Acta Ecologica Sinica 30 (2010) 56–61

Contents lists available at ScienceDirect

Acta Ecologica Sinica

journal homepage: www.elsevier.com/locate/chnaes

Ecosystem service values and land use change in the opium poppy cultivation region in Northern Part of Lao PDR

A. Yoshida [a], H. Chanhda [b,c,*], Ye Yan-Mei [b], Liang Yue-Rong [a]

[a] Zhejiang University Tea Research Institute, Hangzhou 310029, China
[b] Department of Land Resource Management, Zhejiang University, Hangzhou 310029, China
[c] Secretariat of the Lao Government, Prime Minister Office, Vientiane, Lao PDR

ARTICLE INFO

Keywords:
Ecosystem services
Land use
Remote sensing
Lao PDR

ABSTRACT

Land use change and land-cover impacts ecosystem services and functions. In this paper according to the study area's land use characteristic and ecosystem type, the Land use category of the study area was divided into seven categories, including Forest, Grassland, Farmland, Water, Wetlands, Urban land and Barren land. The dynamic information of the forest Land use change during 10 years was calculated by the map algebra in ArcGIS 9.2. Both in 1992 and in 2002, Forest and Grassland were two largest Land use category in the study area. Forest took up 44.7% and 39.4% of the total area, and Grassland was 50.13% and 50.72% of the total area in 1992 and 2002. Finally, we valued change in ecosystem services delivered by each land use category using coefficients published by Costanza et al. [5]. Ecosystem services value of study area, the total ecosystem services value of 10.6 million hectares of this study area decreased by 11.74%. From the coefficient of sensitivity (CS) was less than unity in all case, it indicated that the total ecosystem services values was relatively inelastic and the results suggest that we have to pay attention more on land use change and finally, policy for driving forces of land use change were developed.

1. Introduction

The structure and functioning of forest ecosystems are known to respond to climatic variations [1,13], atmospheric deposition [2,8,10,20], catastrophic disturbances [7,9,26], management actions [3,12] and invasions of exotic species [21,25]. Changes in land use may significantly affect ecosystem processes and services [4]. Ecosystem services represent the benefits that living organisms derive from ecosystem functions that maintain the Earth's life support system, and include nutrient cycling, carbon sequestration, air and water filtration, and flood amelioration, to name a few [5]. Land use change in Lao PDR, especially in the study areas is an essential link between local livelihood and poverty shifts and the environment.

2. Methods

2.1. Study site

The study area located in the Northern Part of Lao PDR that is a trans-boundary river is adjacent China and Burma and Vietnam, where is the mountainous, and difficult to access, by foot and cars. Most of the local farmers were doing with shifting cultivation (see Fig. 1). According to the Opium Poppy Survey in the Lao PDR during 2007, which conducted jointly by the Government of Lao PDR and United Nations Office of Drug Control (UNODC) by helicopter over sample sites in six provinces in Northern Lao PDR, namely: Phongsaly, Luang Namtha, Oudomxay, Luang Prabang, Huaphanh and Xieng Khouang and found that the opium poppy areas are still exists about 1500 ha, it means that 40% decrease in area compared to 2006 (2500 ha), and is 94% lower than in 1998 (26,800 ha) [28]. The main objective of the study were: (1) to identify the Land use change during 1992–2002, (2) to examine the impact of the Land use change on variation in ecosystem services of the study areas, (3) to determine if generalized coefficients can be used to evaluate changes in ecosystem services at regional scale.

In order to estimate the directions and magnitude of Land use changes in the study areas, former GIS data of forest land use change in 1992 and 2002 which obtained from Ministry of Agriculture and Forestry (MAF) used to extract the changes information of forest land cover during the last 10 years. (Figs. 2 and 3).

The land use datasets of the study areas (1:50,000) in 1992 and 2002 were from Agriculture and Forestry Lao PDR (MAF). Forest land use change assessment was conducted by MAF, plot sampling on Satellite Images Maps (SIMs) to detect the changes of land use in 1992 and 2002 for the study area and field verification in order to identify causes of the changes. Then, the dynamic information of

* Corresponding author.
E-mail address: chanhda2006@hotmail.com (H. Chanhda).

1872-2032/$ - see front matter Crown Copyright © 2010 Ecological Society of China. Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.chnaes.2010.03.002

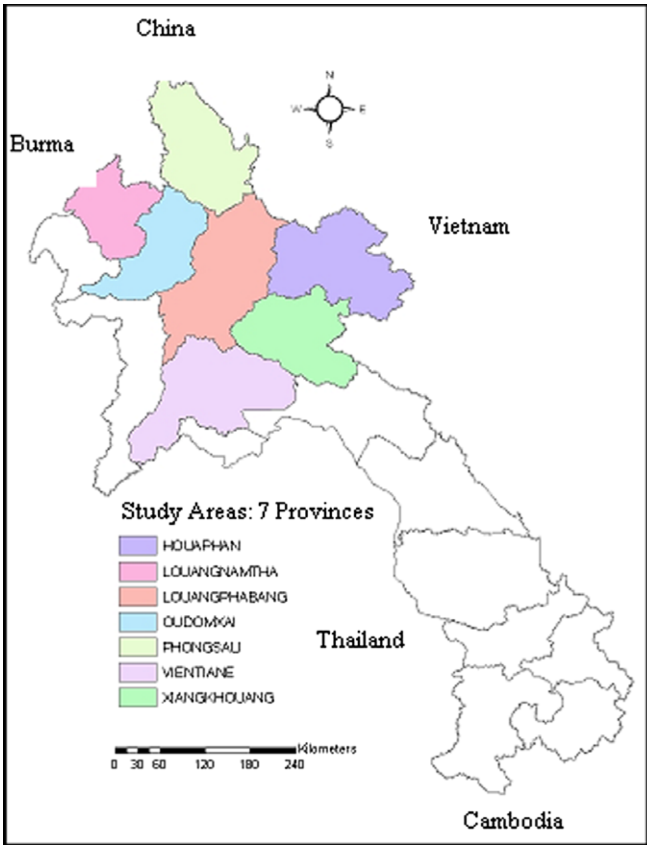

Fig. 1. Location of study areas.

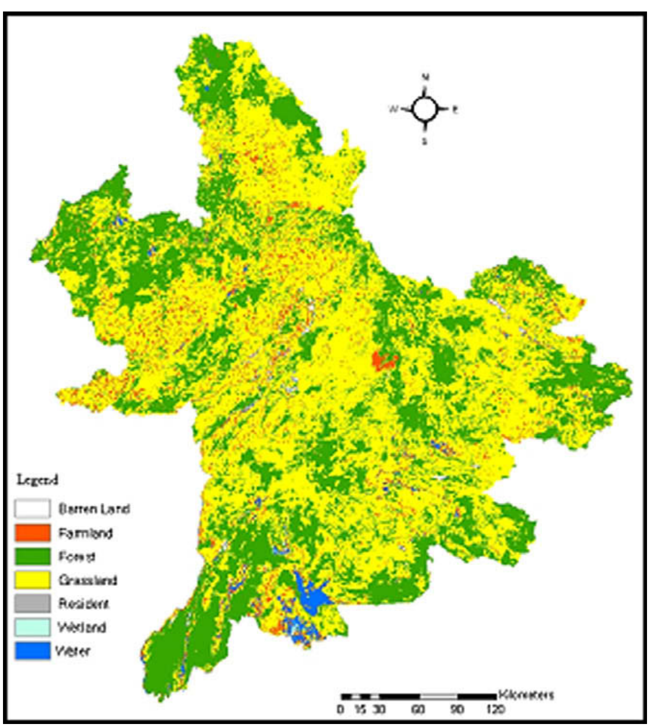

Fig. 2. Land use map in 1992.

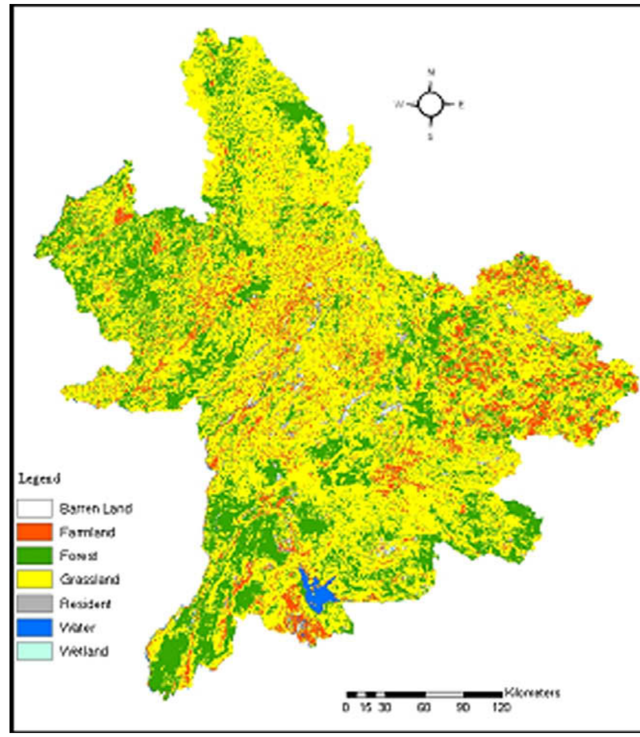

Fig. 3. Land use map in 2002.

the land-cover change during 10 years was calculated by the map algebra in ArcGIS 9.2 software. In this study, the data sets were reclassified into seven categories, including Forest, Grassland, Farmland, Water, Wetland, Resident land and Barren land (Table 1). Map of land use in the study areas for 1992 and 2002 produced from Landsat images were shown in Figs. 2 and 3.

2.2. Land use classification

Generally speaking, seven Land use categories are identified namely: Forest, Grassland, Farmland, Water, Wetland, Resident land and Barren land. The basis for the distinction between forest and other Land use categories is the crown cover exceeding 20%. See the definition of each Land use category in Table 1.

2.3. Map production

The dynamic information of the Land use change during 10 years was calculated by the map algebra in ArcGIS9.2. According to the principle of map algebra, we can calculate any two period of Land use category figure that may be named by A^k and A^{k+1}. The equation is as follows where the number of Land use category should be less than 10

$$C_{ij} = A_{ij}^{k} \times 10 + A_{ij}^{k+1} \quad (1)$$

According to (1), we can get the Land use change figure that can be named C_{ij} from the period k to period $k+1$. The figure C_{ij} can show the Land use change and change distribution. Using this method we gain the transferring matrix that reflects the quantitative transferring relation between different Land use categories in research area (Tables 3–5).

2.4. Assignment of ecosystem service values

In order to obtain ecosystem services values for each of the five Land use categories, each category was compared with the 16 biomes identified in Costanza's ecosystem services valuation model [6] (Table 2). And then, Current Forest, Grassland, Agricultural land, Water bodies, Wetlands were assigned values of 2007, 232, 92, 8498, 14,785 ha^{-1} per year (Table 2). The total value of the ecosystem services represented by each Land use category was obtained by multiplying the estimated size of each land category by the value coefficient

$$ESV = \sum(A_i \times VC_i) \tag{2}$$

where ESV is the estimated ecosystem service value, A_i the area (ha) and VC_i the value coefficient ($/ha/year) for Land use category '*i*' [14]. The change in ecosystem service values was estimated by calculating the difference between the estimated values for each Land use category in 1992 and 2002.

Sensitivity analyses were conducted to determine the dependence of temporal changes in ecosystem service values on the applied valuation coefficients. The ecosystem value coefficients for Forest, Grassland, Farmland, Water, Wetland categories were each adjusted by 50%. In each analysis, the coefficient of sensitivity (CS) was calculated using the standard economic concept of elasticity, i.e. the percentage change in the output for a given percentage change in an input [31,34,35,18,19,29,30,33]

$$CS = \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}} \tag{3}$$

where ESV is the estimated ecosystem service value, VC is the value coefficient, '*i*' and '*j*' represent the initial and adjusted values, respectively, and '*k*' represents the Land use category. If the ratio of the percentage change in the estimated total ecosystem value (ESV) and the percentage change in the adjusted valuation coefficient (VC) is greater than unity, then the estimated ecosystem value is elastic with respect to that coefficient, but if the ratio is less than one, then the estimated ecosystem value is considered to be inelastic. The greater the proportional change in the ecosystem service value relative to the proportional change in the valuation coefficient, the more critical is the cover of an accurate ecosystem value coefficient.

Table 1
Land use category.

Category	Definition
Forest	Forest includes natural forests plantations. It is used to refer to land with a tree canopy cover more than 20% and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m
Grassland	Unfertile or degraded land on which no trees or shrubs grow. It might be an area that is too dry for the tree growth that has been covered by grasses. It could also be an area that has originally been covered by trees that has been heavily disturbed by cutting and fire and gradually depleted. One reason for the absence of trees could be that of big areas have been deforested that the seed supply from surrounding forest has ceased. Areas being burned over and over again (every year) for production of fodder and for hunting purposes etc. could also be classified as Grassland. These types of Grassland could be found on higher elevations in the Northern part of Lao PDR. Grassland could also occur on deep sand with high moisture content
Farmland	Areas of Farmland being used for production of other crops than rice, i.e. various kinds of vegetable, for fruit tree cultivation etc. Plantations with cash crops, such as coffee, tea, cocoa and cotton are also referred to this land use category
Water	The land use class water includes rivers, water reservoirs (i.e. ponds and dams for irrigation and hydro power) and lakes. Water reservoirs and lakes should have an area of 0.5 ha and rivers should be at least 10 m wide to be classified as water. In other cases it should be joined to adjacent land use category
Wetland	Wetlands are areas where the soil is saturated with water. The soil may basically be fertile but the lack if oxygen limits its agriculture or forest-production capacity
Resident land	Resident Areas include all areas being used for permanent settlements such as villages, towns, public gardens etc. It also includes roads having a width of more than 5 m and areas under electric high power lines. Any type of land under high power lines, except Rice Paddy, should be classified as Urban Areas
Barren land	Unfertile or seriously degraded land on shallow soil and rocky areas on which neither trees nor grasses can grow

Source: [15].

Table 2
The land use category and the corresponding ecosystem service coefficient.

Land use category	Equivalent biome	Ecosystem service coefficient ($/ha/year)
Forest	Forest	2007
Grassland	Grass/rangelands	232
Farmland	Cropland	92
Water	Lakes/rivers	8498
Wetland	Wetlands	14,785
Resident	Urban	0
Barren land	Desert	0

Cited from use Costanza et al. [5].

3. Results

3.1. Changes in land use

The overall land use change in 1992 and 2002 were showed in Table 3.

According to this table, Forest and Grassland were two largest Land use category in the study area, both in 1992 and in 2002. Forest took up 44.7% and 39.4% of the total area, and Grassland was 50.13% and 50.72% of the total area in 1992 and 2002. From Table 3 we can see that the areas of Grassland, Wetland and Resident land and Barren land increased from 1992 to 2002. On contrary, the areas of Forest and Water decreased.

The most notable changes of land use in the study areas were declined in Forest and an increase in Grassland, Farmland, Wetlands and Resident land. In 1992, Forest covers about 44.7% in the study areas and with an estimated area in total 4.7 million hectares, but by 2002, the total area of Forest was estimated to have decreased substantially by about 11.7% to 0.5 million

Table 3
Total area of each land use change in 1992 and 2002.

Land use category	1992		2002		1992–2002		
	ha	%	ha	%	ha	%	%/year
Forest	4782951.36	44.74	4221517.32	39.49	−561434.04	−11.74	−1.17
Grassland	5358749.85	50.13	5422336.47	50.72	63586.62	1.19	0.12
Farmland	316979.82	2.97	882448.65	8.25	565468.83	178.39	17.84
Water	188261.37	1.76	73819.71	0.69	−114441.66	−60.79	−6.08
Wetland	2289.96	0.02	2799.18	0.03	509.22	22.24	2.22
Resident land	1708.74	0.02	4732.92	0.04	3024.18	176.98	17.70
Barren land	39017.25	0.36	82304.10	0.77	43286.85	110.94	11.09
Total	10689958.35	100.00	10689958.35	100.00			

Table 4
Transferring matrix of land use category in 1992 and 2002 (ha).

Land use category 1992	2002						
	Forest	Grassland	Farmland	Water	Wetland	Resident land	Barren land
Forest	3116497.86	1401466.05	247136.49	3850.56	28.80	71.19	13900.41
Grassland	1063653.39	3833784.36	412965.54	3809.70	451.17	751.50	43334.19
Farmland	34320.06	165404.97	114427.35	386.37	0.18	2117.61	323.28
Water	3828.87	13007.70	106944.39	63979.47	14.40	331.65	154.89
Wetland	1.08	5.58	16.29	1.17	2266.92	1451.97	24591.33
Resident land	3216.06	83.52	29.34	142.83	37.71	9.00	0
Barren land	0	8584.29	929.25	1649.61	0	0	0

Table 5
The coefficient of sensitivity (CS).

Land use category	Ecosystem Service Coefficient ($/ha/year)	1992 ESV	2002 ESV	1992–2002	
		$/year	$/year	$/year	%
Forest	2007	9599383379.52	8472585261.24	−1126798118.28	−11.74
Grassland	232	1243229965.20	1257982061.04	14752095.84	1.19
Farmland	92	29162143.44	81185275.80	52023132.36	178.39
Water	8498	1599845122.26	627319895.58	−972525226.68	−60.79
Wetland	14785	33857058.60	41385876.30	7528817.70	22.24
Resident land	0	0.00	0.00	0.00	0.00
Barren land	0	0.00	0.00	0.00	0.00
Total		12505477669.02	10480458369.96	−2025019299.06	

hectares. The annual rate of decrease slowed down from 1.7% per year during 1992–2002. Meanwhile Farmland increased from 0.3 million hectares in 1992 to 0.8 million hectares in 2002, with annual growth rate of 17.84% (Table 3). Resident land increased in size from 1.7 thousand hectares in 1992 to 4.7 thousand hectares in 2002, while water decreased slightly from 0.1 million hectares in 1992 to 73.8 thousand hectares in 2002. Wetlands increased from 2.2 thousand hectares in 1992 to 2.7 thousand hectares in 2002 with annual growth rate 2.2%.

The considerable decrease in Forest and the concomitant increase in Grassland and Farmland resulted from many factors namely: high demand for wood and Non-timber forest products in the markets of wood deficient neighboring countries and countries in the region as well as the imposition of logging bans in some neighboring countries about high pressure on forest resources in Lao PDR, shifting cultivation practices, opium poppy cultivation [17,32] and forest fires are still the main causes of land use change particularly in the study areas.

Results of the transition matrix in Table 4 indicated the area increase or decline of each Land use category. See Table 4.

Results of the transition matrix in Table 4 we can conclude that the decrease of Forest is mainly converted to Grassland, Farmland category. The decrease of Grassland is mainly converted to Forest and Farmland. The transferring among Forest, Grassland and Farmland between Water, Wetland, Resident land and Barren land were quite frequent.

3.2. Changes in ecosystem services

Using the estimated change in the size of each Land use category, together with the ecosystem service value coefficients reported by Costanza [5]. The total ecosystem services value in the 10.6 million hectares of the study area was about $9599.3 million in 1992, $8472.5 million in 2002 (Table 5). From 1992 to 2002, the decline in ecosystem service value caused by the decrease of Forest was offset by value increase in Grassland, Wetlands, Water and Farmland. However, the total ecosystem service value decreased by $2025 million.

The land use change was negative in environment namely soil erosion, flooding, drought, decrease in biodiversity and etc. [11,23]. For example the flood of the year 2004 occupied many places, particularly along the Mekong River and its tributaries as such: Vientiane Province, here are two districts affected. Thoulakhom and Long Ngum Districts are located downstream of Nam Ngum reservoir, in which 12 villages and loss area of paddy field of 2000 ha. Vientiane Capital City, in this city is three districts affected, in which 57 villages and loss of paddy field of amount 2.7 thousand hectares. Khammuane Province in this province was affected more than other, there are six districts were affected, 376 villages, 30 thousand people and paddy field loss 16 thousand hectares with total cost estimated amount 4.026 bill kip (4 mill US$) Borikhamsay Province is affected by flood on 10–11 September 2004; there are two Districts affected and loss of area agriculture amount 3.4 thousand hectares. Savannakhet Province was affected 14 thousand hectares of paddy field and there are six Districts. Champasack Province in this Province is affected three Districts and loss paddy field about 8.2 thousand hectares [15,16].

3.3. Ecosystem services sensitivity analyses

The effects of using alternative coefficients to estimate total ecosystem service values in the study area in 1992 and 2002 are shown in Table 6. As shown in Table 6 the percentage change in estimated total ecosystem service value and the coefficient of sensitivity resulting from a 50% adjustment in the value of the coefficient, was calculated using formula (3).

The CS of these analyses was less than unity in all cases. This indicates that the total ecosystem services values estimated in this study area was relatively inelastic with respect to the value coefficients. When the Forest coefficient was increased by 50%, the ecosystem services in the study area increased in value by 38.38% in 1992, 19.15% in 2002.CS for Forest and Grassland was relatively bigger. CS for Forest was the highest, 0.76, because of the large area and high service value coefficient. Although the areas of Water and Wetlands were small, CS for these two Land use categories was relatively large because of their high value coefficients. CS for Water decreased from 0.12 in 1992 to 0.05 in 2002, while that for Wetlands were not increased so much from 0.003 to 0.004.

Table 6
The coefficient of sensitivity (CS).

Change in valuation coefficient	1992		2002	
	%	CS	%	CS
Forest VC ± 50%	±38.38	±0.76	±19.15	±0.38
Grassland VC ± 50%	±4.97	±0.09	±6.00	±0.12
Farmland VC ± 50%	±0.11	±0.00	±0.38	±0.00
Water VC ± 50%	±6.39	±0.12	±2.99	±0.05
Wetland VC ± 50%	±0.13	±0.003	±0.19	±0.004

4. Discussions and conclusion

Our study showed that satellite data and GIS tools were useful and inexpensive for monitoring and analyzing the changes in the value of ecosystem services [22]. In many cases, remote sensing from satellites may be the only economically feasible way to gather regularly land use information with high spatial, spectral, and temporal resolution over large areas [24]. With the help of the satellite data may be one economically and advantage over alternative data-collection methods. Study Areas mountainous country, extensive field survey can be difficult to implement due to restricted accessibility. In the study situations, these methods can facilitate reasonably accurate large scale analysis and time series analysis of land use change.

Costanza's [5] ecosystem service values which represented the most comprehensive set of valuation coefficients are available to us for absolutely accurate coefficients are often less critical for land use change analyses than time-specific analyses of the value of ecosystem services because coefficients tend to affect estimates of directional change less than estimates of the magnitude of ecosystem values at a specific point in time [14]. Nevertheless, in order for the kind of ecosystem service analysis that we conducted to become more meaningful for policy formulation affecting land use, it is imperative to obtain value coefficients for ecosystem services that more accurately reflect local conditions.

Based on the estimated size of five land-cover categories and using Costanza et al.'s [5] ecosystem services values, we determined that the total annual ecosystem service values in the study areas to have declined by $2025 million between 1992 and 2002. This massive decline in ecosystem services is largely attributable to the 11.74% loss of Forest (Table 3). The high rate of loss of such services will undoubtedly have serious negative ecological consequences in the long term. One way to mitigate such massive impacts would be to protect the tropical rain forest areas. Recognizing the environmental importance of the tropical rain forest should pay more attention in the world.

We argue that, in future land-reclamation projects be controlled and based on rigorous environmental impact analyses. To achieve this, more detailed studies of the impacts of land use planning and its impact on the ecosystem services provided in the study areas are necessary. Concerning to address the Land use change in the study areas, Lao Government has developed many policies for improving the social and economic systems concentrate on stabilizing shifting cultivation and opium poppy eradication, poverty eradication and etc. At the same time implementation of these policies is constrained by many factors, including the remoteness of the areas, lack of human resources, lack of roads, difficulties in developing markets and supplying and distributing credit, cultural and linguistic problems in communicating with numerous ethnic groups, and the continuing dangers of unexploded ordnance left from past military activities.

So in order to fulfill the objectives of the Lao Government policy, it needs to do the research more on how to improve the living standards of the local people based on their available natural resources around their region namely: history, culture, geography and so on. For example the study areas have the long history and still rich in natural resources, ecotourism should be strongly promoted, because ecotourism is widely regarded as an industry with more benefits and less damages to natural resources. In case of rubber plantation and ecotourism promotion from Luang Namtha province, Lao PDR which is bordering with Xishoungbanna, Yunnan Province China and one of the opium poppy cultivation province shows that ecotourism activities and rubber plantations can be conducted viably in the same province, but not in the same immediate areas. Designating which areas will be converted to rubber plantations, and which areas will be set aside for ecotourism activities is therefore one priority for provincial planners. Since the forests of the Nam Ha National Protected Areas already provide ecotourism income, food, medicine, and ecological services, and are an irreplaceable repository of biodiversity, it is strongly recommended that the authorities in Luang Namtha Province, Lao PDR formulate and enforce a long-term zoning plan that protects the profitable ecotourism industry and limits further introduction of rubber into the Nam Ha National Protected Area. If the current rate of land clearance and rubber encroachment into the Nam Ha National Protected Area continues to go unchecked, the province will not be able to sustain its profitable and growing ecotourism sector, and the thousands of people that rely on the National Protected Area's diverse forests for ecotourism, food and ecological services may soon find themselves bankrupted by Luang Namtha's dubious 'rubber boom'.

Acknowledgements

The first author wished to take this opportunity to express my most sincere gratitude to Chinese Government for funding my study in Zhejiang University China and many thank to the anonymous reviewers for their helpful comments and suggestions on earlier drafts of this manuscript.

References

[1] J. Aber, R.P. Neilson, S. McNulty, J.M. Lenihan, D. Bachelet, R.J. Drapek, Forest processes and global environmental change: predicting the effects of individual and multiple stressors, BioScience 51 (9) (2001) 735–751.
[2] J.D. Aber, C.L. Goodale, S.V. Ollinger, M.L. Smith, A.H. Magill, M.E. Martin, R.A. Hallett, J.L. Stoddard, Is nitrogen deposition altering the nitrogen status of northeastern forests? BioScience 53 (4) (2003) 375–389.
[3] F.H. Bormann, G.E. Likens, Pattern and Process in a Forested Ecosystem, Springer-Verlag, New York, 1979. p. 253.
[4] G.R. Christian, E.C. Mary, Change in the forested and developed landscape of the Lake Tahoe basin, California and Nevada, USA, 1940–2002, Forest Ecology and Management 255 (8–9) (2008) 3424–3439.
[5] R. Costanza, R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, M. van den Belt, The value of the world's ecosystem services and natural capital, Nature 387 (1997) 253–260.
[6] R. Costanza, R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, M. van den Belt, The value of the world's ecosystem services and natural capital, Ecological Economics 25 (1) (1998) 3–15.
[7] V.H. Dale, A.E. Lugo, J.A. MacMahon, S.T.A. Pickett, Ecosystem management in the context of large, infrequent disturbances, Ecosystems 1 (6) (1998) 546–557.
[8] C.T. Driscoll, D. Whitall, J. Aber, E. Boyer, M. Castro, C. Cronan, C.L. Goodale, P. Groffman, C. Hopkinson, K. Lambert, G. Lawrence, S. Ollinger, Nitrogen pollution in the northeastern United States: sources, effects, and management options, BioScience 53 (4) (2003) 357–374.
[9] D.R. Foster, D.H. Knight, J.F. Franklin, Landscape patterns and legacies resulting from large, infrequent forest disturbances, Ecosystems 1 (6) (1998) 497–510.
[10] F.S. Gilliam, Response of the herbaceous layer of forest ecosystems to excess nitrogen deposition, Ecology 94 (6) (2006) 1176–1191.
[11] X.Y. He, H.Y. Zhao, Y.M. Hu, H.Y. Chang, Q.X. Zhou, Landscape Changes from 1974 to 1995 in the Upper Minjiang River Basin, China, Pedosphere 16 (3) (2006) 398–405.
[12] J.W. Hornbeck, W.T. Swank, Watershed ecosystem analysis as a basis for multiple-use management of eastern forests, Ecological Applications 2 (3) (1992) 238–247.
[13] P.K. Jiang, Q.F. Xu, Abundance and dynamics of soil labile carbon pools, Pedosphere 16 (4) (2006) 505–511.

[14] P. Kreuter, H.G. Harris, M.D. Matlock, R.E. Lacey, Change in ecosystem service values in the San Antonio area, Ecological Economics 39 (3) (2001) 333–346.
[15] Ministry of Agriculture and Forestry (MAF), Forest Cover and Land Use Survey in Lao PDR, vol. 1, Ministry of Agriculture and Forestry Press, Vientiane, 2005. p. 57.
[16] Ministry of Agriculture and Forestry (MAF), Report on Floods and Drought in Lao PDR (in Lao), vol. 1, Ministry of Agriculture and Forestry Press, Vientiane, 2006. p. 63.
[17] NAFRI, CIRAD, 2003. D_veloppement rural en R_publique D_mocratique Populaire Lao – Positionnement du Programme National Agro_cologie. Vientiane, NAFRI – CIRAD, p. 12.
[18] T.H. Li, W.K. Li, Z.H. Qian, Variations in ecosystem service value in response to land use changes in Shenzhen, Ecological Economics 03152 (2008) 9.
[19] W.K. Li, T.H. Li, Z.H. Qian, Impact of land use change on ecosystem service values in Shenzhen (in Chinese), Natural Resources 23 (3) (2008) 440–446.
[20] G.E. Likens, F.H. Bormann, R.S. Pierce, J.S. Eaton, N.M. Johnson, Biogeochemistry of a Forested Ecosystem, Springer-Verlag, New York, 1977. p. 146.
[21] G.M. Lovett, C.D. Canham, M.A. Arthur, K.C. Weathers, R.D. Fitzhugh, Forest ecosystem responses to exotic pests and pathogens in eastern North America, BioScience 56 (5) (2006) 395–405.
[22] L.X. Qian, H.S. Cut, J. Chang, Impacts of land use and cover change on land surface temperature in the Zhujiang Delta, Pedosphere 16 (6) (2006) 681–689.
[23] B. Quan, J.F. Chen, H.L. Qiu, M.J.M. Romkens, X.Q. Yang, S.F. Jiang, B.C. Li, Spatial–temporal pattern and driving forces of land use changes in Xiamen, Pedosphere 16 (4) (2006) 477–488.
[24] A.F. Seidl, A.S. Moraes, Global valuation of ecosystem services. Application to the Pantanal da Nhecolandia, Brazil, Ecological Economics 33 (1) (2000) 1–6.
[25] B. Stadler, T. Muller, D. Orwig, R. Cobb, Hemlock woolly adelgid in New England forests: canopy impacts transforming ecosystem processes and landscapes, Ecosystems 8 (3) (2005) 233–247.
[26] M.G. Turner, V.H. Dale, E.H. Everham, Fires, hurricanes, and volcanoes: comparing large disturbances, BioScience 47 (11) (1997) 758–768.
[28] United Nation Office of Drug and Crime (UNODC), Opium Poppy in the Golden Triangle Lao PDR, Myanmar, Thailand, UNODC, 2007. p. 146.
[29] W.H. Xun, Y.Q. Wang, X.G. Li, Effects of land use change on values of ecosystem services in old industrial base of Shenyang city, Research of Agricultural Modernization 29 (4) (2008) 435–438 (in Chinese).
[30] S.P. Yue, S.W. Zhang, Y.C. Yan, Impacts of land use change on ecosystem services value in the Northeast China Transect (NECT), Acta Geographica Sinica 62 (8) (2007) 879–886 (in Chinese).
[31] Z.M. Wang, B. Zhang, S.Q. Zhang, X.Y. Li, D.W. Liu, K.S. Song, J.P. Li, F. Li, H.T. Duan, Changes of land use and of ecosystem service values in Sanjian Plain Northeast China, Environmental Monitoring and Assessment 112 (2006) 69–91.
[32] Watershed, Aspects of forestry management in the Lao PDR, Watershed 5 (3) (2000) 57–64.
[33] H.J. Wu, X.L. Wang, L.M. Ning, Y.F. Lu, Effects of land use change of land use changed on ecosystem services value, Resources and Environment in the Yangtze Basin 15 (2) (2006) 185–190 (in Chinese).
[34] B. Zhao, U. Kreuter, B. Li, Z.J. Ma, J.K. Chen, N. Nakagoshi, An ecosystem service value assessment of land-use change on Chongming Island, China, Land Use Policy 21 (2004) 139–148.
[35] Zhang, B., Li, W.H., Xie, G.D., Xiao, Y., 2008. Water conservation of forest ecosystem in Beijing and its value. Ecological Economics 03238 (11 pages).