigation system and characteristic of the land resource. For instance, in Ta Lai in the BZ there were three rice seasons per year in some areas thanks to Vam Ho Irrigation Dam. Paddy cultivation was an important component of on-farm operation in both the BZ (0.17 ha per capita) and the TZ (0.077 ha per capita), whilst the paddy rice area in the CZs was very low 0.0024 ha per capita (table 3). So the people in the CZs could not produce enough rice for their subsistence. Additionally, the areas of paddy cultivation in the surveyed hamlets in the CZs and the TZ area did not change during the 7 year period from

Land use types	CZs				BZ				TZ			
	A (ha)	RT (%)	AC (ha)	RH (%)	A (ha)	RT (%)	AC (ha)	RH (%)	A (ha)	RT (%)	AC (ha)	RH (%)
Agriculture												
<i>Paddy land</i>	0.2	0.07	0.0024	11.11	49.95	13.5	0.17	90.2	6.85	34.72	0.077	80
<i>Vegetable land</i>	0	0	0	0	0.4	0.11	0.001	1.96	0	0	0	0
Sub-total	0.2	0.07	0.0024	11.11	50.35	13.61	0.19	92.2	6.85	34.72	0.077	80
Home garden	0.19	0.06	0.002	83.3	5.47	1.48	0.02	29.4	5.03	37.91	0.057	66.7
Forestry land												
<i>Upland</i>	104.7	33.98	1.28	100	117.7	31.8	0.39	82.4	7	16.22	0.08	40
<i>Protection forest (01) *</i>	203	65.89	2.48	83.3	117	31.6	0.39	15.7	0	0	0	0
<i>Production forest (02) **</i>	0	0	0	0	76	20.5	0.25	25.5	0.5	2.53	0.006	6.7
Sub-total	307.7	99.87	3.75		310.7	83.97	1.03		7.5	18.75	0.085	
Other lands	0	0	0	0	3.9	1.05	0.013	49.02	1.4	8.62	0.016	26.7
Total	308	100	3.8		370	100	1.23		21	100	0.24	

Note: A: area (ha);
RT: ratio of the land type area to the total land (%);
AC: area per capita (ha);
RH: ratio of households having that land to the total surveyed households of each zone (%)
(The total households surveyed: 84);
Other lands including aquaculture and grassland;
* Forested land allocated to local households according to Decree 01/CP 1995 for forest protection, the land holders having right to gather a small amount of NTFPs on that land and to get subsidies for the forest protection incentive;
** Forestry land (with or without forest) allocated to households according to Decree 02/CP 1994 for forestry development, the land holders having rights to use the land for a long term but no finance paid for their management of that land.

Table 3. Distribution of the land holding size per capita by land use types (Data appendix used for the compilation of the table are available from the authors)

1998 to 2005; the reasons were that most areas in those hamlets in the CZs were upland and low lands for paddy in the BZ were in short supply; the same was true for the TZ (Sang et al., 2009). Conversely, in the 7 year period, the areas of paddy land of surveyed households in the BZ increased 14.2 ha (about 0.28 hectares per household); this increase was the result of the forest encroachment activity (Sang et al., 2009); the people there were very poor and short of food in some months, so they must encroach the forest land for agriculture cultivation so as to meet their basic needs. According to the field survey, all of the increase area for paddy land in this zone was encroached by most of the poor households, but not by any rich households. So, it is apparent that the high rate of poverty in the BZ was the reason for the encroached forest areas and the conversion of forest land to paddy fields. Of course, the impact on biodiversity conservation of this livelihood strategy was very high.

The wealth of each household was classified into one of the four levels: well-off households (group I), medium households (group II), poor households (group III) and very poor households (group IV) (Data appendix used for these wealth categories are available from the authors). Using Wilcoxon signed ranks test to compare the change of the total land area per surveyed household in the 7 year period, the increase of the total land area in the CZs and the BZ was significant, but not in the TZ (table 5). Besides, in 1998 the people’s average gross incomes in the CZs and the BZ were below the poverty line (Sang et al., 2009). Likewise, the increase of the land area of the poor and very poor households in the CZs made up 74.8% of the total area increase, and 86.7% in the BZ (table 4). So it is clear that the low income led to the increase of the area of land use in the CZs and the BZ, and the increase of the land use area of the rich and medium households was for cash income. The increase of the total land area in the TZ was not significant (table 5).

Zone	Total land area increase of the surveyed households (ha)	Increase of the land area of the poor and very poor households Surveyed	
		Ha	% in the total area increase
CZs	214.3	160.3	74.8
BZ	224.2	194.4	86.7
TZ	5.8	5	86.2
Total	444.3	359.7	81

Table 4. Increase of the total land area of the poor and very poor households in the 7 year period (Data appendix used for the compilation of the table are available from the authors)

Zones	Z	Asym.sig (2- Tailed)
CZs	-3.628	0.000**
BZ	-5.152	0.000**
TZ	-2.366	0.18

Note: Statistic Test: Wilcoxon Signed Ranks Test
*,** denotes significance at 0.05 and 0.001 level

Table 5. Comparison of the total land area per household in the 7 year period (Data appendix used for the compilation of the table are available from the authors)

With the development trend of cashew plantations in south-east provinces in Vietnam, since 1993 most of the households in Cat Loc including the surveyed hamlets in CZs and BZ have encroached on the forest land to plant cashew because the soil in this area is very good for the crop. The people in South Cat Tien comprising the hamlets in BZ and TZ cultivated rice on low land and cashew on hills. The people got high cash income from cashew and used rice mainly for self consumption.

Zone	Total encroached area (ha)	Area per household (ha)	Area per capita (ha)
CZs	11.42	0.63	0.14
BZ	51.2	1	0.17
TZ	5.31	0.34	0.06
Total	67.68	0.8	0.14

Table 6. Encroached forest areas by the local people in the 7 year period (Data appendix used for the compilation of the table are available from the authors)

In 1998 about 56.07% of the sample population in three zones was poor (Sang et al., 2009). Hence, many of them encroached on the forest land to cultivate crops. According to table 6, the total encroached forest area of sample households in three zones was 67.68 ha (about 0.8 ha per surveyed household). The people in the BZ had the largest encroached area per household (1 ha), the residents in the TZ the smallest (0.34 ha per household) (table 6). The ones in the CZs had 0.63 ha. The people in the BZ encroached on much forest land since the poor people made up 73% of the sample people in the hamlets in 1998 (Sang et al., 2009).

Zones	Z	Asym.sig (2- Tailed)
CZs	-1.483	0.138
BZ	-4.760	0.000**
TZ	-2.366	0.018*

Note: Statistic Test: Wilcoxon Signed Ranks Test for means of two related samples

*,** denotes significance at 0.05 and 0.001 level

The increase of cultivated areas came from encroached land.

Table 7. Comparison of cultivated land area per household in the 7 year period (Data appendix used for the compilation of the table are available from the authors)

The Wilcoxon signed ranks test was used to check the significance of the change of cultivated areas of households in each surveyed site among the three zones. The result in table 7 shows that the change was significant in the surveyed sites of the BZ and the TZ. According to the field survey, the sampled poor households in the BZ encroached 99.4% (50.9 ha) of the total encroached area, and 94.2% (5ha) in the TZ. Only a few well-off and medium households encroached on the forest land for cash income. This means that the low income in these two zones caused the encroachment. On the other hand, the locals in the CZs encroached large cultivated land areas from 1990 to 1998 (5.2 ha per surveyed household) (Sang et al., 2009); that is the reason why they were very poor in 1998 when their cashew was at young ages, but they have encroached on a small cultivated area since 1998. To sum up, the low income of the sample people in three zones of CTBR is the reason for the encroached forest areas.

Regarding NTFP usage, most of the locals, especially the EMs have harvested these resources for both subsistence and cash income (Sang et al., 2009). Many species are commonly exploited for a variety of uses such as fuelwood, foodstuffs, materials for handicraft and construction, agricultural tools, fodder, medicine and resin products. Nearly 100% of EM households collected the fuelwood which mainly came from natural forest; the demand for fuelwood for subsistence was very high; only one family of indigenous ethnic minorities had gas for cooking. About 58.8% of surveyed households of Kinh people gathered fuel wood mostly for their self consumption, only one of them for income generation (Sang, 2010). The demand for fuel wood reduced from the CZs to the TZ (Sang, 2006). The average amount of fuelwood for subsistence in the area was about 22 kg per household per day (Sang, 2006). Many Kinh households in BZ and TZ used gas for cooking because they were busy with on-farm, off-farm, and non-farm jobs. All of them collected branches or stems for firewood from natural forests, forest plantations and allocated forest land in CTBR, but primarily from natural forests. All EMs indicated to gather the firewood and carry it in a dossier (Gui) on one's back, but Kinh people used ox carts or even bicycles to carry fire wood. Each dossier of fuelwood weighs about 15-20 kg. From these results, it is clear that the EMs have depended much on fuelwood than Kinh people. The conservation impact of this utilization is likely to be moderate.

All of the EMs and more than 35% of Kinh families surveyed gathered and harvested some or many species of the edible forest plants for both subsistence and income generation, primarily for daily consumption. The edible forest plants were used as vegetable, fruit, traditional medicine, yeast, spice, water, agar, and fodder. The species were collected from natural forests, forest plantations and allocated forest land (table 3) in CTBR, but primarily from natural forests. Plants used as vegetables were the most important food for all of indigenous ethnic minorities. Particularly, leaves of *Gnetum gnemon* and shoots of some rattan species were used extensively as daily food by indigenous ethnic minorities; but only a small percentage of migrant minorities exploited these NTFPs and they seldom used these species for food (Sang & Ogata, 2011). Moreover, these species are also among 15 favorite main foods for Javan Rhinos in CTBR. With regard to forest plants used to make pickle, 5 out of 9 species are bamboos whose shoots were used for that product (Sang et al., 2011). The material for pickle also came from fruits of 2 wood species and petioles of 2 species belonging to Araceae. That product is very good for long term use, especially during the dry season. Edible forest fruits are commonly used in the area, they collected those from species in the natural forest of CTBR for subsistence, and half of them are wood species. Many households reported that their children were the primary collectors. Especially, one important species for high cash income is *Scaphium macropodium* whose nuts are collected on trees by males or on the forest floor; the harvest season stretches from March to May and it only flowers at an interval of 3 or 4 years. "Last season (2010) I harvested nuts of this species and earned about 17 million VND (USD 1 = 20,700 VND, approximate exchange rate in August of 2011), this income is really high for us", said a Chau Ma man in Brun Hamlet of Lam Dong Province. However, because the trees are high the people often cut down them to harvest nuts for convenience. And more than 10 respondents cut down trees for collecting the products. The conservation impact of this way of exploitation is likely to be high, so it should be strictly prohibited and changed to more sustainable ways. Additionally, the indigenous ethnic minorities in the area used the forest edibles as spice or for their water content. The majority of species used for spice were herbs (5 species); but each of the

following life forms had only one species: tree, climber and shrub (Sang et al., 2011). They also drank water from 2 climber species in case of lacking in boiled water during the time in jungles. Noticeably, bark of *Cinnamomum iners* or leaf of *zingiber sp.* is the key material for yeast to make an indigenous traditional alcohol called "Ruou Can". These species have been retained in their traditional drink which appeared in their traditional festivals, parties of the lunar new years, weddings, or other events. Remarkably, *Canarium tramdenum* is a wood species providing fruit found in the Red Data Book of Vietnam (2007). This is vulnerable, possibly threatened to be extinct. *Mangifera dongnaiensis* that also provides fruits is an endemic flora species in CTBR (CTBR, 2010). However, poor harvesting practices and high intensity of collection were threatening their sustainability, the local uses and even the food sources for wildlife. Additionally, most of the gathering was officially illegal since it occurred in national protected forests.

Using some of the NTFPs for handicraft and other home appliances also brings both opportunities and challenges to the biodiversity conservation in CTBR. Particularly rattans and bamboos were very important for making handicraft for self consumption and cash income of the locals. Additionally, a majority of families who got income from the activity were poor or very poor, or had idle labors. About 9% of the total surveyed Kinh households in the TZ depended much on bamboo baskets and joss-sticks which brought daily main income to their family, 17.6% of interviewed households of EMs earned from indigenous indigo textile fabric and other kinds of handicraft (Sang & Ogata, 2010; Sang, 2006). This activity had a low conservation impact, the people needed only a certain amount of material from forest and they could add much more value to their final products thanks to their skill and time intensive at home. Regarding NTFPs for other home use products, there was a high subsistence demand in the area. 100% of the surveyed households used the forest resources for self consumption. They used many species of rattan and bamboo for weaving home appliances such as baskets, trays, boxes, dossiers (Gui), fishing traps, and so on. Considerably, the most useful and traditional tool of the indigenous ethnic minorities is a dossier made from rattan species such as *Calamus dioicus*, *Calamus poilanei*, *Calamus sp.*, *Calamus tetradactylus*, *Deamonorops pierreanus*, *Korthalsia laciniata*, and *Plectocomiopsis geminiflorus*. 100% of indigenous respondents had at least one Gui in their families, but migrant ones and Kinh people did not use them. Canes of *Calamus poilanei*, *Calamus rhabdocladus*, *Deamonorops pierreanus*, and *Korthalsia laciniata* have been used for furniture frames (Sang & Ogata, 2011). Particularly, mature stem logs of some bamboo species were used to cook their traditional bamboo-tube rice (Com Lam) and used as tubes to imbibe traditional "tube wine" (Ruou Can) from a jar. Moreover, many NTFPs were gathered for wrapping foods, and for making thatch roofs, bamboo walls, brooms, ladders, joss-sticks, chopsticks, fishing-rods, cages, ethnic musical instruments, looms, conduits, bamboo strings, hunting arrows, other tools.

Timber was a valuable forest product for which there was both high self consumption and high income generation in CTBR, especially those in the BZ and CZs. However, the conservation impact of timber logging is high because whole stems of trees were cut. The dry season is the favourite time for them to harvest timber as it is easier to harvest and transport timber out of the forest. Wood species logged are as follows: *Azela xylocarpa* (Go do), *Dipterocarpus intricatus* (Dau long), *Dipterocarpus alatus* (Dau rai), *Dalbergia mammosa* (Cam lai), *Lagerstroemia calyculata* (Bang lang), *Sindora siamensis* (Go mat), *Tectona grandis* (Go

tech) and so on. According to the field survey in 2010, 18.2 % of the sampled households involved in the illegal logging activity for cash income, while the figure was high in 1998 - around 27.4% (Sang, 2006, 2010). Although the ratio has been decreased, the activity is strictly prohibited in the CZs and natural forests in the other zones. One example, in 2010, 4 indigenous ethnic ones in the survey hamlet in Ta Lai and 3 outsiders who logged 12.039 m³ of *Azelia xylocarpa* were put in jail (CTBR, 2011). Recently, it has occurred that outsiders hired indigenous ethnic minorities for carrying or harvesting timber “illegally” because they had their local knowledge (Sang, 2010). This trend was common in the surveyed hamlets in Da Nhar (BZ) and Da Oai (TZ), but not in the surveyed areas of the CZs and Brun Hamlet (BZ) because the topography was full of obstacles and difficult of access. To carry timber out of the reserve; motorcycles, buffaloes, and means of river transportation were used. Their transportation income from forest to outside was reported about 150,000 – 300,000 VND per time (Field survey, 2010). And many of them were hired 2 times per day. Concerning timber for local subsistence demand, 100% of the surveyed households in the CZs used both converted timber and wood poles for the construction of their houses, pigsties, hen-coops, and stalls. For the indigenous ethnic minorities in the BZ, before the program of settlement and fixed cultivation the construction of their houses was also made of the above material; then thanks to the program the government built concrete houses for them.

Wildlife poaching has been carried out by both Kinh people and the EMs for self consumption, high cash income, and occasional barter. However, this activity makes a severe conflict between local residents and forest rangers in CTBR in term of biodiversity conservation. The percentage of local households involved in wildlife poaching reduced from the CZs to the TZ: the CZs 50%, the BZ 52.9%, and the TZ 20%, respectively (Sang et al., 2010). After 7 years, the ratio became lower with every passing day; its reduction was as follows: the CZs 5.6%, the BZ 13.8%, and the TZ 13.3%. Likewise, the annual income from wildlife poaching per capita decreased at the following rates: the CZs 8.1%, the BZ 10.4%, and the TZ 11.3% (Sang et al., 2010). According to our own survey in 2010, the reduction in income and involvement rate of wildlife poaching was mainly caused by further distance or longer time for the activity and more severe punishment. However, forest guards often turn a blind eye when seeing the locals fishing with traditional ways in the reserve. Recently, many households in the CZ in West Cat Tien and some in other parts of the reserve have used electric shock fishing that has killed not only fish but also all aquatic life in wetlands, rivers, and streams of CTBR. It can endanger one of the food chains of the ecosystem of the reserve.

In respect of purposes of forest resource uses, 80.6% of the surveyed households used the biological forest products for their subsistence; whereas 96.4% of them sold the products from upland cultivation to the market. Most of the products from the cultivation were cashew which gave high income to the local people; only 3.6% of households used the products from the upland cultivation for self consumption because some areas were cultivated to grow maize, green bean, cassava (table 8). They usually consumed most amounts of products from fishing, NTFP collection, hunting for daily foodstuffs; 17.5% of them sold products from the biological forest resources and 27.6% of households used timber harvested for cash income. In 2005, 60.8% of the total sampled households used the products from the biological forest resources and uphill cultivation for subsistence, 37% for cash income, and only 2.2% for storage (table 8).

Zones	Upland cultivation			Logging			NTFPs			Hunting & fishing			Forest resource uses		
	Subsistence	Cash income	Storage	Subsistence	Cash income	Storage	Subsistence	Cash income	Storage	Subsistence	Cash income	Storage	Subsistence	Cash income	Storage
CZs	0	100	0	50	50	0	90	5	5	88.9	0	11.1	57.2	38.8	4
BZ	5.9	94.1	0	84.3	15.7	0	76.5	19.6	3.9	92.2	7.8	0	64.7	34.4	0.9
TZ	0	100	0	50	50	0	62.5	37.5	0	100	0	0	53.1	46.9	0
Mean	3.6	96.4	0	72.6	27.6	0	76.2	20.2	3.6	92.9	4.8	2.3	60.8	37	2.2

Table 8. Purposes of forest resource uses (in %) (Data appendix used for the compilation of the table are available from the authors)

As for the forest protection program, the government has implemented this for poor households in CTBR since 2001. In local reality, a group of households in a hamlet took responsibility, on a rotational basis, for patrolling a large forest area; the group was managed by a head of a hamlet or a village, or a staff of local government who was responsible for signing of forest protection contract, patrol plans and benefit sharing. Under this program, the participants have got subsidies for the forest protection incentive (table 3). The annual payment was 50,000 VND per hectare, since 2010 the amount has been 100,000 VND. However, to compare the income with the total forest resource income per capita, the rate was very small: the CZs 0.97%, the BZ 0.49, the TZ 5.82% (Sang et al., 2010). This could not encourage the locals to participate in the program. For example, in 2009, the household group in the surveyed hamlet (CZ) in Bu Dang withdrew from the forest protection program.

Another program initiated by CTBR was ecotourism in South Cat Tien in 1995. Since then only a few indigenous ethnic minorities in Ta Lai (BZ) have had a chance to earn their living as guides or handicraft sellers. All of ecotourism guides were Chau Ma minorities in Ta Lai and their participation was at both active and passive levels. Handicraft products were sold at Ta Lai Cultural Centre for the Indigenous Ethnic Minorities by a S’Tieng staff and at the Headquarters of CTBR by a Chau Ma woman. Handicraft materials came from rattan, bamboo and some other NTFPs; thanks to the low amount of materials harvested, the conservation impact of harvesting was low. Before these people did not have any jobs and all of them ventured into CTBR illegally in search of wood, NTFPs and even encroached forest land for cultivation. Recently they have had alternative sources of income from ecotourism activities for their basic needs in the daily lives. As a result, they have gradually changed from high intensive of forest resource use to a more sustainable way. Since 2009, some further activities such as the programs of long houses and gong performances were implemented (gong is a traditional musical percussion instrument of the indigenous ethnic minorities in the Central Highlands of Vietnam which was recognized by UNESCO as a Masterpiece of the Intangible Heritage of Humanity on November 25th 2005). However, only 12.5% of indigenous participants had got dominant sources of incomes from guides or handicraft sellers (Sang & Ogata, 2010). In reference to local participants’ satisfaction about the income derived from ecotourism, only 2.5% of them rated it as satisfactory. On the

whole, the indigenous ethnic minorities in CTBR were employed in ecotourism activities on a small scale rather and not at the decision-making and management level (Sang & Ogata, 2010). And most of their involvement in ecotourism in CTBR was at the passive participation level (Sang & Ogata, 2010). Passive participation meant an elementary level participation in tourism development and its object was as much to prevent a too hurried residents' intervention into tourism development by providing residents with longer term sustainable participation opportunities (Tosun, 2000). Moreover, the distribution of the ecotourism program was in unbalanced among the various sectors of CTBR.

Change of forest resource income (FRI) in the 7 year period was dramatically in the CZ and the TZ, but slightly in the BZ (Sang et al., 2010). The rate of FRI to the total income per capita of surveyed households in the CZ increased significantly, from 66.8% to 97.2%. This rate in the BZ rose slightly, from 57.5% to 64.2%. In comparison, the rate decreased rapidly in the sample hamlet in the TZ, from 45.1% to 19.1% (Sang et al., 2010). Furthermore, the proportion of the annual increase of FRI to the increase of total annual income per capita in the CZ was very high (105.5%); this rate in the sample hamlets of the BZ was high (68.4%); but the sample one in the TZ had only 4.8% (Sang et al., 2010). This indicates that the income of the residents in the CZ and the BZ increased significantly thanks to the forest resources, but the contribution of forest resources to the rise of total income in the TZ was very small. According to table 9, the increase of FRI per capita was significant in the sampled hamlets in the CZ and the BZ, but not in the hamlet of the TZ.

Zones	Pairs	T	Df	Sig. (2-tailed)
CZ	Average gross FRI per capita in the 7 year period	-5.212	17	0.000**
BZ	Average gross FRI per capita in the 7 year period	-2.031	50	0.048*
TZ	Average gross FRI per capita in the 7 year period	-0.103	14	0.898

Note: *, ** denote significance at level of 0.05 and 0.001
Method: Paired Sample T Test for the income in 1998 and 2005.

Table 9. Comparison of average gross FRI per capita in the period of 7 years (Data appendix used for the compilation of the table are available from the authors)

The locals in CTBR have accumulated their LEK of forest resource use which includes both potentials and challenges for biodiversity conservation. From generations to generations, they have not only depended on forest resources but also summed up the experience in upland cultivation and NTFP harvest. With regard to the LEK of upland cultivation, they have long experience in land distinction and management of its fertility (table 10). The people could not distinguish different land types by color or texture, but they were able to identify fertile land from ground objects. In fact, to have good upland for cultivation, they selected a cultivated area on a less steep hill without stone surface, bamboo and species of dipterocarpaceae; their experience showed that the presence of these plant species may be a reliable indicator of poor land to cultivate; they also preferred to choose the arable land deriving from forest of plant diversity, especially near water sources. In addition, upland

cultivation has been the traditional activity of the local residents, especially ethnic minorities. It was the result of the shifting cultivation in the past time. Some years ago, with unsustainable forest management and unawareness of forest protection, shifting cultivation systems were popular within and around the reserve. According to local elders, the fallow period of upland fields was up to 20 years, and the fallow period came after 1 or 2 years of cultivation. The period had reduced to 10 years, in which upland cultivation was conducted in 2-3 years, and then a fallow period lasted only 3-5 years. At present, due to the strict management of the reserve, it is more difficult to encroach on the forest land, so there are no fallow periods in upland cultivation. This leads to soil erosion and land degradation, which makes soil unable for cultivation.

Kind of LEK	Effects	Trend of change	Applicability for local residents, CTBR and local government
Land distinction for upland farming	Selecting forest upland for farming, then asserting land ownership and tenure in the community, but no official land titles	Unofficial ownership, so decrease in area	Participatory planning for upland use
Crop diversification	Multi crop products, plant diversity, higher output	Genetic degradation of native crop species	Conservation of native crop species
Soil fertility management	Periods for recovering fertility	Traditional upland farming with fallows, recently industrial crops and no more fallows	Recycling and composting organic materials, manure from livestock

Table 10. LEK of upland farming (Source: Sang, 2006, 2010; Sang & Diep, 2007)

As for the LEK of NTFP harvest, the locals can know when, where and how to harvest the NTFPs such as rattan species, nuts of *Scaphium macroporium* and resin from some wood species belonging to *Dipterocarpaceae* (Sang & Ogata, 2011; Sang & Diep, 2007). As for rattan use, they can know the mature age of rattan through its color of leaves or canes; for example, the rattan can be harvested when its stem becomes yellow, gray to almost white and relatively smooth with scars left by fallen leaves (table 11); after harvesting, rattan stumps need more than five years to provide the stem products; a near total of households (98.8%) identified that most rattan species were overharvested nearby and they had to go further in order to harvest young shoots or stems. Many species harvested for stem products in CTBR included *Calamus tetradactylus*, *Calamus scipionum*, *Calamus poilanei*, *Calamus rhabdocladus*, *Calamus dioicus*, *Calamus sp.*, *Deamonorops pierreanus*, *Korthalsia laciniosa*, *Plectocomiopsis geminiflorus*. Regarding *Scaphium macroporium*, the residents have summed up the knowledge that this species produces fruits irregularly one in every three to four years

NTFPs	Signals of ripeness or mature	Places to harvest	Time	Harvesting tools	Use
Seed of <i>Scaphium macroporium</i>	Nuts falling on ground, changing from green to light red	Evergreen rain forest	March to May, producing nuts only every 3-4 years	Collecting seed on forest floor or on trees, cutting down trees and harvesting	After being soaked and the seed kernel removed, the flesh is used with granulate-d sugar
Cane of rattan species	Stem becoming yellow, gray to almost white; relatively smooth with scars left by fallen leaves	Relatively high land with relative high canopy, along streams	Mainly dry season	Long knife, sickle	Handicrat, home appliance, ropes to combine parts in construct-on
Resin of some <i>Dipterocarpaceae</i> species	Tree trunk greater than 20 cm in diameter	Steep slope in deciduous forest with species of <i>Dipterocarpaceae</i> species	Mainly dry season	Collecting solid resin on forest floor or directly on trees by using a pole; liquid resin on trees by cutting a large notch on trunks near the ground, then burning, liquid oozing out	Used for making boats, baskets, ceilings, and bamboo walls watertight; handicraf, lighting

Table 11. LEK of NTFP harvesting (Source: Sang, 2006, 2010)

(table 11); before the harvesting season, they marked on the trees to assert informal ownership in the community, then built a hut near the trees for laborers to stay many days there, take care and harvest nuts; they usually used all of their household labor, even children to gather this NTFP, during the harvesting season many children of the indigenous ethnic minorities played truant in order to participate in the activity for high cash income; this livelihood strategy is not sustainable, young generation continued to be forest resource dependents. On the subject of resin harvesting, resin of *Anisoptera costata*, *Shorea obtuse*, *Dipterocarpus alatus* and some others in CTBR used to be harvested a lot for high cash income thanks to high market demand, for example, a litter of *Dipterocarpus alatus* cost about

30,000 VND; but recently only some surveyed households have involved in this activity because the resource was overexploited some years ago. The people from the different ethnic groups had a lot of experience in harvesting the product (table 11); the species producing resin were abundant on steep slope with rocky soil; tree trunks which had many branches and were attacked by insects gave much resin; solid resin harvested on trees had better quality than that gathered on the ground. In addition, liquid resin was extracted from *Dipterocarpus alatus* by cutting a large notch on trunks near the ground, then firing, waiting for ooze of liquid, and collecting the liquid resin; this not only destroyed the species but also caused forest fire which damaged the habitat of wildlife and the ecosystem; so the conservation impact caused by these activities was high; sustainable extraction methods should be applied.

In the local reality, they must encroach upon forest lands for cultivation; poach wildlife; collect NTFPs for self consumption and income generation; and some of them must join illegal logging activities. Obviously, they have a variety of livelihood strategies, but it is very limited for them to select more sustainable ways.

5. Discussion and conclusions

It appears from the research that CTBR is naturally endowed with a great variety of forest resources on which the locals, especially the EMs in the CZs and the BZ depend (table 4 & 5). As mentioned above, the resources and their LEK have been contributing very much to the local livelihoods in the CZs and BZ of the reserve, especially richer households; the income of the residents in these two zones increased significantly thanks to the forest resources (table 9), but the contribution of forest resources to the rise of total income in the TZ was very small because many of them involved in wage and salary earnings, trade and handicraft (figure 2) (Sang et al., 2010). So it was said that low rate of off-farm and non-farm jobs in the area led to the high rate of the local people involved in forest resource use activities. Likewise some of the households who participated in the programs of forest protection and ecotourism initiated by CTBR with very low income withdrew from them; of course, they continued to involve in forest resource use illegally (Sang & Ogata, 2010; Sang, 2010). It was concluded that low income of many households in CTBR was the reason for the encroached forest land areas (table 6 & 7). However, a large majority of families in the CZs and the BZ used the forest resources at a high intensive level for their basic needs as well as income generation. In short, the locals depended heavily on the forest resources because the income from the resources was much higher than the other incomes (table 9). Their dependency on the resources causes a lot of negative impacts on biodiversity conservation of CTBR through overexploitation of the resources as well as encroachment of forest land (Sang, 2006). To sum up, poverty, occupation structure, high values of the forest resources, and negative side effects of LEK brought negative impacts to biodiversity conservation in CTBR.

To overcome these situations, the following recommendations are made. Firstly, higher yielding crops with appropriate techniques including agro-forestry models should be introduced and cultivated in areas outside the CZs as well as natural forest land. In addition, fast growing species should be introduced on the bare lands for securing firewood and increasing green cover. In particular, the EMs should be encouraged to do aquaculture and raise more poultry so that they may fulfill their subsistence foodstuffs and even earn

more income. Although ecotourism creates jobs for the indigenous EMs it also brings disturbance to wildlife, so it should be carried out outside the CZs; their participation in ecotourism and forest protection should be preferred and benefits from the activities should be increased. The approach of their participation should aim at involving them not only in benefit sharing from the projects but also in the process of sustainable conservation management. Irrigation systems should be developed to enable people to grow rice for three seasons per year so that their food shortage can be lightened. The poor people in the area should have more access to credit at reasonable interest rates and over long term, enabling them to use their land effectively. Secondly, co-management arrangement (Polet, 2003) among the management board of CTBR, local government, and local people should be put into practice and effect so as to aim at sustainable uses and management of the forest resources. Thirdly, the local government and the reserve should develop the potential of ethnic minorities' indigenous knowledge in craft products, and promote home industry through craft activities. This creates long term employment for local workforce, especially for the residents in the CZs and the BZ; vocational training for the poor and unemployed people, especially in the CZs and the BZ would be also introduced.

As mentioned above, LEK contains both positive and negative sides for biodiversity conservation in CTBR. To contribute to both biodiversity conservation and development, the positive points of LEK should be applied widely and integrated with scientific knowledge. The people who are good at LEK should be encouraged to participate in the programs of biodiversity conservation, environmental education, and ecotourism. Further research to discover and understand more LEK in the area for enhancing the adaptive capacity of sustainable use is needed.

6. Appendix



Fig. A1. A captured monkey in the surveyed hamlet in the CZ in Cat Loc Sector
Source: Photo by Dinh Thanh Sang, field survey, 2010



Fig. A2. A young woman carrying bamboo poles by bicycle
Source: Photo by Dinh Thanh Sang, field survey, 2010



Fig. A3. Young women carrying fuel wood from the forest
Source: Photo by Dinh Thanh Sang; Sang, 2006



Fig. A4. Timber and a car of illegal loggers confiscated by forest guards in TZ, Lam Dong Province

Source: Photo by Dinh Thanh Sang; Sang, 2006



Fig. A5. A deforested upland with some young cashew trees in the CZ in West Cat Tien

Source: Photo by Dinh Thanh Sang, field survey, 2010



Fig. A6. A surveyed hamlet with cashew plantations in the CZ in Cat Loc Sector
Source: Photo by Dinh Thanh Sang, field survey, 2010



Fig. A7. Rice field in Ta Lai Commune in the BZ, a former area of the CZ
Source: Photo by Dinh Thanh Sang; Sang, 2006

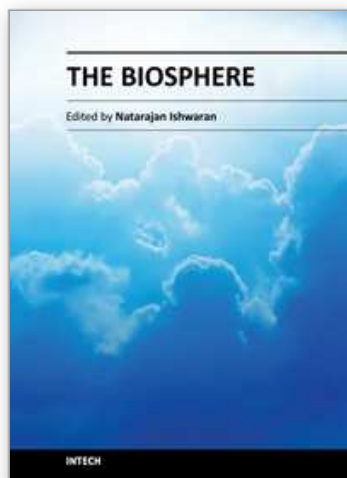
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In this book entitled "The Biosphere", researchers from all regions of the world report on their findings to explore the origins, evolution, ecosystems and resource utilization patterns of the biosphere. Some describe the complexities and challenges that humanity faces in its efforts to experiment and establish a new partnership with nature in places designated as biosphere reserves by UNESCO under its Man and the Biosphere (MAB) Programme. At the dawn of the 21st century humanity is ever more aware and conscious of the adverse consequences that it has brought upon global climate change and biodiversity loss. We are at a critical moment of reflection and action to work out a new compact with the biosphere that sustains our own wellbeing and that of our planetary companions. This book is a modest attempt to enrich and enable that special moment and its march ahead in human history.

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