Impact of Land Use and Land Cover Changes on Ecosystem Services in Southwest China

Presented by

HU Huabin

OUTLINE

- Introduction
- Methods
- Results
- Discussion

Ecosystem services refer to the conditions and processes provided by ecosystems and species for human to sustain.

Introduction

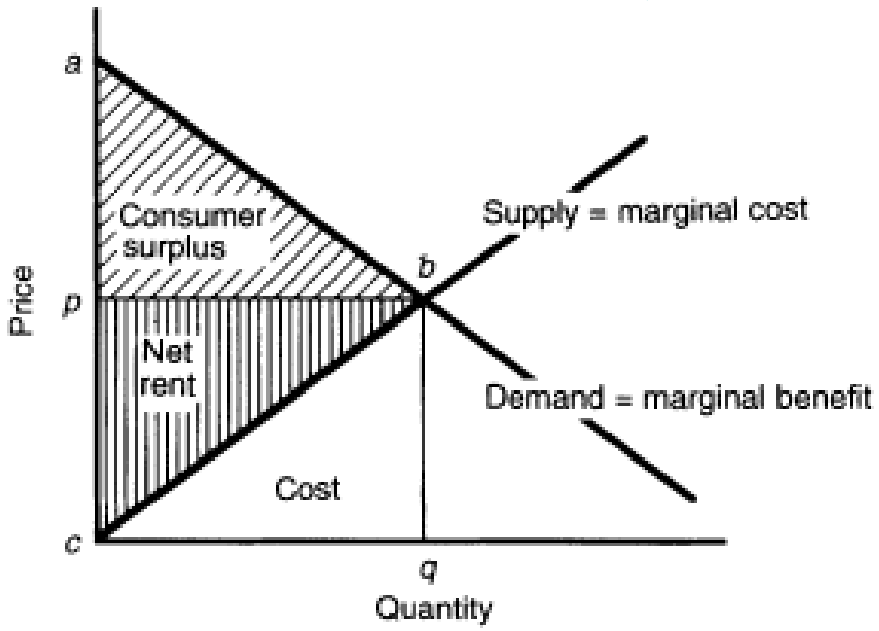
- Land use / land cover change
  - Top 10 priority research topics for landscape ecology (Wu & Hobbs 2002)
    - causes, processes, and consequences of land use and land cover change
    - integrating humans and their activities into landscape ecology
- Ecosystem services & values
  - 'free gifts of nature' ? "Ecosystem are not fully 'captured' in commercial markets or adequately quantified in terms of comparable with economic services and manufactured capital, they are often given too little weight in policy decision"(Costanza 1997). "ecosystems are poorly understood, scarcely monitored, and undergoing rapid degradation and depletion. Often the importance of ecosystem services is widely appreciated only upon their loss."(Daily 2000)
  - global biosphere values of 17 ecosystem services provided by 16 dominant global biomes. (Costanza et al. 1997)

Ecosystem Services

		Ecosystem functions	Examples
1	gas regulation	Regulation of atmospheric chemical composition.	CO_2/O_2 balance, O_3 for UVB protection, and SO_x levels.
2	climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels.	Greenhouse gas regulation, DMS production affecting cloud formation.
3	disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.	Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure.
4	water regulation	Regulation of hydrological flows.	Provisioning of water for agricultural (such as irrigation) or industrial (such as milling) processes or transportation.
5	water supply	Storage and retention of water.	Provisioning of water by watersheds, reservoirs and aquifers.
6	erosion control	Retention of soil within an ecosystem.	Prevention of loss of soil by wind, runoff, or other removal processes, storage of silt in lakes and wetlands.
7	soil formation	Soil formation processes.	Weathering of rock and the accumulation of organic material.
8	nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.	Nitrogen fixation, N, P and other elemental or nutrient cycles.
9	waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	Waste treatment, pollution control, detoxification.
10	pollination	Movement of floral gametes.	Provisioning of pollinators for the reproduction of plant populations.
11	biological control	Trophic-dynamic regulations of populations.	Keystone predator control of prey species, reduction of herbivory by top predators.
12	habitat / refugia	Habitat for resident and transient populations.	Nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds.
13	food production	That portion of gross primary production extractable as food.	Production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing.
14	raw material	That portion of gross primary production extractable as raw materials.	The production of lumber, fuel or fodder.
15	genetic resources	Sources of unique biological materials and products.	Medicine, products for materials science, genes for resistance to plant pathogens and crop pests, ornamental species (pets and horticultural varieties of plants).
16	recreation	Providing opportunities for recreational activities.	Eco-tourism, sport fishing, and other outdoor recreational activities.
17	cultural	Providing opportunities for non-commercial uses.	Aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems.

17 Cultural

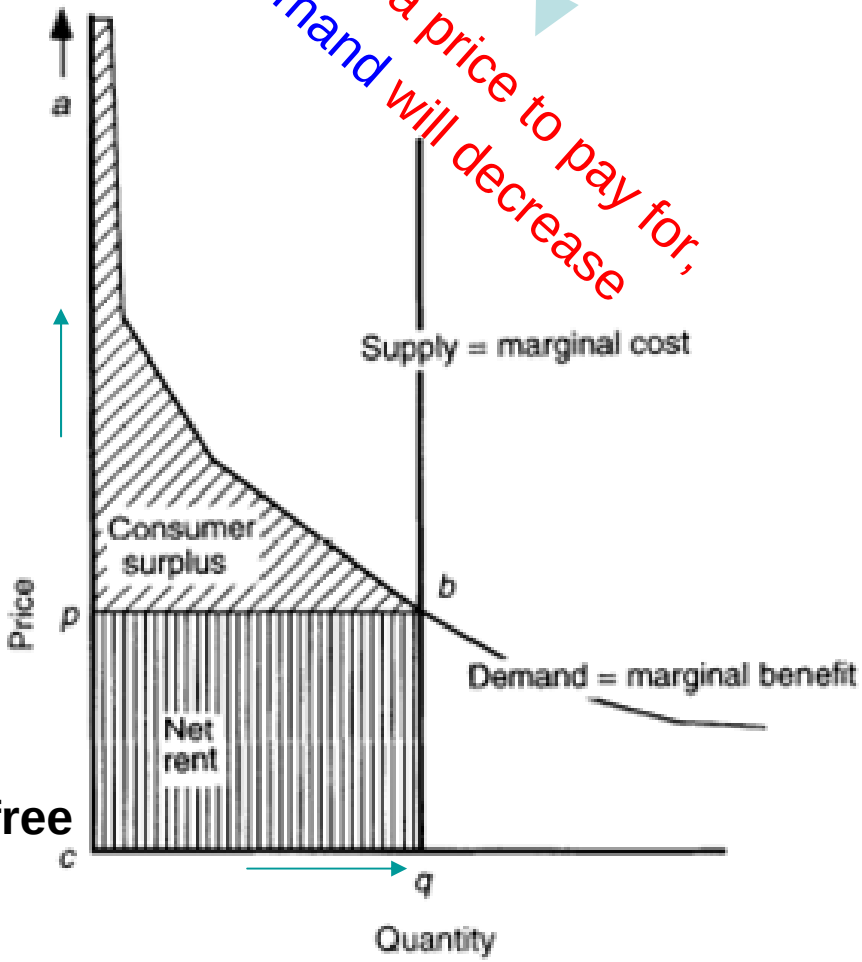
Supply and demand curves, showing the definitions of cost, net rent and consumer surplus for normal goods (**a**) and some essential ecosystem services



(Costanza et al. 1997)

(b)

If there is a price to pay for, the demand will decrease



Price=free

Which ecosystems supply what services? How much?

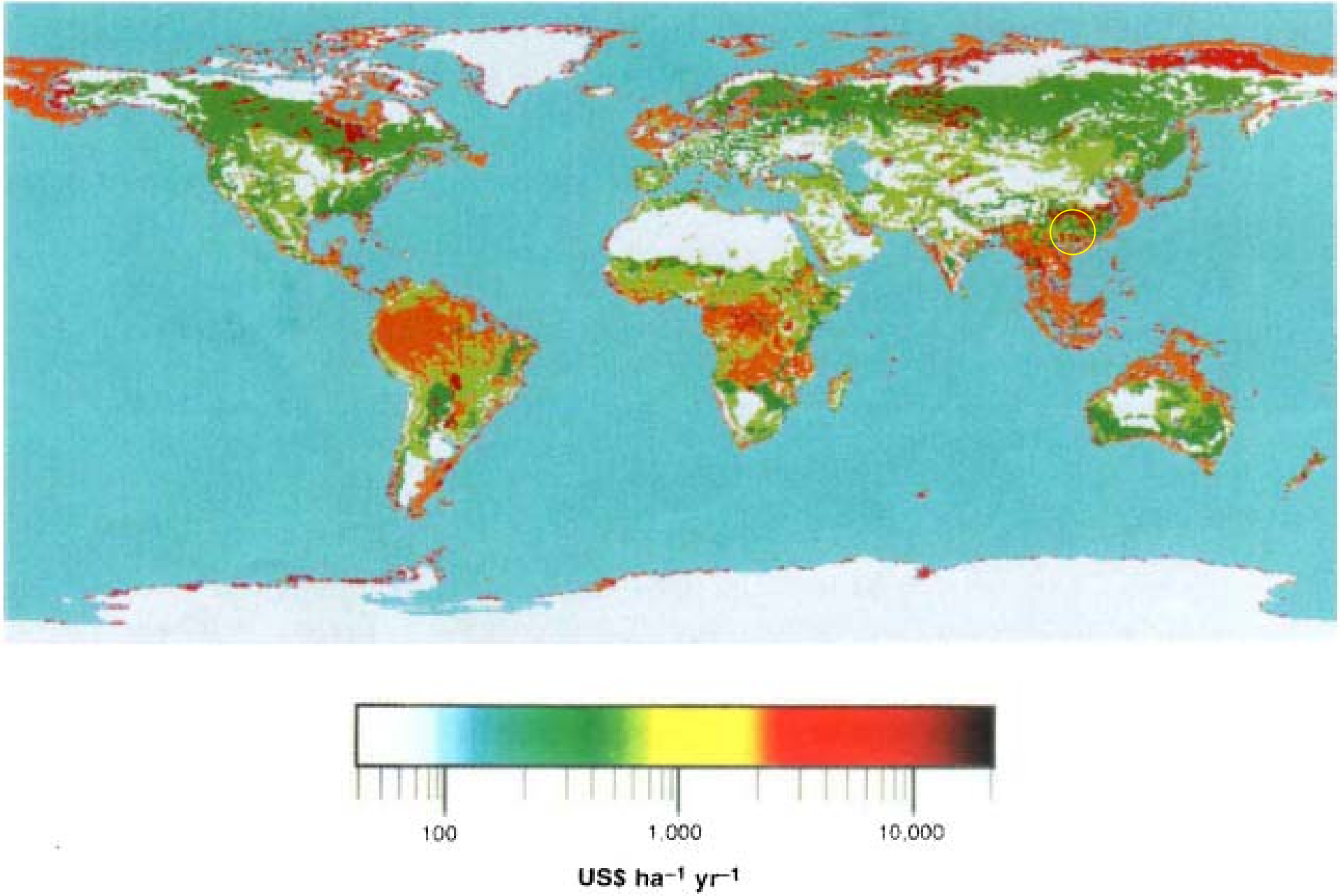
Ecosystem services (1994 US$ ha^{-1} yr^{-1})

Biome	Area ($ha \times 10^6$)	1 Gas regulation	2 Climate regulation	3 Disturbance regulation	4 Water regulation	5 Water supply	6 Erosion control	7 Soil formation	8 Nutrient cycling	9 Waste treatment	10 Pollination	11 Biological control	12 Habitat/ refugia	13 Food production	14 Raw materials	15 Genetic resources	16 Recreation	17 Cultural	Total value per ha ($ha^{-1} yr^{-1})	Total global flow value ($ yr$^{-1} \times 10^6$)
Marine	36,302																		577	20,949
Open ocean	33,200	38							118			5		15	0			76	252	8,381
Coastal	3,102			88					3,677			38	8	93	4		82	62	4,052	12,568
Estuaries	180			567					21,100			78	131	521	25		381	29	22,832	4,110
Seagrass/ algae beds	200								19,002						2				19,004	3,801
Coral reefs	62			2,750						58		5	7	220	27		3,008	1	6,075	376
Shelf	2,660								1,431			39		68	2			70	1,610	4,283
Terrestrial	15,323																		804	12,319
Forest	4,855		141	2	2	3	96	10	361	87		2		43	138	16	99	2	999	4,706
Tropical forest	1,900		223	5	6	8	245	10	922	87				32	315	41	112	2	2,007	3,813
Temperate/boreal	2,955		88		0			10		87		4		50	25		36	2	302	894
Grass/rangeland	3,898	7	0		3		29	1		87	25	23		67		0	2		232	906
Wetlands	330	133		4,539	15	3,800				4,177			304	256	106		574	881	14,785	4,879
Tidal marsh/ mangroves	165			1,839						6,696			169	466	162		668		9,990	1,648
Swamps/ floodplains	165	265		7,240	30	7,600				1,659			439	47	49		491	1,781	19,580	3,231
Lakes / river	200				5,446	2,117				665				41			230		8,498	1,700
Desert	1,925																			
Tundra	743																			
Ice/rock	1,640																			
Cropland	1,400										14	24		54					92	128
Urban	332																			
Total	51,625	1,341	684	1,779	1,115	1,692	576	53	17,075	2,277	117	417	124	1,386	721	79	875	3,015		33,268

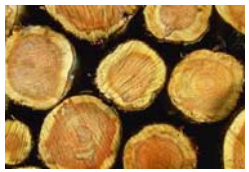
Numbers in the body of the table are in $ha^{-1} yr^{-1}. Row and column totals are in $ yr$^{-1} \times 10^6$, column totals are the sum of the products of the per ha services in the table and the area of each biome, not the sum of the per ha services themselves. Shaded cells indicate services that do not occur or are known to be negligible. Open cells indicate lack of available information.

63% from marine ecosystems

37% from terrestrial ecosystems

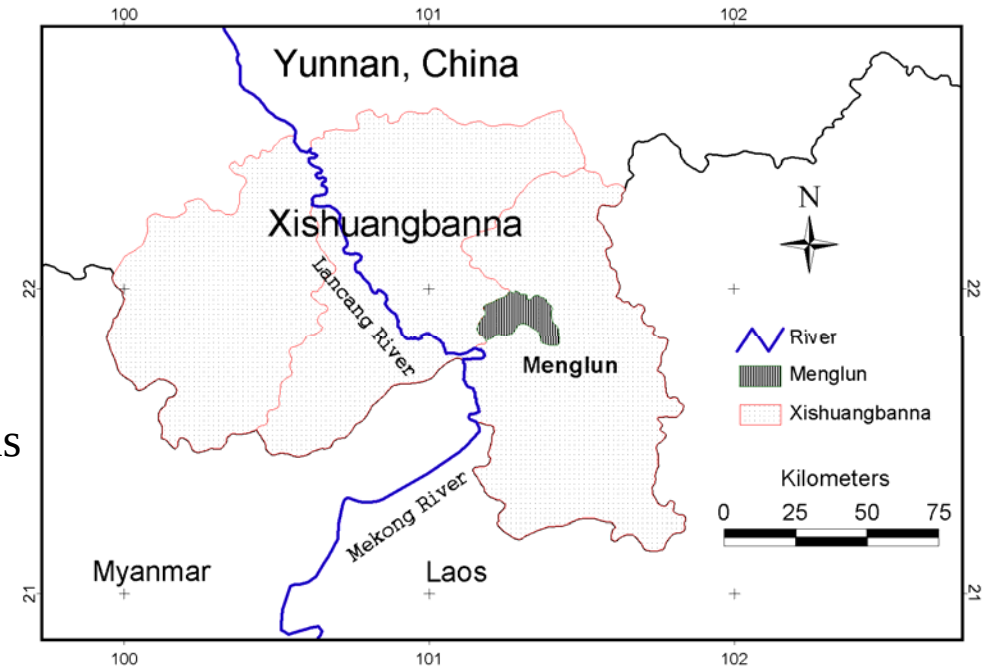

100
1,000
10,000
US$ ha⁻¹ yr⁻¹

- Methods of ecosystem service valuation
  - Classification
    - Direct uses: goods
    - Indirect uses: services
  - Valuation
    - Energy:
    - Material:
    - Monetary:



Methods

Study area



Xishuangbanna: a Dai Autonomous Prefecture in S Yunnan

Lancang River

Biodiversity:

total land area of **1,915,167** ha, it covers only **0.2%** of the land area of China, but supports nearly **16%** of its higher plant species, and more than **23%** of China's animal species can be found here.

about **14%** of the total land area as nature reserve.

•**Local economy**: crop production (tea, rubber, fruits), tourism etc. The GNP for the year 1988 and 2003 were $163.20 million (NPV) and $701.09 million respectively.

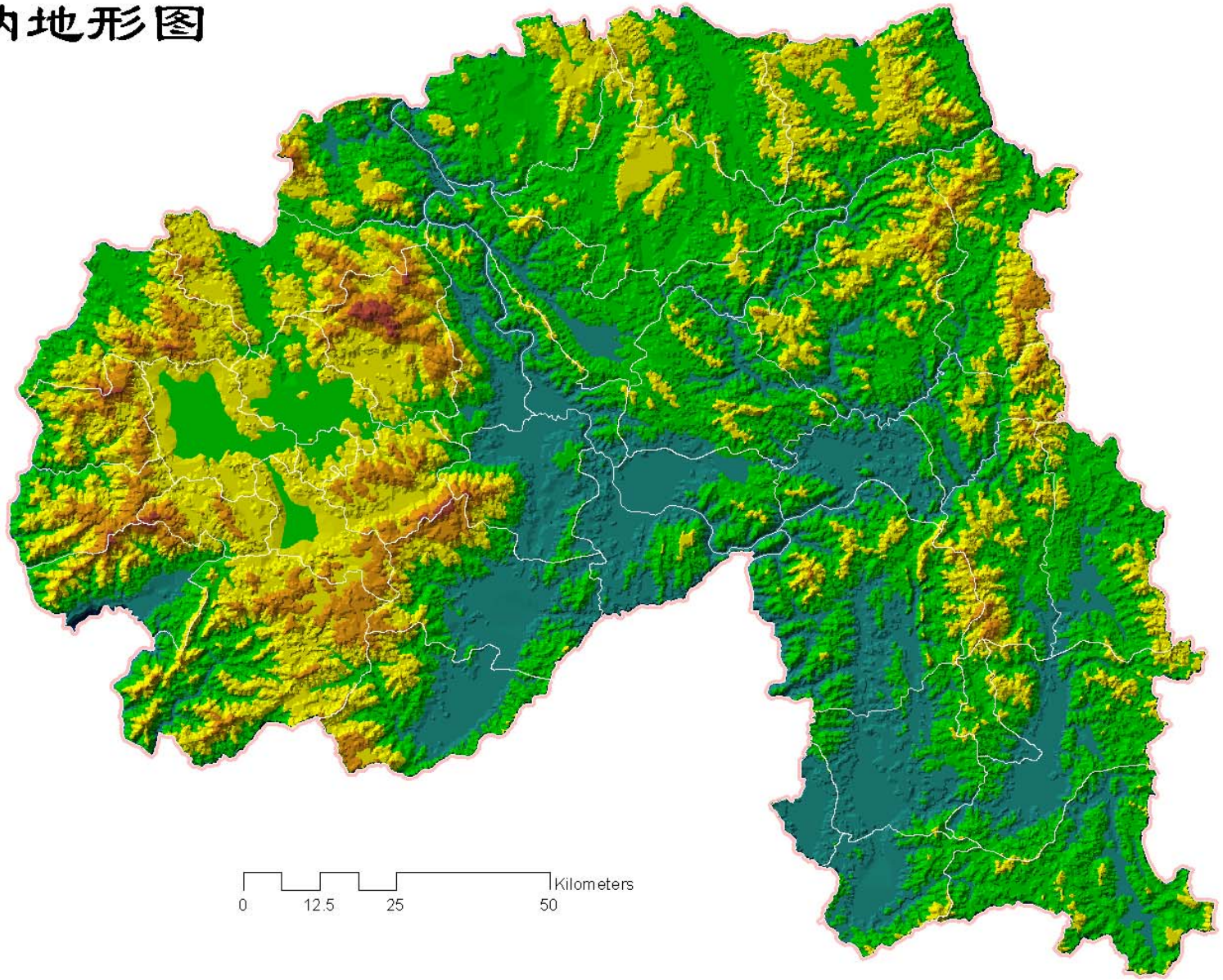
Menglun: a typical township in Xishuangbanna, area: **33488** ha.

•ecologically important

•representative of the environmental and socio-economic conditions of Xishuangbanna.

•**Luosuo River**, winds from the north to the southwest to feed the Mekong River.

西双版纳地形图


N
W
E
S
图例
海拔高度
2000-2400
1600-2000
1200-1600
800-1200
400- 800
<= 400
乡界
州界
0
12.5
25
50
Kilometers

About Menglun

More than 10 ethnic groups in Menglun Township, *Dai, Hani, Han, Yi, Ji'nuo, Lahu, Wa, Bai. Yao, Hui, Bulang*, etc.

- **Dai and Hani accounted for 56.3% and 22.4% respectively;the Han Chinese is only 14.3%. Most of the villages are mainly composed of the Dai.**
- **Traditionally, Dai people live in the lowland area near river, paddy cultivation is their major agriculture activity; while Hani people live in mountainous area, slash-and-burn farming is their major way of food production**
- **Since 1982, the rural economic reform had resulted in re-allocation of land to individual households; therefore, villagers have more freedom to use their land for different economic activities (tropical fruits, tea, rubber plantation). A series of ecological problems emerged since then.**

The GNP for the year 1988 and 2003 were $3.11 million (NPV) and $9.10 million respectively

Data collection and preparation

The data used to estimate the areas of different land use and land cover for Xishuangbanna and Menglun were extracted from:

- cloud-free LANDSAT TM / ETM images obtained in February 1988 and March 2003.
- The data sets were re-geo-referenced with the aids of 1:50,000 topographic maps, and GPS points using the ERDAS Imagine software, which incorporates functions for both image processing and the use of geographic information system (GIS).
- We used the RESAMPLING module to resample the data into a Universal Transverse Mercator (UTM) coordinate system. Average root mean square (RMS) error of less than 0.5 was achieved for both images and the pixel size were kept as 30 x 30 m.

Land use Classification

- The LANDSAT data were classified by using a combination of unsupervised and supervised classification techniques.
- Some aerial photos of 1988 and an ikonos satellite image (obtained in February 2002) covering part of the Menglun township were used as references for land use classification;
- we conducted intensive ground truth studies, Classified images generally agree visually with actual land cover.

The **10 land use categories** were:

(1) arable land, including paddy field and rain fed upland;
(2) orchard, including plantations of fruit trees, tea, vanilla, other cash crops;
(3) rubber plantation;
(4) special land use including arboretum, nursery, experimental fields, bamboo forest, and pine forest etc.;
(5) swidden field refer to land abandoned after slash-and-burn cultivation;
(6) shrub land (with woody bushes greater than 20% and tree cover less than 20%);
(7) waste land/logging area, referring to land covered by grasses and difficult to use;
(8) river;
(9) forested area, including nature reserve, primary and secondary forests;
(10) settlement, including urban and rural settlements with buildings.

Assignment of Ecosystem Service Value

In order to obtain ecosystem service values for various ground cover types, the 10 land cover categories used to classify LANDSAT TM/ETM datasets were compared with the 16 biomes identified in Costanza et al.'s (1997) ecosystem service valuation model. The most representative biome was used as a proxy for each land cover category:

Table 1 Costanza et al. (1997) biome equivalents for the land categories, and corresponding ecosystem values

Land use and land cover categories	Equivalent biome	Ecosystem service coefficient ($ ha^{-1} yr^{-1})
Arable land including paddy field, rain fed upland, orchard, rubber plantation	Cropland	92
Special land uses including arboretum, nursery, experimental areas, bamboo forest, pine forest	Forest	969
Forested area	Tropical forest	2007
Swidden field, shrub land, waste land	Grass/rangeland	232
River	Lakes/river	8498
Settlement	Urban	0

The **total value of ecosystem service** in the study area in 1988 and 2003 was obtained as follows:

$$ESV = \sum (A_k \times VC_k)$$

where ESV is the estimated ecosystem service value, A_k is the area (ha) and VC_k the value coefficient ($\$ ha^{-1}$ per year) for land use category 'k'.

we also estimated the impacts of such changes on individual ecosystem functions within the study area. The **values of services provided by individual ecosystem functions** were calculated using the following equation:

$$ESV_f = \sum (A_k \times VC_{fk})$$

where ESV_f is the estimated ecosystem service value of function 'f', A_k is the area (ha) and VC_{fk} the value coefficient of function f ($\$ha^{-1}\ yr^{-1}$) for land use category 'k'.

Results

Land use changes

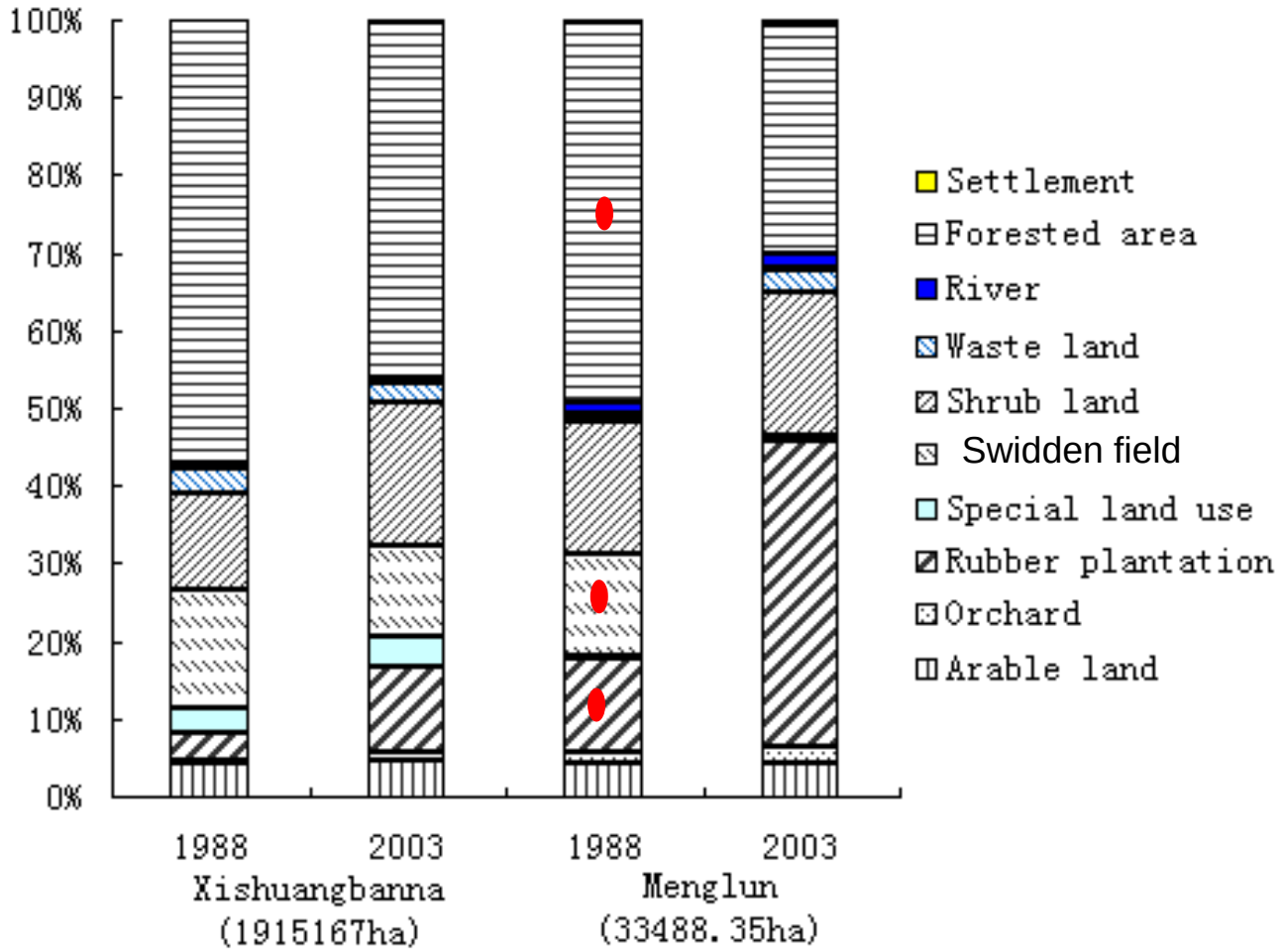
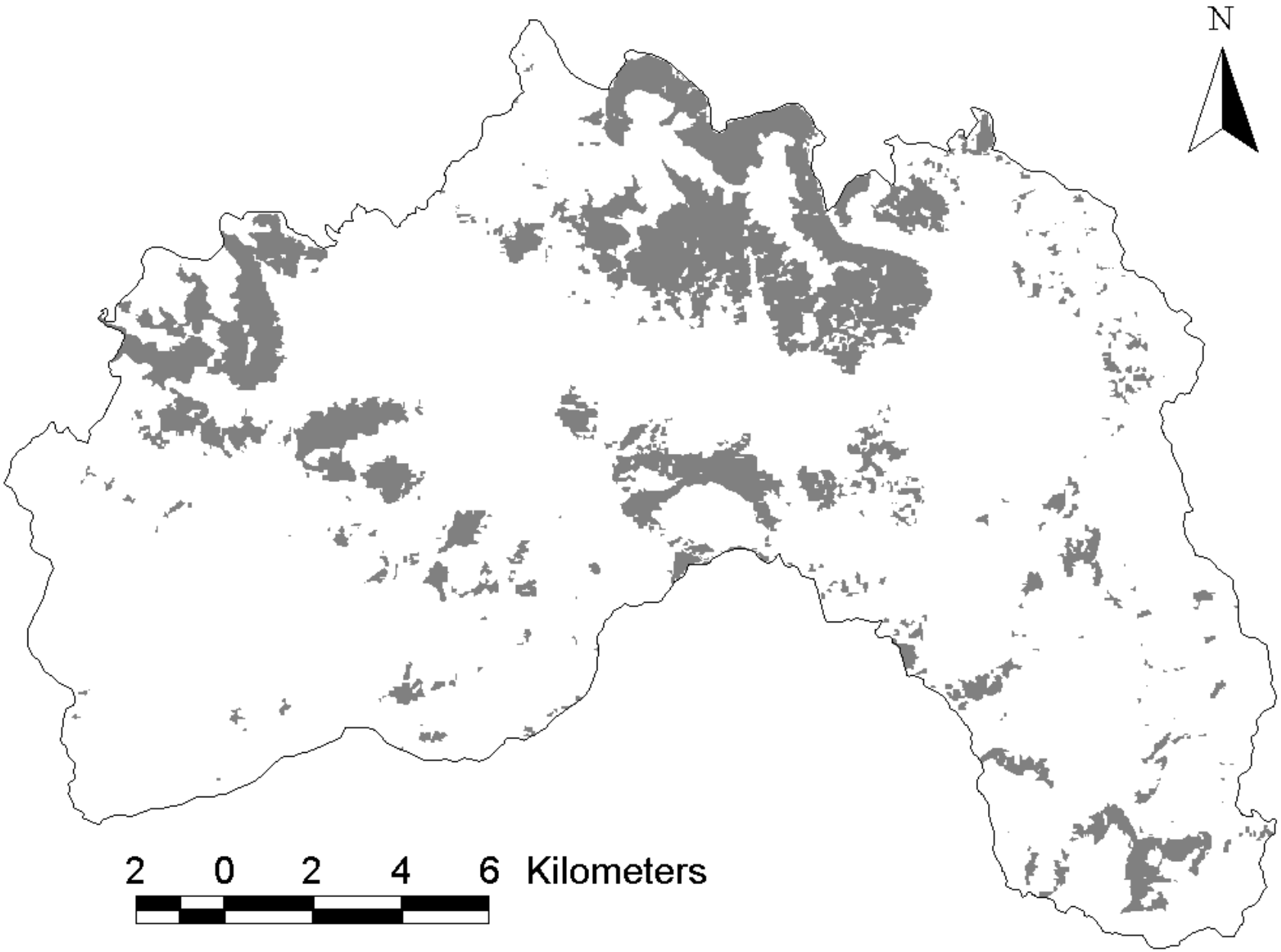
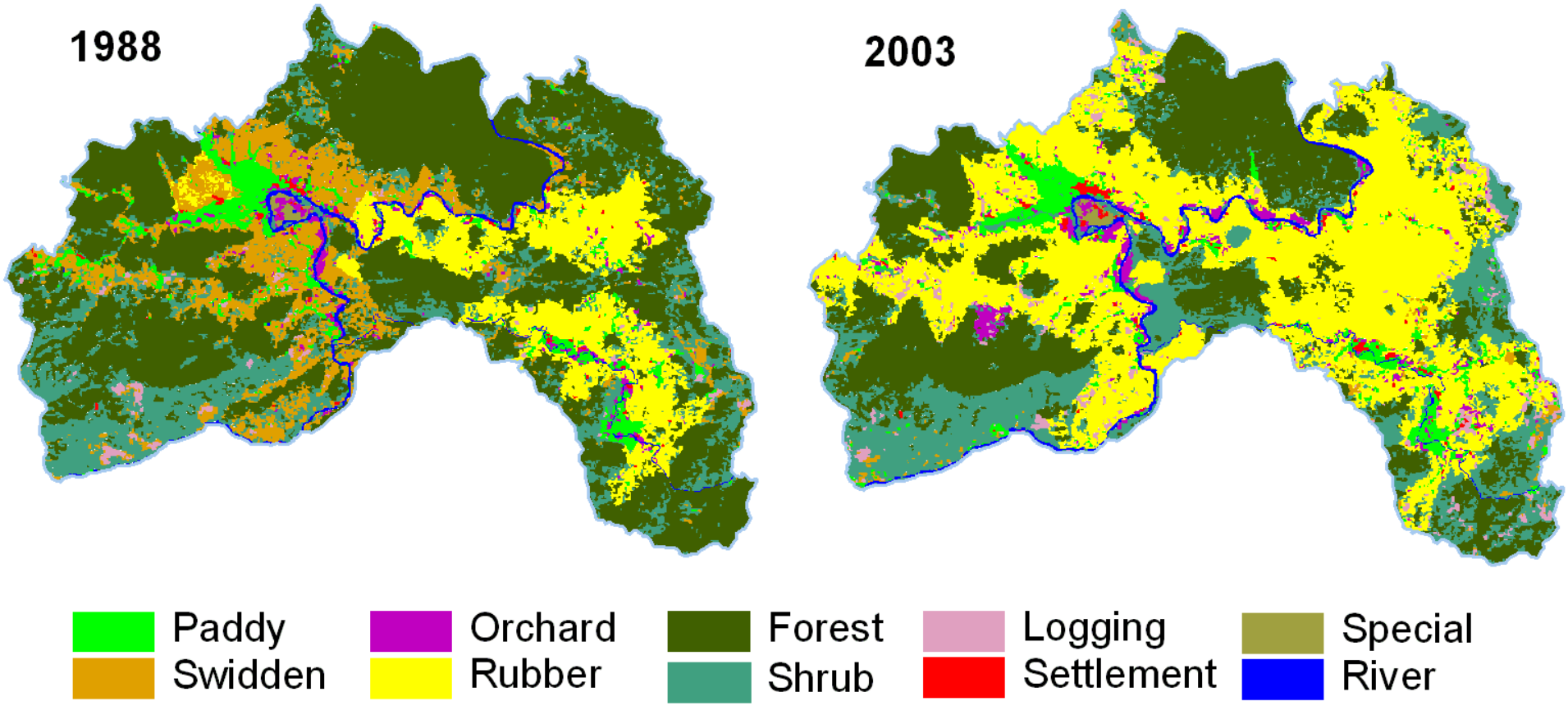


Table 2 Land use and land cover change detection

Land use category	Xishuangbanna						Menglun					
	Area (ha)			Percentage			Area (ha)			Percentage		
	1988	2003	Change	1988	2003	Change	1988	2003	Change	1988	2003	Change
Arable land	81922	87970	6048	4.28%	4.59%	0.32%	1425.33	1406.04	-19.29	4.26%	4.20%	-0.06%
Orchard	4303	17974	13671	0.22%	0.94%	0.71%	462.21	775.3	313.09	1.38%	2.32%	0.93%
Rubber plantation	72714	216074	143360	3.80%	11.28%	7.49%	4039.57	13101.42	9061.85	12.06%	39.12%	27.06%
Special land use	61078	72930	11852	3.19%	3.81%	0.62%	70.55	72.9	2.35	0.21%	0.22%	0.01%
Swidden field	287888	221240	-66648	15.03%	11.55%	-3.48%	4414.42	247.71	-4166.7	13.18%	0.74%	-12.44%
Shrub land	239708	353532	113824	12.52%	18.46%	5.94%	5791.56	6371.11	579.55	17.29%	19.02%	1.73%
Waste land	63257	52865	-10392	3.30%	2.76%	-0.54%	301.6	881.46	579.86	0.90%	2.63%	1.73%
River	7571	8058	487	0.40%	0.42%	0.03%	532.39	560.94	28.55	1.59%	1.68%	0.09%
Forested area	1094331	880794	-213537	57.14%	45.99%	-11.15%	16324.76	9857.14	-6467.6	48.75%	29.43%	-19.31%
Settlement	2395	3730	1335	0.13%	0.19%	0.07%	125.96	214.33	88.37	0.38%	0.64%	0.26%


N
2 0 2 4 6 Kilometers

Land Use / land Cover Change: Menglun



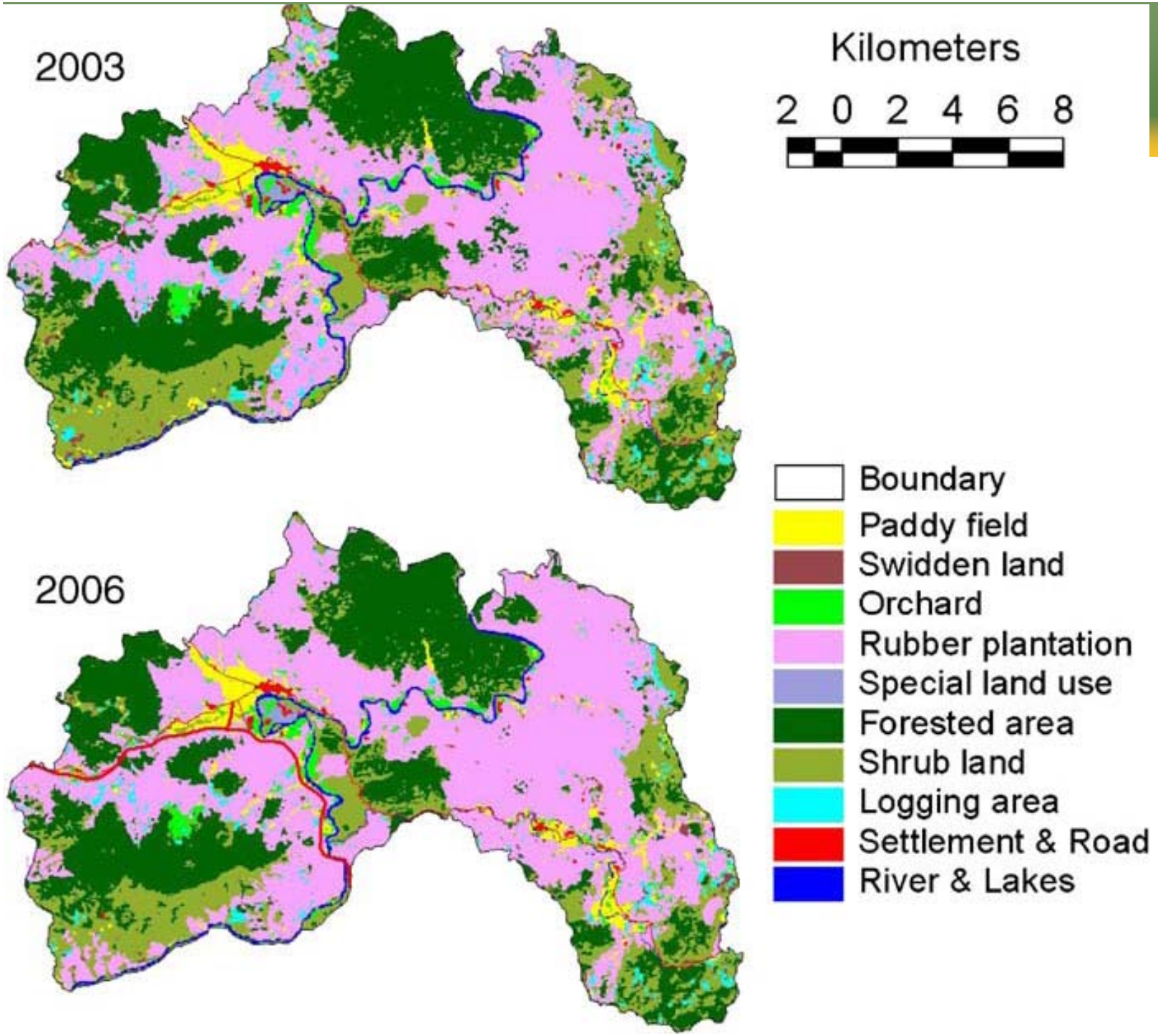

2003
2006
Kilometers
2 0 2 4 6 8
Boundary
Paddy field
Swidden land
Orchard
Rubber plantation
Special land use
Forested area
Shrub land
Logging area
Settlement & Road
River & Lakes
ADB

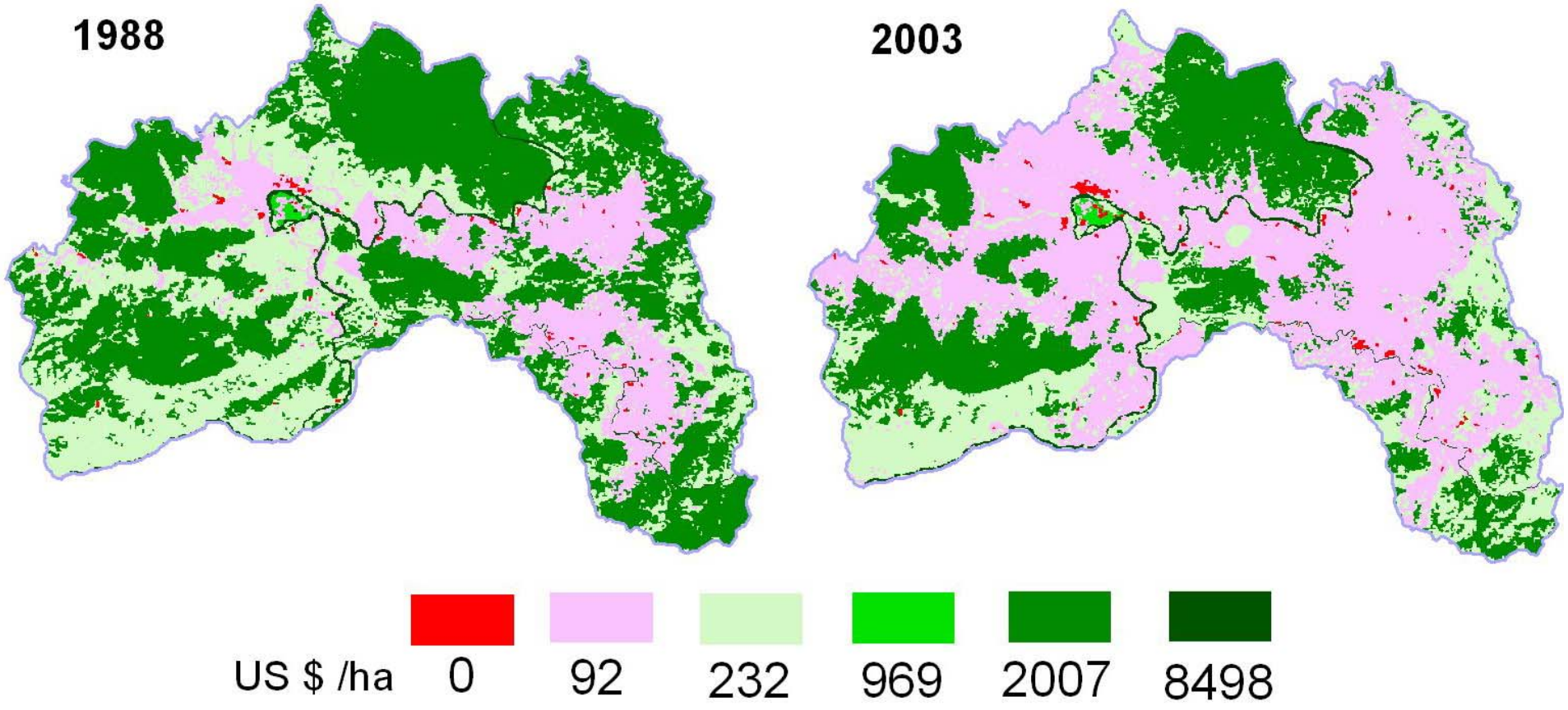
Table 3 Total ecosystem service values estimated for each land cover category in the study area using Costanza et al. coefficient, and changes between 1988 and 2003

Land use category	Xishuangbanna				Menglun			
	ESV ($ million)		Change		ESV ($ million)		Change	
	1988	2003	$ million	CC_k*(%)	1988	2003	$ million	CC_k*(%)
Arable land	7.54	8.09	0.56	0.02%	0.1311	0.1294	-0.0018	0.00%
Orchard	0.40	1.65	1.26	0.05%	0.0425	0.0713	0.0288	0.07%
Rubber plantation	6.69	19.88	13.19	0.53%	0.3716	1.2053	0.8337	2.06%
Special land use	59.18	70.67	11.48	0.46%	0.0684	0.0706	0.0023	0.01%
Swidden field	67.37	51.77	-15.60	-0.63%	1.0330	0.0580	-0.9750	-2.41%
Shrub land	56.09	82.73	26.66	1.08%	1.3552	1.4908	0.1356	0.34%
Waste land	14.80	12.37	-2.43	-0.10%	0.0706	0.2063	0.1357	0.34%
River	64.34	68.48	4.14	0.17%	4.5243	4.7669	0.2426	0.60%
Forested area	2197.42	1768.63	-428.78	-17.33%	32.7801	19.7931	-12.9870	-32.16%
Settlement	0	0	0	0	0	0	0	0
Total ESV	**2473.82**	**2084.27**	-389.55	-15.75%	**40.38**	**27.79**	-12.59	-31.17%
GNP ($ million)	**163.20****	**701.09**			**3.11****	**9.10**		
ESV / GNP	**15.2**	**3.0**			**13.0**	**3.1**		

* Contribution of change in ESV: $CC_k = (ESV_{2003} - ESV_{1988}) / \sum ESV_{1988}$

** Accounted to Net Present Value for comparisons.

Ecosystem Service Value: Menglun



ESV= $40.38 million

ESV= $27.79 million

Possible trend of ESV

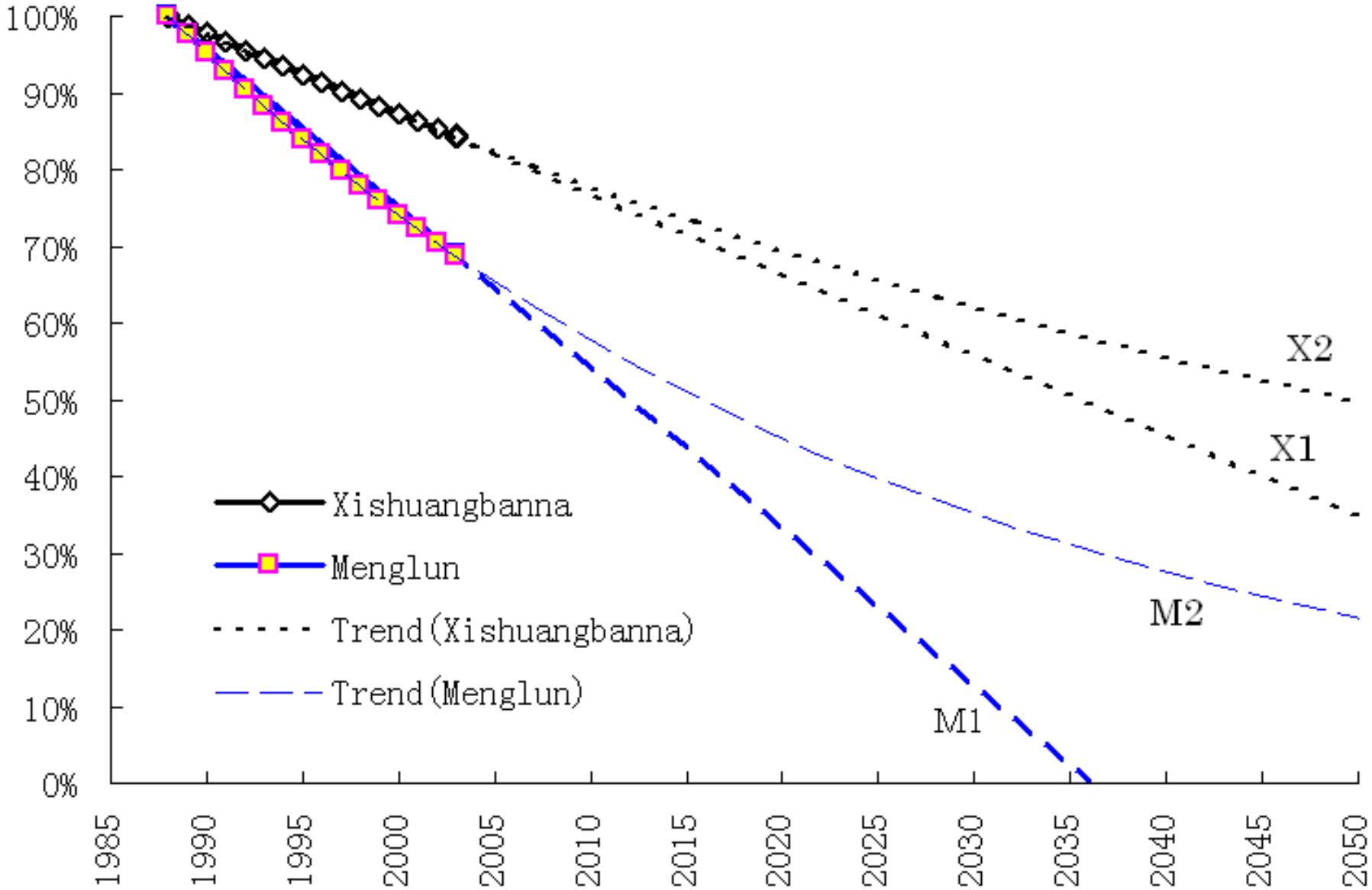


Table 4 Estimated annual value of ecosystem functions (ESVf in $ million per year)

Ecosystem Services	Xishuangbanna				Menglun			
	ESV_{f1988}	ESV_{f2003}	Change	CC_f* (%)	ESV_{f1988}	ESV_{f2003}	Change	CC_f* (%)
1 gas regulation	4.14	4.39	0.26	0.01%	0.0736	0.0525	-0.0211	-0.05%
2 climate regulation	252.65	206.70	-45.95	-1.86%	3.6504	2.2084	-1.4419	-3.57%
3 disturbance regulation	5.59	4.55	-1.04	-0.04%	0.0818	0.0494	-0.0323	-0.08%
4 water regulation	49.69	51.20	1.51	0.06%	3.0290	3.1367	0.1077	0.27%
5 water supply	24.97	24.32	-0.64	-0.03%	1.2579	1.2666	0.0087	0.02%
6 erosion control	291.11	241.00	-50.11	-2.03%	4.3111	2.6395	-1.6716	-4.14%
7 soil formation	12.14	10.16	-1.98	-0.08%	0.1745	0.1068	-0.0677	-0.17%
8 nutrient cycling	1031.02	838.42	-192.60	-7.79%	15.0769	9.1146	-5.9623	-14.77%
9 waste treatment	156.96	142.94	-14.02	-0.57%	2.6946	1.8895	-0.8051	-1.99%
10 pollination	17.00	20.20	3.20	0.13%	0.3457	0.4015	0.0558	0.14%
11 biological control	17.53	22.31	4.78	0.19%	0.3841	0.5394	0.1554	0.38%
12 habitat / refugia	-	-	-	-	-	-	-	-
13 food production	80.22	84.82	4.60	0.19%	1.4663	1.5943	0.1281	0.32%
14 raw material	353.14	287.51	-65.63	-2.65%	5.1520	3.1151	-2.0370	-5.04%
15 genetic resources	45.84	37.28	-8.57	-0.35%	0.6704	0.4053	-0.2651	-0.66%
16 recreation	129.52	106.57	-22.95	-0.93%	1.9765	1.2528	-0.7237	-1.79%
17 cultural	2.31	1.91	-0.40	-0.02%	0.0328	0.0199	-0.0129	-0.03%
TOTAL	2473.83	2084.28	-389.55	-15.75%	40.3773	27.7923	-12.5850	-31.17%

* Contribution of change in ESV_f: $CC_f = (ESV_{f2003} - ESV_{f1988}) / \sum ESV_{f1988}$

Change of landscape indices: Menglun

- Number of patches
- Mean patch size
- Largest patch index
- Patch density

Index	Land	1988	2003	Change
NP	Swidden	566	137	-429
	Rubber	77	137	60
	Forest	520	492	-28
MPS	Swidden	7.79	1.81	-5.98
	Rubber	52.42	95.57	43.15
	Forest	31.40	20.03	-11.36
LPI	Swidden	3.25	0.06	-3.19
	Rubber	5.39	18.06	12.68
	Forest	11.51	8.53	-2.98
PD	Swidden	1.69	0.41	-1.28
	Rubber	0.23	0.41	0.18
	Forest	1.55	1.47	-0.08

Discussion

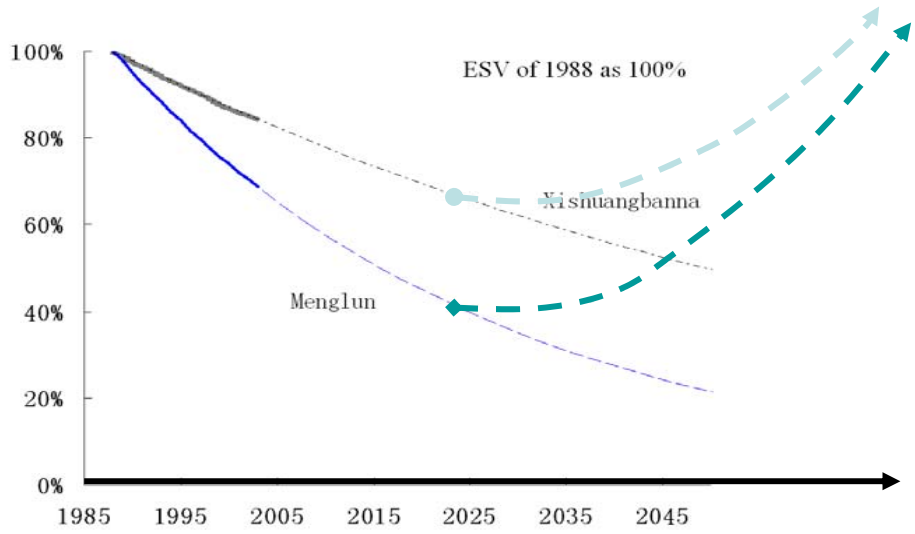
- the land use and land cover in the study area experienced significant changes. The increase of rubber plantation was at the expenses of ecologically important tropical forests and traditionally practiced swidden farming, especially, the mono-cultured rubber plantation in Menglun Township has become a dominant type of land use and land cover to support local economy;
- the estimated ecosystem service values (ESV) at both prefecture level and township level dropped by $389.55 million/year and $12.58 million/year respectively;
- The ESVs in 2003 were about 3 times as much as the values of local GNP, while they were 15 times and 13 times in Xishuangbanna and Menglun respectively in 1988 ;
- In the agriculture-based economy as Menglun Township, it can be assumed that a $1 increase in GNP was at the cost of at least $2 decrease in ESV.

- Tropical forests play an important role in ecosystem services and processes in the study areas;
- the abrupt shift of land use has resulted in aggregate decline of ecosystem services;
- significant changes occurred in the ecological functions such as nutrient cycling, erosion control and climate regulation, provision of raw materials and habitat or refugia for wildlife.

The weakening of such services was convinced by a number of studies:

- Li and Sha (2005) presented that the rubber plantation and upland rice field were very low in nitrogen storage and mineralization rate and exhibited significant variation comparing with other land use patterns;
- Zhang et al. (1997) compared the runoff characteristics between tropical rainforest and rubber plantation;
- Liu et al. (2003) reported that rubber plantation is less capable of intercepting fog in dry season that compensates rainfall deficits in this area;
- Li (2001) described the climate changes in Menglun of Xishuangbanna for the last 40 years, and concluded that the climate becomes warmer and drier partly due to changes in tropical forest cover;
- Zhu et al. (2004) reported habitat change and biodiversity losses in Xishuangbanna due to forest fragmentation.
- Loss of traditional swidden field also resulted in loss of agro-biodiversity according to Guo et al. (2002)

- policy effects and market conditions;
- effort for the conservation of tropical forest ecosystem should be enhanced;
- provision of alternative economic opportunities, particularly for private rubber growers; ……
- appropriate ecological compensation mechanisms should be established on the basis of ESV; Which ecosystems supply what services? How much?
- "Green GNP" as performance indicator ?



Thank you

SpringerLink

For recent publication:
doi: 10.1007/S10661-007-0067-7