Greater Mekong Subregion
Core Environment Program
(ADB TA 6289)

Valuation of Ecosystem Services in Xishuangbanna Biodiversity Conservation Corridors Initiative Pilot Site, China

Final Draft

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Table of Contents

List of Figures

List of Tables

List of Appendices

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Executive Summary

The Greater Mekong Subregion (GMS) is one of the fastest growing regions in the world, which involves significant economic and social changes transforming economies, countries and natural landscapes in the subregion inevitably affecting the environment. Recognizing this development challenge, in 2004, the GMS Working Group on Environment (WGE), facilitated by the Asian Development Bank (ADB), initiated a review of the GMS economic program from an environmental sustainability and management point of view. Both the Environment Ministers Meeting in Shanghai (May 2005) and the 2nd GMS Summit of Leaders and Heads of State held in Kunming (July 2005) endorsed the Core Environment Program and its flagship component, the Biodiversity Conservation Corridors Initiative (BCI), for implementation.

The GMS BCI identified nine key biodiversity conservation landscapes (BCL) representing ecological networks, with natural and/or semi-natural landscape elements of high biodiversity value in which six pilot sites were selected for launching the BCI implementation between 2006 and 2009. The long term vision of BCI is that by 2015, GMS countries will have established priority biodiversity conservation landscapes and corridors for maintaining the quality of ecosystems, ensuring sustainable use of shared natural resources, and improving the livelihoods of people.

The tropical forests of Xishuangbanna in Southwest China (Yunnan) are unique because of the transitional geographic location and climatic features crossing the tropics and subtropics, which harbor some of the richest fauna and flora and provide habitats for various animal species. While the initial BCI focal area identification takes a long term approach towards establishing linkages in the fragmented ecosystem, identifying eight potential corridors, BCI implementers in phase I (2006 – 2009) gave priority to establishing connectivity between: (i) Nabanhe to Mangao; and (ii) Mengla to Shangyong (wild elephant sanctuary), which is also a transboundary Nature Reserve bordering Lao PDR.

While the importance of Xishuangbanna, as one of the last remaining tropical rainforests of the GMS, is well known, it also has tremendous pressure on land, and fast changing land use, with a high rate of conversion of forests to rubber plantations. The decline in rainforest area and degradation of watersheds are bound to affect ecosystem services in Xishuangbanna as well as the water flow downstream for the Lower Mekong countries of the GMS.

Ecosystem services are increasingly receiving attention in valuation exercises. This research focuses on the valuation of ecosystem services in the Xishuangbanna Biodiversity Conservation Corridors Pilot Site to demonstrate economic value and provide policy justification for maintaining ecosystem connectivity in the last remaining tropical rainforests of China. Ecosystem services can be defined as goods and services provided by a natural unit of living things (animals, plants and micro-organisms) and their physical environment that benefit human beings.

While some of the forest ecosystem services (e.g. water, clean air, pollination etc.) are difficult to quantify or put a value in money terms, certain other goods such as timber and non-timber forest products (e.g. forest food, rattan, latex, resins, etc.) are tradable in the market. However, the price mechanism often fails to reflect the real value of those ecosystem service products because their valuation is based on the cost of extraction (labor, equipment, and transport) and raw material only. It does not take into consideration the ecosystem service value, such as watershed protection, soil fertility, carbon sequestration, and biodiversity conservation. As markets and economic development planning rarely reflect the full social costs or benefits of environmental goods or services, valuation of ecosystem services is essential in the correction of market failures and in supporting economic policy making by planners and decision-makers.

The real or true value of the ecosystem (e.g. source of water supply, pollination, medicinal herbs, essences, oils, and cosmetic ingredients, food and food supplements through non-timber forest products) for local people need to be considered as an opportunity cost vis-à-vis rubber plantations (of high economic value due to market demand) and weighed against those gained from human induced, and irreversible changes in the Xishuangbanna tropical forests ecosystem. Anticipated negative impacts of climate change will also likely take their toll unless mitigation and adaptation measures are put in place. Amidst the large scale land use change that replaces forest ecosystems with commercial agricultural crops like rubber, the state may have to regulate more vigorously to protect watersheds in order to guarantee essential ecosystem services, such as a sustainable supply of water or soil conservation. These impacts are not captured in decision-making because some of the ecosystem goods and services affected are not sold in markets or attached with an economic value for society at large.

Based on data availability and time constraints, only major ecosystem services were selected for inclusion in the valuation study of the corridor segments in the Xishuangbanna BCI Pilot Site. The selected ecosystem services covered in this research are:

- Non timber forest products (NTFPs)
- Climate Regulation (including carbon sequestration and oxygen generation)
- Water Regulation (including watershed protection – storage and water quality)
- Soil erosion protection
- Nutrient cycle, and
- Air purification.

Specific methods for estimating particular ecosystem services according to the nature of goods or services and proxy function availability usually list contingent valuation method (CVM), hedonic prices, direct estimation of opportunity costs, replacement costs, cost savings, threshold values etc. However, almost all methods contain varying degrees of constraints and not all may be applicable in each case study. The choice of appropriate methodology usually depends on the selection of ecosystem service to be valued. In this research, market analysis, cost saving and damage cost methods have been applied with combination of local surveys, local studies and benefit transfer.

The valuation results show a potential value of $1.162 billion could be provided annually by the forest ecosystem services of Xishuangbanna BCI Pilot Site, namely, Mengla-Shangyong BCI Segment and Mangao-Nabanhe BCI Segment, taking into account a forested area of 164,913 ha, which translates into just over $7,047 per ha per year (see table 14 in Section III). Carbon sequestration contributes the largest portion of benefits from ecosystem services covering the total area studied ($362 million/year), water regulation ($274 million/year) and nutrient cycling ($182 million/year) also provide significant benefits, while NTFP turns out to be a minor factor due to its limited collection and marketing practiced in the corridor area. However, NTFP plays a very important role in people’s lives and has the greatest potential to capture the value of the ecosystem services and improve local livelihoods. Not all the ecosystem services are included and factored in the valuation framework; therefore, the total value of ecosystem services may have a higher value if data and model are further developed in the future.

The scenarios analysis simulates the costs and benefits of the future pictures in different development patterns. Conservation scenario stands out to be the better option in both BCI corridor segments, while development scenario causes huge invisible loss of benefits in ecosystem services. Expansion of rubber plantation is the major driver and threat to forest conversion, though it is the most beneficial option for the local people to enjoy short-term high economic returns, while risk of rubber related disease and current global economic downturn shows the great vulnerability and uncertainty of monoculture rubber plantations.

The value of ecosystem services, particularly the indirect use values, are not well reflected and factored in both individual and governmental policy decision making, due to its environmental externalities. Therefore, it is essential to formulate corridor management policies and payment for ecosystem services (PES) scheme to provide the right incentives for forest conservation, restoration and watershed protection and disincentives for uncontrolled expansion of rubber and forest conversion on marginal soil and steep slopes.

In order to secure and capture the value of ecosystem services of Xishuangbanna BCI site, several policy implications need to be considered:

1. Formulate legal framework and BCI management guidelines that include:
    a. Regulations on natural forest protection and restoration of degraded forest areas for maintaining important ecosystem services (i.e. watershed protection, soil erosion control, nutrient cycling, etc.)
    b. Zoning the corridor area
        i. Core area – reforestation and restricted development to ensure ecosystem connectivity and biodiversity conservation
        ii. Buffer zone – sustainable forest management and livelihood activities (i.e. NTFP, fuel wood, agro-forestry, livelihood plantation, etc.)
    c. Regulation on rubber plantation expansion and conversion back to forest (geographic location, slope, altitude, etc.)

2. Establish payments for ecosystem services scheme, such as:
    a. PES for watershed services
    b. PES based on carbon sequestration and deforestation avoidance (Payments for REDD - Reducing Emissions from Deforestation and Degradation), Certified Emissions Reduction (CER) for carbon trading and carbon offsets (nationally)
    c. PES for NTFP (eco-certification and eco-labeling of organically produced goods
    d. PES for biodiversity off-sets and ecosystem restoration (livelihood interventions/incentives including promotion of agro-forestry and livelihood plantations in return for conservation contracts for maintaining natural forests; public reforestation program and payments, rural greening and promotion of wood based industries (i.e. The National Natural Forest Protection (NNFP) program and the Sloping Lands Reconversion Program (SLP))
    e. PES for recreation (eco-tourism / nature based tourism).

There are certain limitations of this research. Some of the very important ecosystem services are excluded in the valuation framework, i.e. biodiversity, recreation/tourism, pollination and seed dispersal, social benefits (e.g. poverty reduction, employment). Also because of constraints of data availability and accessibility, most of the coefficients and values are taken from existing research findings, consultations and other secondary literature. Furthermore, valuation is based on a local framework without comparing or considering the regional and global level frameworks or values that may be higher.

In future, further research could focus on improving valuation framework wherever data is available and appropriate models can be applied. There is potential for incorporation of GIS data and computer simulation technique into the valuation model and develop a robust model for calculating values at prefecture, county, administrative village and even farm levels with higher resolution. The valuation methods applied here can be used in other BCI pilot sites (such as in Cambodia, Thailand and Viet Nam or expand the valuation to cover the entire Xishuangbanna Prefecture). And a more systematic and programmatic PES mechanism for Xishuangbanna BCI site could be designed.

Abbreviations

ADB	Asian Development Bank
BCI	Biodiversity Conservation Corridor Initiative
BCL	Biodiversity conservation landscapes
CEP	Core Environment Program
CER	Certified Emission Reduction
CDM	Clean Development Mechanism
CVM	Contingent valuation method
EEPSEA	Economy and Environment Program for Southeast Asia
EIS	Ecological information system
EOC	Environment Operations Center
ETM	Enhanced Thematic Mapper
GMS	Great Mekong Subregion
GIS	Geographic information system
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Return of Rate
MSS	Multi Spectral Scanner
NPV	Net present value
NNFP	National Natural Forest Protection Program
NTPF	Non timber forest products
PAE	Policy Analysis Exercise
PES	Payment for ecosystem services
REDD	Reducing Emissions from Deforestation and Degradation
SLP	Sloping Lands Reconversion Program
UNFCCC	United Nations Framework Convention on Climate Change
VES	Values (Valuation) of Ecosystem Services
WGE	Working Group on Environment
XEPB	Xishuangbanna Environmental Protection Bureau
XNNRMB	Xishuangbanna National Nature Reserves Management Bureau
XTBG	Xishuangbanna Tropical Botanical Garden

I. Introduction

A. Definition: valuation of ecosystem services

Ecosystem services can be defined as goods and services provided by a natural unit of living things (animals, plants and micro-organisms) and their physical environment that benefit human beings[1]. Most of the forest ecosystem services (e.g. water, clean air, pollination etc.) are very difficult to quantify or put a value in money terms. Although timber (e.g. tree), non-timber forest products (e.g. forest food, rattan, latex, resins, etc.) are tradable in the market, the price mechanism often fails to reflect the real value of those ecosystem services because their valuation is based on the cost of extraction (labor, equipment, and transport) and raw material only; this does not take into consideration the ecosystem service value, such as watershed protection, soil fertility, carbon sequestration, biodiversity protection. Therefore, market failures often occur in ecosystem management as markets and economic development planning rarely reflect the full social costs or benefits of environmental goods or services, and valuation of ecosystem services is essential in correction of market failure and economic planning to support decision making.

B. Background: Greater Mekong Subregion and Biodiversity Conservation Corridors Initiative[2]

The Greater Mekong Subregion (GMS) is one of the fastest growing regions in the world involving significant economic and social changes, transforming economies, countries and natural landscapes in the subregion that will inevitably affect the environment. Recognizing this development challenge, in 2004, the GMS Working Group on Environment (WGE), facilitated by the Asian Development Bank (ADB), initiated a review of the GMS economic program from an environmental sustainability and management point of view. Both the Environment Ministers Meeting in Shanghai (May 2005) and the 2nd GMS Summit of Leaders and Heads of State held in Kunming (July 2005) endorsed the Core Environment Program (CEP) and its flagship component, the Biodiversity Conservation Corridors Initiative (BCI), for implementation.

The basic concept of biodiversity corridors initiative is to rebuild connectivity of fragmented natural ecosystems through corridor approaches. The long term vision of BCI is that by 2015, GMS countries will have established priority biodiversity conservation landscapes and

[1] Defra. 2007. *An introductory guide to valuing ecosystem services.* www.defra.gov.uk
[2] The source of information and maps in this section is from the client agency-Greater Mekong Subregion Environment Operations Center (GMS-EOC).

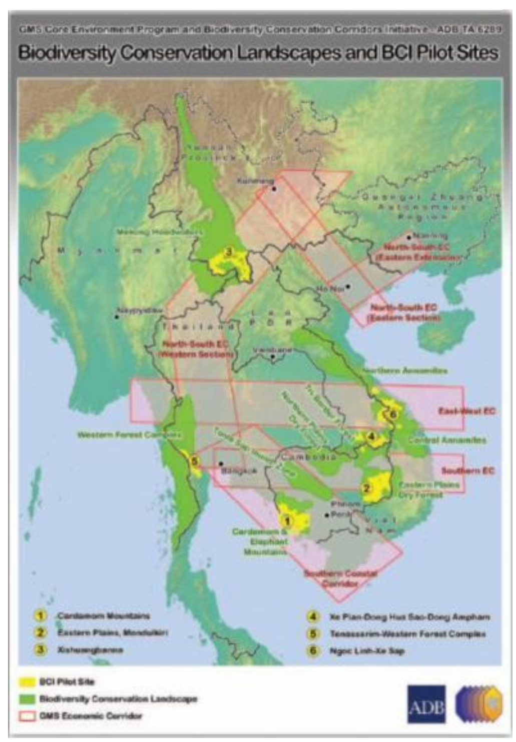
corridors for maintaining the quality of ecosystems, ensuring sustainable use of shared natural resources, and improving the livelihoods of people. During the first phase (2006-2009) of the BCI program, six pilot sites were selected for implementation (See Appendix 1).

C. Objective and Scope of the Valuation Study

Under the sustainable financing component of BCI, valuation and establishment of payment for ecosystem services (PES) mechanisms are key activities to be conducted in order to secure long-term sustainable financing for the biodiversity corridors and livelihood improvement.

In the context of GMS CEP/BCI Program, valuation of ecosystem services is aimed at providing an economic justification for policy formulation and decision making that provides incentives for conservation and sustainable development and disincentives to curtail unsustainable activities. The objective and scope of the proposed study is: Valuation of ecosystem services in a selected area of Xishuangbanna, Biodiversity Corridor Pilot Site in Southern Yunnan, China, as a basis for identifying integrated real costs and reflection of economic values in government planning and decision-making for establishment of payment for ecosystem services (PES). However, PES needs more comprehensive analyses, which is beyond the scope of this study and could become a subsequent study after the valuation.

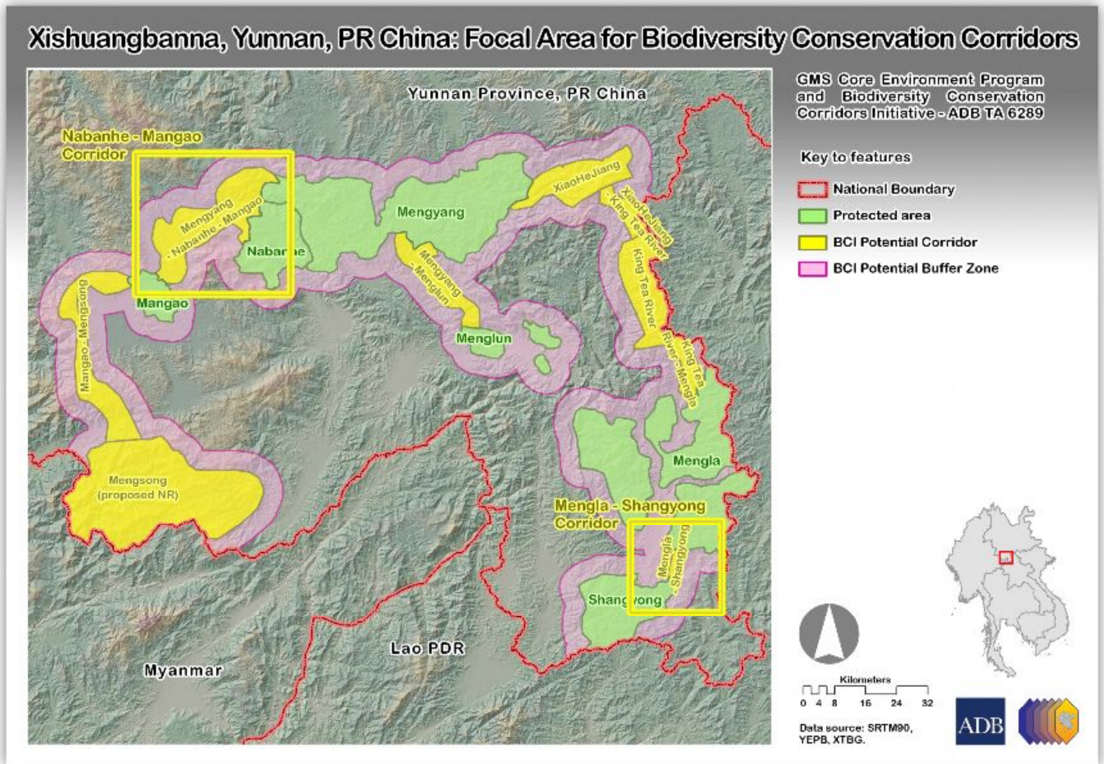
Figure 1 GMS BCI Pilot Sites



D. Study Area – Xishuangbanna BCI Site

The tropical forests of Xishuangbanna in Yunnan Province, China are unique because of the transitional geographic location and climatic features crossing the tropics and subtropics, which harbor some of the richest fauna and flora and provide habitats for various animal species. While the initial BCI focal area identification takes a long term approach towards establishing linkages in the fragmented ecosystem, identifying eight potential corridors, BCI implementers in phase I gave priority to establishing connectivity between: (i) Nabanhe to Mangao; and (ii) Mengla to Shangyong (wild elephant sanctuary), which is also a transboundary Nature Reserve bordering Lao PDR(See figure 2 below). The valuation study has mainly focused on these two pilot corridor segments.

Figure 2. Xishuangbanna Biodiversity Conservation Corridors

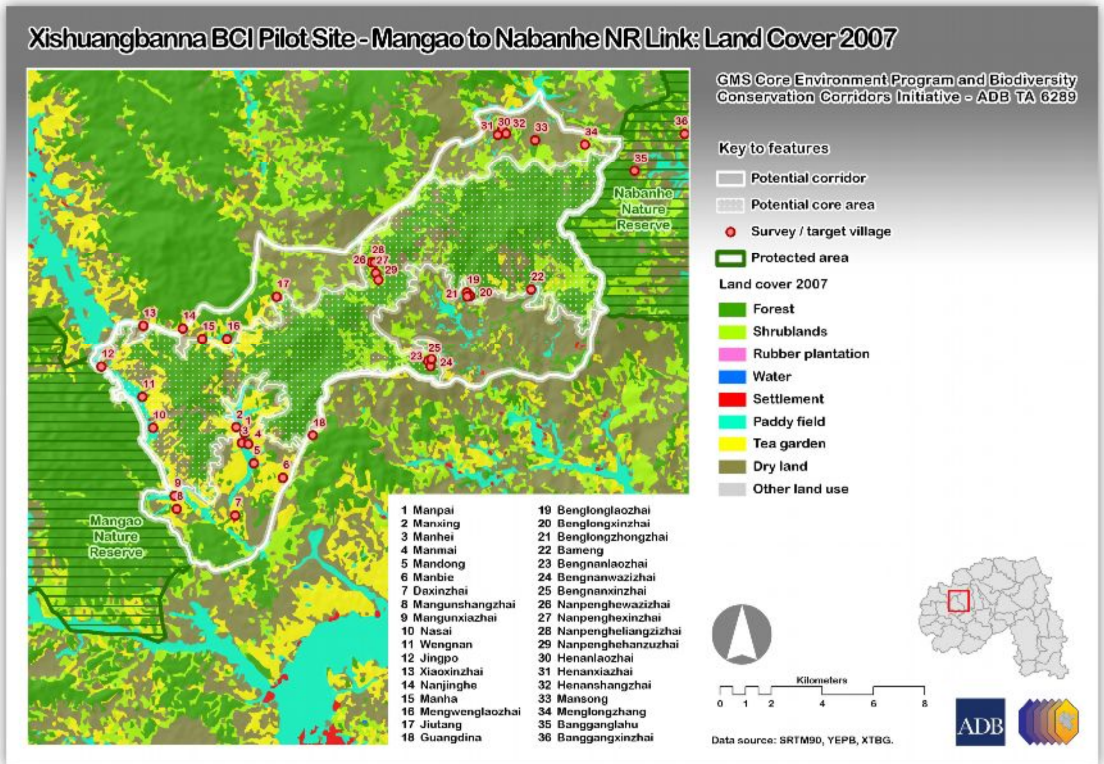


<u>Nabanhe—Mangao Biodiversity Corridor Segment</u>[3]

The proposed corridor area between Nabanhe Nature Reserve and Mangao Subreserve is estimated at 15,446.74 ha with an outer perimeter and an inner core having a linear forest connectivity stretching to roughly 25 km. This corridor covers 40 natural villages in three administrative villages of Menghai and Mengsong townships in Menghai County. All villages are located inside the proposed boundary. There are 1,938 households with a total of 8,944 rural population. Within the corridor, a linear forested "core" strip has been identified that is dissected in the north and the south by two roads. This area also has the weakest link in the forest cover and requires stabilization and restoration measures. Current land use includes 6,447.67 ha as forested area, of which 3,870.02 ha is state forest, and 2,607.65 ha is described as collective forest under the management and use right of the villages. There is an additional 8,944.73 ha under other land use, which includes bush, tea plantation, rice paddy, upland field, settlement, etc. (See figure 3.)

[3] Information and maps in this section are from BCI Status Report 2007, published Jan 2008

Figure 3. Land cover in the Nabanhe - Mangao Corridor (2007)

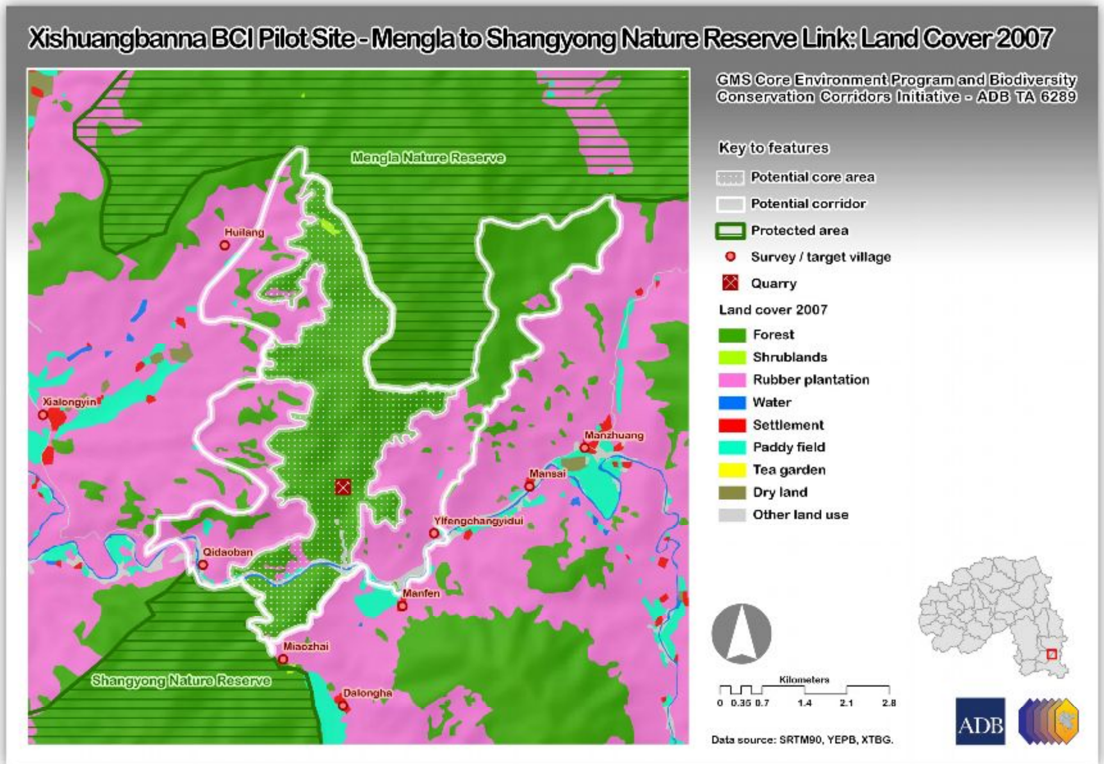


Mengla-- Shangyong Biodiversity Corridor Segment

The biodiversity corridor strip between Mengla-Shangyong Subreserves covers a total area of 2,471.43 ha. It is a narrow strip of forest connectivity that still remains between Mengla and Shangyong. This corridor covers eight natural villages in two administrative villages of Mengla and Shangyong townships in Mengla County. All village settlements are located outside the proposed corridor boundary but some of the village lands fall within. There are 495 households with a total population of 2,289.

Within the proposed corridor area, 1,475.81 ha are forested, and the remaining land use includes bush, rubber plantation, rice paddy, upland field, settlement, etc. covering 955.62 ha. Out of the total forested area, 466.82 ha is state forest while 604.62 ha is classified as collective forest (see figure 4). Currently, quarry operations are ongoing in the forested area of the corridor. Wild animals such as tiger (in Shang Longyin village), monkey, bear, boar, and wild elephant used to be in the corridor area but cannot be found anymore because of denudation of forests and replacement with large areas of rubber plantation.

Figure 4. Land cover in the Mengla - Shangyong Corridor (2007)



E. The need for valuation – in the context of Xishuangbanna BCI sites

Fragmentation of the tropical forest has occurred as large-scale cash crop plantations (rubber) have been undertaken in Xishuangbanna. And a severe decline of local primary forest cover took place which led to the loss of habitats for some local animal and plant species as well as a large number of endangered species. Is the real or true value of the ecosystem considered as an opportunity cost vis-à-vis what is gained from human induced irreversible changes in the Xishuangbanna tropic forests ecosystem? Would policy makers consider the value of such ecosystem services of equal importance if not more as compared to benefits to be gained from developmental changes? In an atmosphere of rapid climate change and anticipated negative impacts, this needs to be assessed and underlined in the policy dialogue. Even if rubber plantations are of high economic value due to market demand (high price/return), what is the trade off and where does the state have to regulate to protect watersheds in order to guarantee essential ecosystem services, such as a sustainable supply of water or soil conservation. These impacts are not captured in decision-making because some of the ecosystem goods and services affected are not sold in markets or attached with an economic value for society at large. Economic valuation of ecosystem services aims to express all the various benefits in monetary terms so that they can be added up and compared. Hence, a study on valuation of ecosystem services in Xishuangbanna BCI pilot site is necessary and critical for sound decision-making.

F. Research Questions

In order to achieve the objective of the study, more specifically, this valuation study aimed to explore answers for the following three questions: 1) What is value of ecosystem services provided by the tropical forests in Xishuangbanna BCI Pilot Site; 2) What development pattern is more beneficial for Xishuangbanna BCI Corridor? Rubber plantation or forest ecosystem conservation and restoration; 3) What are the policy implications to secure and capture the value of ecosystem services in the Xishuangbanna BCI site to benefit the local people and improve their livelihood?

II. Methodology and Theoretical Framework

A. Concepts and methodology

Methodologically, starting as early as 1958 with the Proposed Practices for Economic Analysis of River Basin Projects by the Committee on Water Resources[4], valuation of ecosystems was given its basic framework and was further developed by Gretchen Daily (1997)[5] and Costanza et al (1997)[6] estimating, more than a decade ago and at that time, a staggering value of $33 trillion for ecosystem services across the globe. By 2007, a study of only two protected areas in Cambodia in the Greater Mekong Subregion (Phnom Aural and Phnom Samkos Wildlife Sanctuaries) by IIED[7] showed a net present value of over $1.89 billion covering only an area of 585,787 ha taking into consideration only sustainable timber harvesting, agriculture, non-timber forest products, and carbon storage. Also in 2007, a study in Menglun County,

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[4] Bingham, G., Costanza, R., et. al. 1995. Issues in ecosystem valuation: improving information for decision making. Ecological Economics 14, 73-90.

[5] Daily, G.C. (Ed), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, D.C.

[6] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260.

[7] International Institute for Environment and Development (IIED) 2007. Sustainable Financing of Protected Areas in Cambodia: Phnom Aural and Phnom Samkos Wildlife Sanctuaries. Report prepared for Cardamom Mountains Wildlife Sanctuaries Project, Fauna and Flora International, Phnom Penh, Cambodia. May. 60pp.

Xishuangbanna Prefecture in Southwest China[8] using Constanza's coefficients shows a value of $29.8 million covering an area of 33,488 ha in one county alone. In Viet Nam, the Da Nhim watershed[9], water regulation and value of reducing sedimentation downstream has been estimated at $69 per ha per annum covering an area of 63,000 ha. This only underlines the fact that valuation methodologies vary widely and may not be comparable across all countries or sites. Nevertheless, it is important to note that valuation exercises are increasingly being conducted and can become the basis for policy decisions on securing sustainable financing, providing a conducive incentive framework for PES, conservation and sustainable use, or for climate change mitigation and adaptation considerations.

In China, valuation of ecosystem also have been studied and practiced in several cities and specific types of ecosystems for the last decade. In 2003, Xie Gaodi et. al. developed "List of Unit Ecosystem Services Value of Different Ecosystem Types in China"[10], based on a questionnaire survey of 200 ecological experts and previous studies on ecological information system (EIS) developed by Chinese Academy of Sciences[11].

Valuation methods of ecosystem services can be classified into two broader economic categories based on demand and supply: 1) stated preference methods by asking people for their willingness to pay for a certain ecosystem service; 2) revealed preference methods by using a relation with a market good or service to estimate the willingness-to-pay for the service. Specific methods[12] for estimating particular ecosystem services according to the nature of goods or services and proxy function availability usually list contingent valuation method (CVM), hedonic prices, direct estimation of opportunity costs, replacement costs, cost savings, threshold values etc. However, almost all methods contain varying degrees of constraints and not all may be applicable in each case study. The choice of appropriate methodology usually depends on the selection of ecosystem service to be valued.

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8 Hu Huabin, Liu Wenjun, Cao Min, 2008.Impact of Land use and Land cover Changes on Ecosystem Services in Menglun, Xishuangbanna, Southwest China. Environmental Monitoring and Assessment 146(1-3):147–156.

9 Asia Regional Biodiversity Conservation Program (ARBCP) 2008. Values of Forest on Water Conservation and Erosion Control. Da Nhim Watershed, Lam Dong Province. Draft Final Report, p.33

10 Xie Gaodi , Lu Juanxia . Valuation of Ecological Capital in Qianhai-Tibetan Plateau Ecosystem [J] . Journal of Natural Resources, 2003, 18(2): 189—259.

11 Chen Zhongxin, Zhang Xinshi. Valuation of Ecosystem Services in China[J]. Journal of Sciences, 2000, 45(1):17-22.

12 Thampapillai, D. J. (2002). Environmental Economics: Concepts, Methods and Policies, Oxford University Press, Melbourne.

B. Theoretical Framework

The study has been conducted based on the following steps and theoretical framework:

- Step1: Identify geographic focus to understand the characteristics of the ecosystem and socio-economic conditions of the study area.
- Step 2: Identify potential ecosystem services to be valued through field study and consultation with stakeholders and experts.
- Step 3: Develop valuation methods of the selected ecosystem services based on available valuation methods and data.
- Step 4: Collect required data for valuation through field consultation and secondary literature review of local studies.
- Step 5: Apply the valuation methods and calculate the value for each selected ecosystem service.
- Step 6: Conduct scenario analysis based on different land use options and sensitivity analysis for deal with uncertainties of the results.
- Step 7: Document the findings and analyze policy implications.

C. Valuation Methods for Selected Ecosystem Services

By consulting with local experts from Xishuangbanna Environmental Protection Bureau (XEPB), Xishuangbanna National Nature Reserves Management Bureau (XNNRMB) and Xishuangbanna Tropical Botanical Garden (XTBG), China Academy of Sciences, a series of ecosystem services had been identified as shown in the table 1 below:

Table 1 Types of ecosystem services in Xishuangbanna BCI pilot sites

Direct use values	Indirect use values	Non-use value
- Non-Timber Forest Product (NTFP) (i.e. Food, medicine plants, fuel wood, materials, etc.) - Recreation and tourism - Plant genetics - Agro-biodiversity	- Climate Regulation (Carbon Sequestration, Oxygen Generation) - Water Regulation (Watershed Protection, Storage, Water Quality regulation) - Soil erosion protection - Nutrient cycling - Micro climate functions (temperature / humidity prevention - Air purification - Pollination - Biodiversity	- Existence value - Culture/spiritual value

The commonly used valuation techniques to value the different value components of a tropical forest are listed in the Appendix 2. Due to the data availability and time constrain, only a few major ecosystem services are selected to be included in this valuation study. The selected ecosystem services and their valuation methods are presented in the table below:

Table 2 Valuation Methods for selected ecosystem services

Ecosystem services	Valuation Method	Data requirements	Data collection
NTFP	Market Analysis	Biophysical data Cost inputs Prices of outputs	Local survey & studies
Climate Regulation - Carbon Sequestration - Oxygen Generation	Cost saving	International carbon sequestration or industrial oxygen production cost; areas of the ecosystems; carbon sequestration or industrial oxygen production capacity of ecosystems	Local studies; Benefit transfer
Water Regulation - Watershed Protection (Storage) - Water Quality regulation	Cost saving	Reservoir construction cost; annual precipitation of area in research; annual evaporation in forest of all climate types; area of coniferous and broadleaf forest of all climate types	Local studies; Benefit transfer
Soil erosion provention	Damage cost	Erosivity of different types of forest land and non-forest land; Area of ecosystems; cost of 1 ton sediment removal；Ratio of sediments entering river or reservoir to total soil loss；	Local studies; Benefit transfer
Nutrient Cycle	Cost saving	Area of ecosystems；Erosivity difference of ecosystems and non-forest land; N,P,K contents in ecosystem soil; ratio of pure N,P,K to N,P,K contained fertilizer; price of various fertilizers	Local studies; Benefit transfer
Air purification	Cost saving	Annual unit pollutant absorption of coniferous and broadleaf forest； Annual particulate adsorption of coniferous and broadleaf forest per unit area; area of coniferous and broadleaf forest of all climate types in China; treatment cost of pollutants, particulates	Local studies; Benefit transfer

III. Valuation of Ecosystem Services

A. Non-Timber Forest Products

NTFP plays an essential role in local livelihoods in the corridor area. The most important types of NTFPs are: 1) Food (Ci Zhu/ Bamboo, Mushroom, Mu Er - Auricularia auricular, Wild herbal vegetables, Honey, and Duoyi -fruit); 2) Medicinal plants; 3) Fuel Wood; 4) Materials (Rattan, Bamboo); 5) Oils; and 6) Orchids. Food and fuel wood are the major consumption goods for the local livelihoods from the forests.

It is difficult to estimate quantity of NTFPs available and how much is being collected from the corridors. For instance, some like mushrooms are seasonal while the Ci Zhu bamboo is collected all year round. Based on interviews and surveys conducted with local villagers, a number of products were assessed and some price estimations were made based on surveys and interviews in the local markets. Wild herbal vegetables (estimated at 15 – 20 Kg per household per year) and fuel wood estimated at 6-10 m3 per household per year) seem to be the main NTFPs consumed, while potential sources of cash based livelihoods are represented such NTFPs as Ci Zhu bamboo (estimated at RMB 1,500 per household per year) and the Duoyi (local fruit estimated at an average of RMB 500 per household per year). On an average, $35 per month per household amounts to $420 per year covering 1,938 households in the Mangao – Nabanhe corridor and 495 households are living in the Mengla – Shangyong corridor. Thus the value of NTFPs collected currently is just over a $1 million, which is negligible compared with the value of other ecosystem services. However, if we include processed oils, aromatic essences, and orchids the values may be higher but information on these NTFPs is scattered as their collection and marketing by households is not well developed. As livelihoods of local communities depend also on forest ecosystem and the valuation in this case is a conservative estimate, the actual importance of NTFPs must be rated higher than its nominal value. However, NTFP is under threat of overexploitation in Xishuangbanna BCI Pilot Site.

B. Climate Regulation

Forests play a major role in balancing oxygen and carbon dioxide in the atmosphere. Amounts of O_2 released and CO_2 absorbed per year were calculated per ton of biomass formed based on the photosynthesis equation. For all types of forests, amounts of O_2 released and CO_2 absorbed per year per hectare are computed using the net production of forests each year. The formula is written as:

V=Q*P*S

Where：V—Release or absorption service value (RMB)

Q - carbon sequestration or industrial oxygen production capacity of ecosystems

P—International carbon sequestration or industrial oxygen production cost（RMB）

S—Area of each forest type (ha).

Carbon Sequestration

Discussion at COP 13 (2007) of the United Nations Framework Convention on Climate Change (UNFCCC) in Bali made the Reduction of Emissions from Deforestation and Land/Forest Degradation an important platform for boosting investments to enhance carbon sequestration potential of natural forests and plantations and reduce emissions from land use change and forest destruction. Carbon sequestration capacity is assumed to be 50% of the biomass carbon density. Estimates of forest biomass carbon density in Xishuangbanna were conducted by a research group in Xishuangbanna Tropical Botanical Garden based on the forest inventory data and other vegetation biomass carbon data (see Appendix 4). The prices estimated for carbon sequestration vary from different sources. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC 2007) suggests that real prices at $20-$50 per ton of CO_2, however, the average price in the Clean Development Mechanism (CDM) was $10.5 per ton of CO_2. $10/ton of CO_2 is taken for estimation of carbon sequestration potential in this study as it is the price quoted in the carbon trading case of reforestation in Tengchong, Yunnan in the voluntary market in Chicago in 2007[13]. The total value amounts to $362 million for both corridors including the nature reserves connected by the two corridor segments as given with details in table 3 below.

[13] Information is given by Ms. Xiaohua, Forest Bureau of Yunnan Province, China

Table 3. Value of Carbon Sequestration by Vegetation Type

Vegetation Type	Area (ha)	Biomass Carbon Density[14] (ton/ha)	Carbon Sequestration (ton/ha)	Value (USD)
Mengla – Shangyong Corridor				
Tropical seasonal rain forest (inside Nature Reserve)	134523	121.74	60.87	300,514,871
Tropical Seasonal rain forest and Mountain rain forest	1409.37	75.17	37.585	1,944,042
Rubber plantation	976.57	30.47	15.235	546,024
Paddy	54.59	5.41	2.705	5,419
Total				303,010,356
Nabanhe - Mangao Corridor				
Tropical seasonal rain forest (inside Nature Reserve)	134523	121.74	60.87	47,749,066
Tropical Seasonal rain forest and Mountain raion forest	7197.15	75.17	37.585	9,927,529
Conifer forest	408.98	51.44	25.72	386,046
Shrublands	15.3	14.56	7.28	40,88
Shifting cultivation/ grasslands	1402.38	3.81	1.905	98,045
tea garden	1228.47	14.26	7.13	321,455
Paddy	5006.13	5.41	2.705	496,976
Total				58,983,205

Oxygen Generation capacity has been calculated from carbon sequestration capacity, based on the photosynthesis reaction equation.

$$6CO_2\ (264g) + 12H_2O\ (180g) \rightarrow C_6H_{12}O_6\ (180g) + 6O_2\ (192g)$$

$$\downarrow$$

Polysaccharide (162g cellulose or starch)

According to the equation above, 1 ton of CO_2 absorbed will release 0.73 ton O_2. The cost of industry O_2 production in China is: P= RMB 40/ton. Table 4 below shows details of oxygen generation values by vegetation/crop type.

[14] Hongmei Li, Youxin Ma, T. Mitchell Aide, Wenjun Liu, (2007) Past, present and future land-use in Xishuangbanna, China and the implications for carbon dynamics. Forest Ecology and Management 255 (2008) p.19

Table 4. Oxygen Generation by Vegetation Type

Vegetation Type	Carbon Sequestration (ton/ha)	O_2 Release (ton/ha)	Value O_2 (USD)
Mengla-Shangyong Corridor			
Tropical Seasonal rain forest(NR)	60.87	163.08	128,477,807
Tropical Seasonal rain forest and Mountain rain forest	37.585	100.69	831,128
Rubber plantation	15.235	68.91	233,439
Paddy	2.705	7.25	631
Total			129,543,005
Nabanhe- Shangyong Corridor			
Tropical seasonal rain forest(NR)	60.87	163.08	20,413,949
Tropical Seasonal rain forest and Mountain rain forest	37.585	100.69	4,244,273
Conifer forest	25.72	68.91	165,045
Shrublands	7.28	19.50	1,748
Shifting cultivation/ grasslands	1.905	5.10	41,917
Tea garden	7.13	19.10	137,430
Paddy	2.705	7.25	212,470
Total			25,216,831

C. Water Regulation

Xishuangbanna is rich in rainfall and rivers, which is important in watershed protection and maintenance of equilibrium. The mechanism of **watershed protection** of forest is manifested in the retention of water by the crown, trunk, undergrowth vegetation, forest litter and soil through which water is relocated to regulate availability of surface water and runoff. The Forest is often referred to as a "sponge" and "green reservoir" for its immense osmosis effect and watershed protection capacity. By regulating runoffs, forests can contribute to delay in flood peak and reducing flood volumes; in dry seasons, forests gradually release absorbed water to increase river flow and relieve droughts. One commonly adopted method is the rainfall storage method (Li Jinchang, 1997):[15]

[15] Li Jinchang, Ecological value. Chongqing, *Chongqing University Press*, 1997.

$$V=Q*C_{yt}$$
$$Q=S*J*R$$
$$J=J_O*K$$
$$R=R_O-R_g$$

Where Q——Increase in water preserved in forest (meadow) ecosystems, compared to bare land(m^3);

S——Area of the forest (ha);

J——Annual average precipitation runoff yield of the study area (mm);

J_o——Annual average precipitation of the study area (mm):

K——Ratio of precipitation runoff yield to total precipitation of the study area;

R——Benefit coefficient of reduced runoff in forests (meadow) compared to bare land (or non-forested area)(%);

R——Precipitation runoff rate under precipitation runoff condition in bare land (%);

Rg——Precipitation runoff rate under precipitation runoff condition in forests (%);

C_{yt}——Investment cost of reservoir construction per m^3= RMB 0.80/year (He Guoqiang, 2005[16]):

V——Annual economic value of forest ecosystems in watershed protection (RMB).

Using distribution characteristics of annual average precipitation in China, the country is divided into five regions of different precipitation intensity. The precipitation and parameters are listed in Table 5 below. (Zhao Tongqian etc, 2004)[17]. Based on measurement, average annual precipitation is 1,557mm，thus J_O=1400, taken as 1.40[18] for calculation.

Table 5. Rainfall distribution area and parameters

Rainfall area(mm)	400~600	600~800	800~1200	1200~1600	1600
Jo Parameters(mm)	500	700	1000	1400	1800

The area under calculation is divided into North and South areas by the line connecting Qing Ling and Huai River. Parameter K is chosen based on rainfall characteristics[19]: K is 0.4 for North area and 0.6 for South area. Based on existing measurement and results, R value is

[16] "The biological benefit measurement and economic evaluation of the forest of Simao Yunnan", He Guoqiang, *Journal of Simao Teachers' Colleage*, 2005, 21(3):18~21.
[17] "Forest ecosystem services and their valuation in China", Zhao Tongqian, Ouyang Zhiyun, Zheng Hua, Wang Xiaoke, Miao Hong, *Journal of natural resources*, 2004, 19(4):480~490.
[18] Evaluation of function of major ecosystems and research of ecological compensation in Yunnan.
[19] Zhao Tongqian, 2004, *Assessment and Valuation of Forest Ecosystem Services in China*. s Natural Resources Journal, 2004, 19(4):480-490

obtained with consideration of forest ecosystem distribution, vegetation coverage, soil, landform and corresponding bare land characteristics (Zhao Tongqian, 2004), See table 6 below.

Table 6. R value of the various forest ecosystems in China

Type of forest ecosystems	R value
Cold-temperate larch	0.21
Temperate evergreen coniferous forest	0.24
Temperate, subtropical deciduous broadleaf forest	0.28
Temperate deciduous, lobular sparse forest	0.16
Subtropical evergreen deciduous forest and broadleaf forest	0.34
Subtropical evergreen broadleaf forest	0.39
Subtropical, tropical evergreen coniferous forest	0.36
Subtropical bamboo forest	0.22
Tropical forest, monsoon forest	0.55

Thus the value of water storage (quantity) in Xishuangbanna biodiversity corridor segments under study is over $89 million as given below in table 7.

Table 7. Value of water storage in Xishuangbanna Corridors

Corridor Area	Area of Broadleaf forest (Ha)	Area of Coniferous forest (Ha)	Value (USD)
Nanbanhe-Mangao	27,732.99	1,247.62	15,449,395
Shangyong-Mengla	135,892.82	39.56	73,551,331

Water Quality Regluation: According to the research carried out by Beijing Forestry Bureau and Beijing Forestry University, rainwater retained by forests can reach drinking water quality (Yu Xinxiao etc, 2002 [20]. One possible method to value the water quality is as follows:

$$V=Q^{*}P$$

Where: V—Value of water purification by forest

Q—Amount of water preserved in ecosystems (alternatively, we can consider the households' consumption of the water supply)

P—Unit cost of impurity removal (price of water supply)

Applying this formula, the total value of water purification by the forests in the biodiversity corridor segments in Xishuangbanna (see table 8 below) amounts to $185 million, whereby the unit price of water assumed in the calculation is that of treated water supply in Jinghong City,

[20] "The forest ecosystem services and their valuation of Beijing mountain areas", Yu Xinxiao, Qin Yongsheng, Chen Lihua and Liu Song, *Acta ecologica sinica*, 2002, 22(5):783-786.

which is RMB 1.5/m^3.

Table 8. Value of water quality in Xishuangbanna Corridors

Corridor Area	Area of Broadleaf forest (Ha)	Area of Coniferous forest (Ha)	Value (USD)
Nanbanhe-Mangao	27,732.99	1,247.62	28,967,615
Shangyong-Mengla	135,892.82	39.56	156,300,748

D. Soil Erosion Prevention

As a protection layer of the ground, forest helps to prevent soil erosion and minimize sedimentation in reservoirs and rivers, thus extending reservoir life. The ability of forest in rainwater retention and reduction of rainfall volume and velocity reaching the ground serves to regulate runoff quantity and speed and minimize soil loss. (Run Junhua , 1999)[21]. One method of estimating the value of reduction in soil loss (soil conservation) is equivalent to the cost of sediment removal from rivers and reservoirs (dredging). The formula for calculating the value of soil erosion prevention by forests is as follows:

$$V_k=K\cdot G.\sum S_i*(d_i-d_o)$$

Where: Vk - Economic value of soil conservation;

K - Cost of 1 ton sediment removal;

S_i - Area of forest of all types (ha)

G - Ratio of amount of sediments entering rivers or reservoirs to total soil lost;

d_i - Erosivity of all types of forest(t/ha);

d_o - Erosivity of non-forest land (t/ha).

In the Xishuangbanna study, the average cost of 1 ton of sediment removal is K= RMB10[22] and the ratio of sediments entering rivers or reservoirs to total soil loss is 50% or G=0.5. According to the fifth forest inventory data, the soil erosion in non-forest area is 319.8ton/ha/yr, and the erosion of broadleaf forest and coniferous forest are 0.5ton/ha/yr and 7.8ton/ha/yr respectively[23]. The total value of soil erosion prevention provided by the Xishuangbanna BCI

[21] Run Junhua, a review of forest hydrology studies, Journal of tropical and subtropical botany, 1999,2(2):347~356.

[22] Li Yide, Chen Bufeng, et al.(2003), The values for Ecological Services Function of Tropical Natural Forest in Hainan Island, China. Forest Research, 2003, 1(62):164~125

[23] The Fifth Forestry Inventory, 1999, Forestry Science Data Center, China

Pilot site is $39 million each year (details shown in table 9 below).

Table 9. Value of soil erosion prevention in Xishuangbanna Corridors

Corridor Area	Area of forest (Ha)	Value (USD)
Nanbanhe-Mangao	28,980.61	31,773,947
Shangyong-Mengla	135,932.39	6,774,164

E. Nutrient Cycling

The forest also helps to maintain fertility since soil erosion may result in losses of N, P, K and organic substance which can be regarded as proxy for nutrient cycling function. Thus, for nutrient cycling the formula used is as follows:

$$V_f = D \cdot S \cdot \sum P_{1i} \cdot P_{2i} \cdot P_{3i}$$

Where:

D - Erosion reduction in forest land compared to non-forest land

P_{1i} - Content of N,P,K in forest soil (%) (see table 10)

P_{2i} - Ratio of pure N,P,K to their fertility counterparts. The ratio of N, P, K to their fertilizer counterparts are 60/28,406/62,74.5/39 respectively (common fertilizers used are urea for N, Calcium Superphosphate for P and Potassium Chloride for K).

P_{3i} - Price of fertilizers. Price of urea, Calcium Superphosphate and Potassium Chloride are RMB1,600/t, RMB500/t and RMB1,250/t respectively.

Table 10. Soil fertility in the different forest types in Xishuangbanna

Forest	Organic substance, g/kg	Total N, g/kg	Total P, g/kg	Total K, g/kg
Tropical monsoon forest	23.88	1.31	0.26	7.33
Secondary forest	39.84	2.47	0.62	11.1
Artificial rubber forest	24.02	1.38	0.32	13.14

Source: Research on the difference of soil fertility in the different forest types in Xishuangbanna [24]

[24] "Research on the difference of soil fertility in the different forest types in Xishuangbanna", Tang Yanlin, Deng Xiaobao, Li Yuwu and Zhang Shunbin, *Journal of Anhui agricultural sciences*, 2007, 35(3):779-781.

The total value of nutrient cycling provided by the Xishuangbanna BCI Pilot site is $182 million each year and details are shown in table 11 below.

Table 11. Value of Nutrient Cycling in Xishuangbanna Corridors

Corridor Area	Area of secondary forest(ha)	Area of primary forest (ha)	Value (USD)
Nanbanhe-Mangao	7,606.13	21,374.48	146,110,811
Shangyong-Mengla	1,409.37	134,523.02	35,986,089

F. Air purification

Forest purification includes the following functions: i) Absorption of harmful gases such as SO2、NOx、HF、CL2；ii) reduction of particulates, pollutants absorption, sterilization, noise reduction, release of oxygen anion and terpene materials. The method commonly adopted involves area absorption. The formula is：

$$V = \sum_{i=1}^{n} S_b q_i C_i + \sum_{i=1}^{n} S_c q_i C_i$$

Where：Sb——Area of broadleaf forest（ha）

Sc——Area of coniferous forest（ha）

qi——Absorption or adsorption of the ith pollutant per unit area（kg/ha）

Ci——Treatment cost of the ith pollutant（RMB/kg）

V——Value of air purification by forest per year（RMB）

Table 12. Valuation parameters of air purification

Area of forest	Absorption Capacity[25]		Pollution discharge fee - Treatment cost[26] (RMB)
	Broadleaf forest	Coniferous forest	
SO_2	88.65 kg/ha/yr	215.6kg/ha/yr	0.60/kg
HF	4.65 kg/ha/yr	0.5kg/ha/yr	0.60/kg
No_x	6.0 kg/ha/yr	6.0kg/ha/yr	0.60/kg
Particulates	10.11 t/ha/yr	33.2t/ha/yr	0.60/kg

The total value of air purification provided by the Xishuangbanna BCI Pilot site is $151 million each year (details in table 13 below).

25 "The research report of national condition of biodiversity in China", compiled by research group of national condition of biodiversity in China, Beijing: China environmental sciences press, 1997.
26 The value is based on the national industrial pollution discharge fee set by Ministry of Environment Protection, http://www.zhb.gov.cn/epi-sepa/zcfg/w3/ling2003-31.htm

Table 13. Valuation of Air Purification in Xishuangbanna Corridors

Corridor Area	Area of Broadleaf forest (ha)	Area of Coniferous forest (ha)	Value of Air Purification (USD)
Nanbanhe-Mangao	27,733	1,248	28,535,792
Shangyong-Mengla	135,893	40	121,993,521

G. Overview of Ecosystem Service Values in Xishuangbanna BCI Pilot Site

The total value of ecosystem services assessed in the Xishuangbanna biodiversity corridor segments of a) Nabanhe – Mangao (including Nature Reserves) and b) Mengla – Shangyong (including Nature Reserves) amounts to $1.162 billion (see table 14 below), which translates into just over $7,064 per ha, if we take into account the total forested area of both corridor segments and nature reserves to be 164,913 ha. However, the result is very sensitive to the carbon price, if we take a range between $20 - $50 per ton of CO_2, the total value will range between $1.524 - $2.61 billion annually with a unit value of $9,421 - $15,827 per ha.

Table 14: Overview of Summary Value of Tropical Forest Ecosystem Services in Xishuangbanna (in million USD)

Ecosystem Services	Mengla-Shangyong (135,932 ha)	Nabanhe-Mangao (28,981 ha)	Total value	Unit Value ($/ha/yr)
1. NTPF	0.2	0.8	1.0	-
2. Carbon Sequestration	303	59	362	2,195
3. Oxygen Generation	130	25	155	938
4. Watershed Protection (Storage/Quantity)	74	15	89	540
5. Water Quality regulation	156	29	185	1,123
6. Soil erosion protection	32	7	39	234
7. Nutrient Cycling	146	36	182	1,102
8. Air purification	122	29	151	913
Total	962	200	1162	7,046

The carbon sequestration service of the forest provides the highest value followed by water quality regulation and oxygen generation. NTFP comes in low because several highly potential products such as oils, aromatic essences, and orchids are not well processed for value addition and also collected by fewer households in limited areas. Medical herbs and some bamboo types are assumed to be over exploited, which may need some domestication and production outside the forest for commercial use.

IV. Scenarios and Analysis

In the last section, we can see that a significant value is provided by the tropical forest ecosystem services in Xishuangbanna BCI pilot site. However, driven by the high market demand and economic incentives, rubber plantation and expansion remain the major threat to the forest conversion and fragmentation. Doubts persist regarding the question whether “rainforests are providing ecosystem services valuable enough to justify conservation? And which development pattern is more beneficial to the society as a whole, business as usual or conservation?” It is, therefore, essential to analyze the trade-offs between forest conservation and other competing land use options. Two scenarios of the BCI corridor development, namely, development scenario (without BCI) and conservation scenario (with BCI), have been developed and simulated for comparison together with the status quo in terms of their Net Present Value (NPV) with the economic analysis of costs and benefits of different land use options.

The scenarios’ specifications for simulation are summarized in table 15 below, and the vegetation areas data and corridor scenario maps are generated using a geographic information system (GIS) modeling.

A. Scenarios Design

The development of Xishuangbanna biodiversity corridor area may meet various constraints, regardless of the establishment of biodiversity conservation corridors in the area. Future development will be limited by a combination of factors, namely geographic conditions, market mechanisms, existing forestry and land use policy, and other land use and human factors. Therefore, restrictive factors must be considered in designing the scenarios. The status quo for both corridor segments is discussed in the introduction section and given in Figure 5 and Figure 6 below.

Figure 5. Vegetation of Status Quo 2007 (Nabanhe - Mangao Corridor)

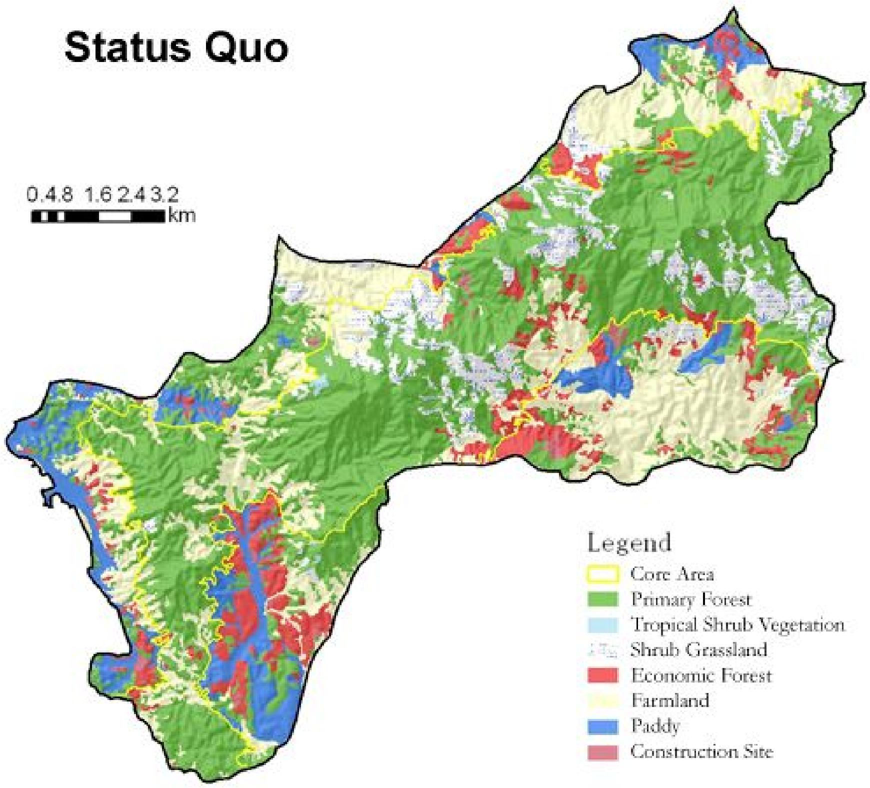
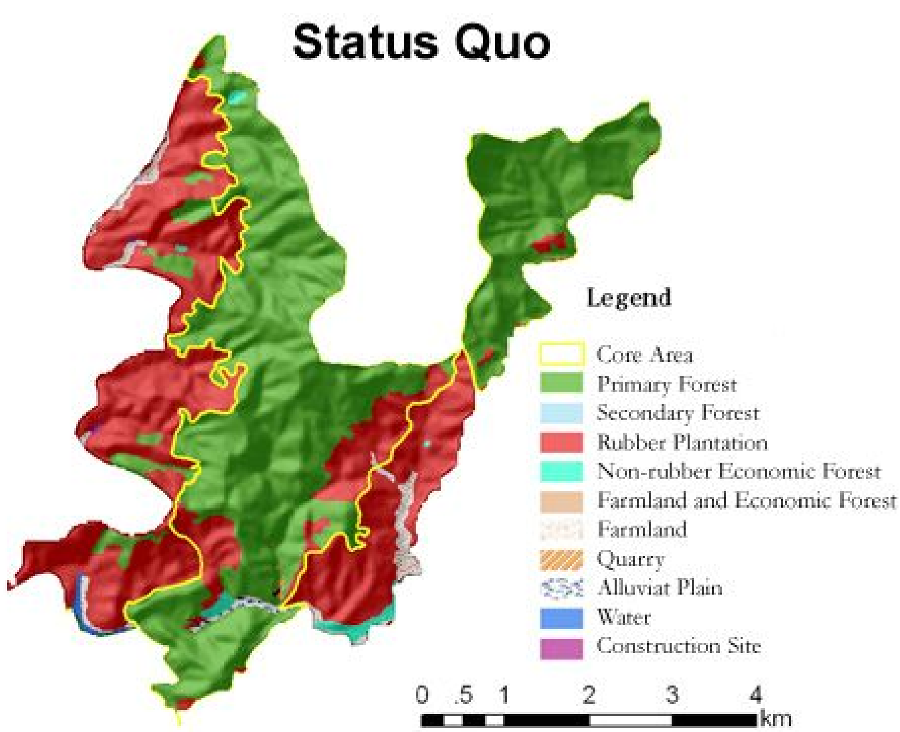


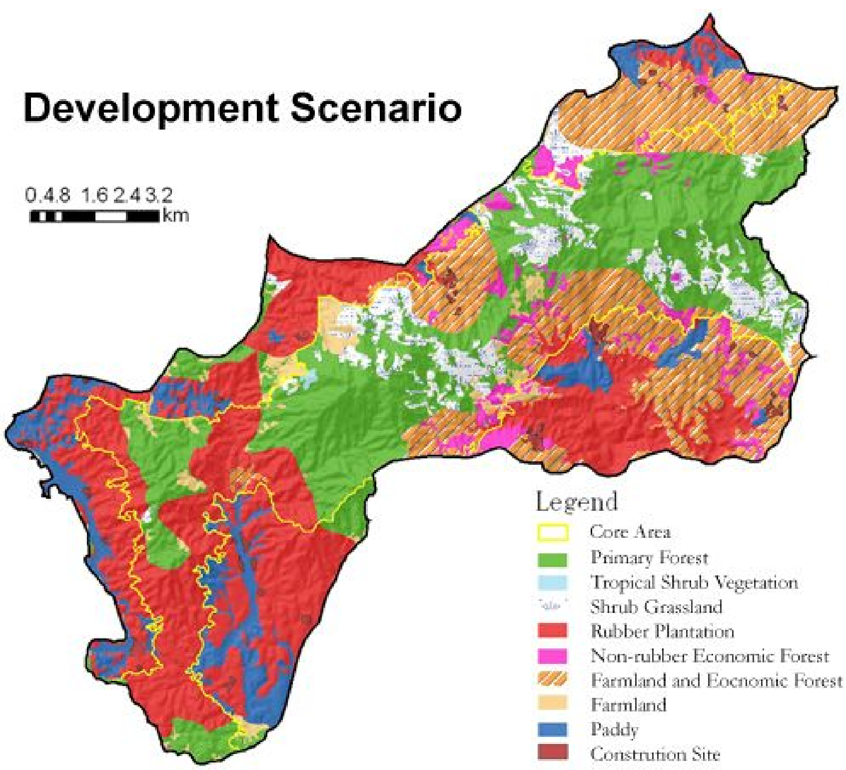
Figure 6. Vegetation of Status Quo 2007 (Mengla – Shangyong Corridor)



Development Scenario (Without BCI)

The Development Scenario simulates the maximum development activity in a corridor area with proper conditions such as market forces, policy permission and suitable growth conditions, assuming no corridor is established / constructed. Driven solely by economic interests, people will choose plantation projects in the following priority: rubber forest > other economic forest > agricultural production. Under the current forest rights policy, farmers are permitted to autonomously manage collective forest allocated to individuals, and those without allocation are not allowed to make use of state-owned forest. Keeping in mind growth conditions, rubber plantations can only be grown at an altitude below 1500m[27], and their growth will be affected above 1500m altitude, there are suitable economic forest crops for areas at any altitude. However, this option is not a conducive one and runs against the current BCI concept and principles. Figures 7 and 8 below show the vegetation changes in the two corridor segments.

Figure 7. Vegetation under Development Scenario (Nabanhe - Mangao Corridor)



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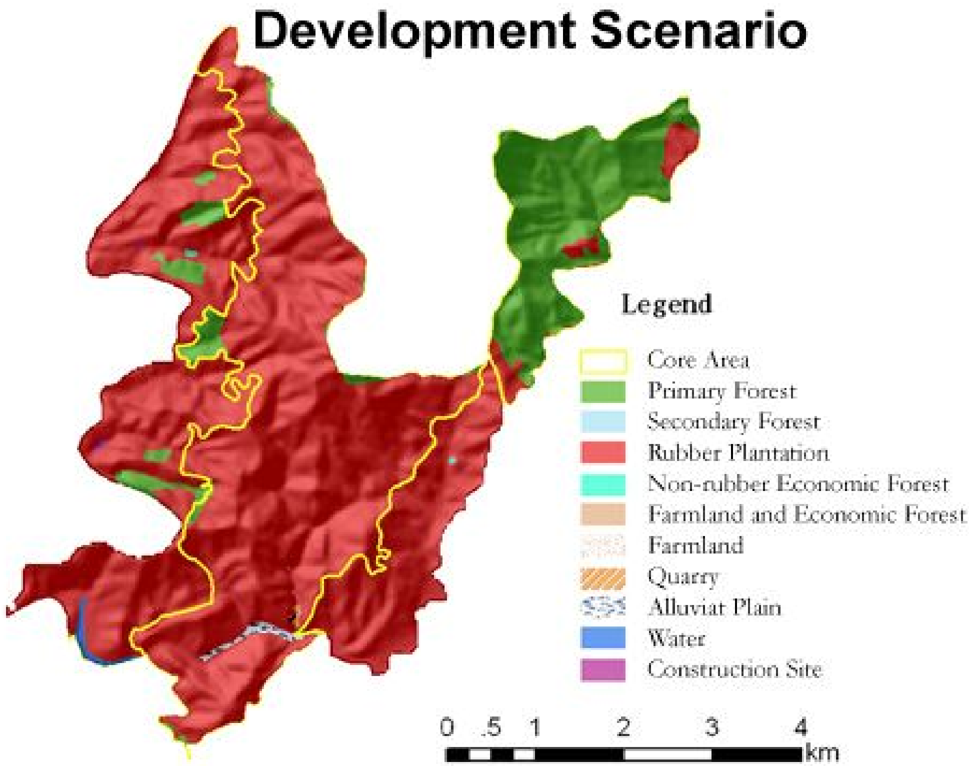
[27] Jiang,A,L.,1982.Upper limits of rice and some other plants in south china. Clim. Notes.29,15-18 Wang,k.,Guo,Y.Q.,Zhong,S.H.,1991.The research of mountainous temperature inversion in Xishuangbanna.j.Yunnan Trop.Crop.SCI.Technol,4(14),1-11.

Figure 8. Vegetation under Development Scenario (Mengla – Shangyong)



Conservation Scenario (With BCI)

Under the Conservation Scenario, the corridor area is divided into core area and buffer area. In the core area, all non-forest area will turn into secondary forest in core area. In the buffer area, it will have the following changes:

i) State-owned forest will remain the same;

ii) Collective forest: Natural forest and other commercial crops remain; other forest at altitude>900m rubber plantation will be converted to economic forest; forest at altitude<900m rubber forest remain unchanged;

iii) All shrub land will be converted to secondary forest;

iv) Farmland: can be considered to be converted to economic forest at steep slope (non-rubber forest);

v) Paddy field, built up and other land use remain unchanged.

Figures 9 and 10 below provide illustrations of the conservation scenario with BCI.

Figure 9. Vegetation under Conservation Scenario (Nabanhe - Mangao Corridor)

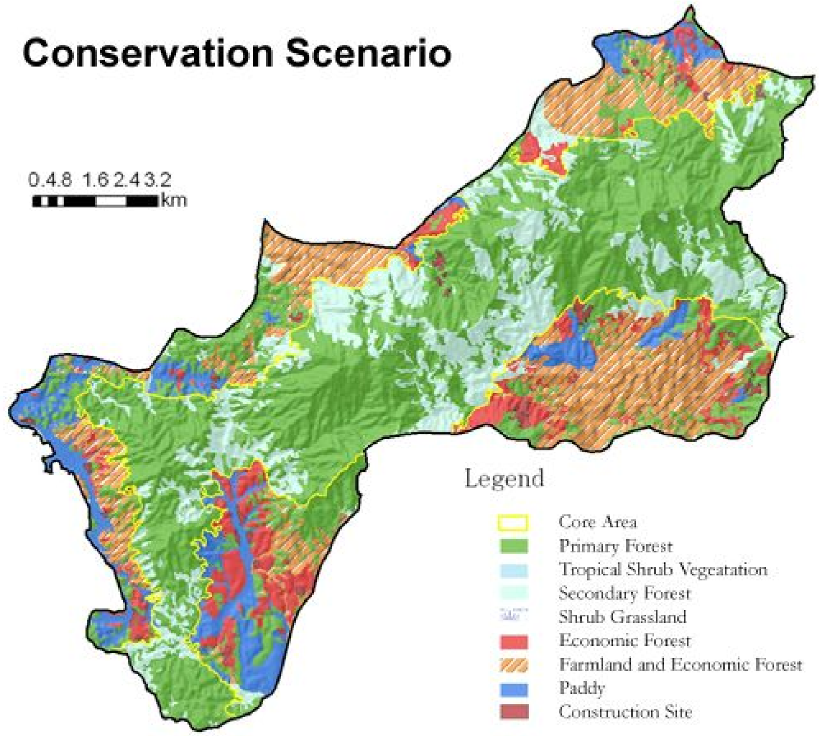


Figure 10. Vegetation under Conservation Scenario (Mengla – Shangyong)

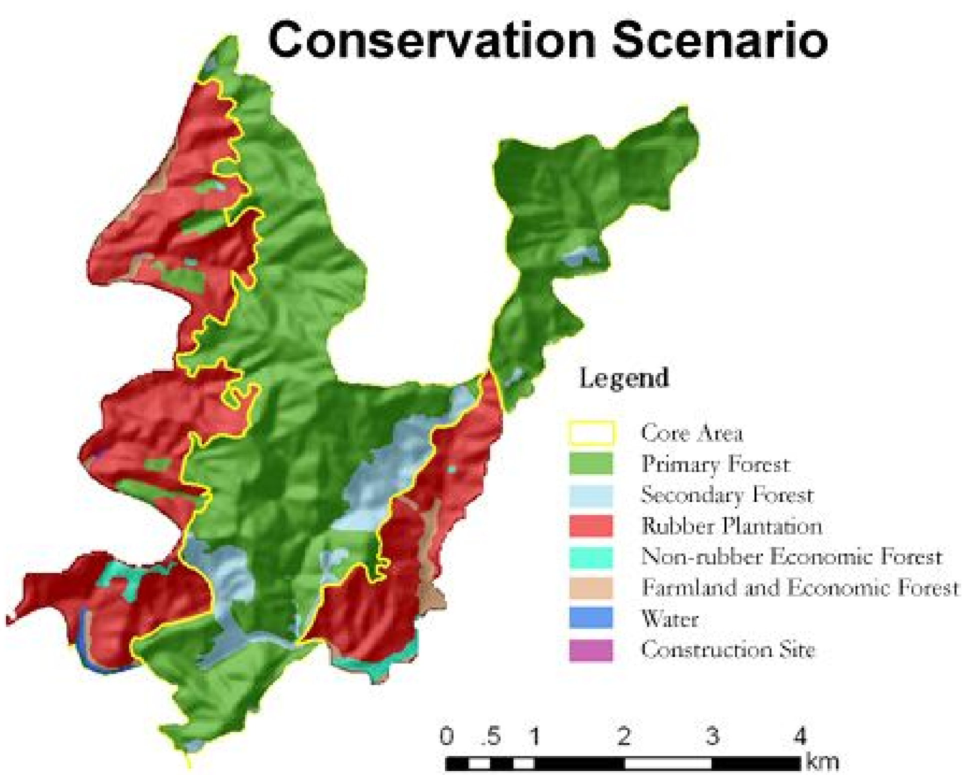


Table 15. Summary of Scenario Design

	Development Scenario (Without –BCI)	Conservation Scenario (With –BCI)
1. Natural Forest		BCI comprises of core area and buffer zones. All non-natural forests turn into to secondary forests in core areas; buffer area will have the following changes
1.1 State-owned forest	1. Altitude>1500m converted to commercial plantation or farmland 2. Altitude<1500m converted to rubber plantation	Unchanged
1.2 Collective forest	1. Altitude>1500m converted to commercial plantation or farmland 2. Altitude<1500m converted to rubber plantation	1. Natural forest and other commercial crops remains 2. Altitude>900m rubber plantation converted to other economic plantation 3. Altitude<900m rubber plantation remain unchanged
2. Shrub land	1. Altitude>1500m converted to commercial plantation or farmland 2. Altitude<1500m converted to rubber plantation	All converted to secondary forest (while shrub land belong to collective forest can be converted to other commercial plantation)
3. Commercial plantation	1. Altitude>1500m unchanged 2. Altitude<1500m non-rubber plantation converted to rubber plantation	Unchanged
4. Farmland	1. Altitude>1500m unchanged 2. Altitude<1500m converted to rubber plantation	Some are considered to be partially converted to commercial plantation
5. Paddy	Unchanged	Unchanged
6. Built-up and others	Unchanged	Unchanged

B. Scenario Analysis

The net present value (NPV) of the costs and benefits associated with each scenario is calculated based on a 35 years timeframe (life cycle of rubber plantation), and with a 10% discounting rate, which has been commonly used in other valuation studies (IIED 2007, De Lopez 2003, Mohd Shahwahid 1999). The higher bound of the prices and yields are taken into calculation for agricultural products, rubber and other commercial plantation. To simplify the model, three broad categories of vegetation are considered for valuation, namely, i) forest, ii) rubber plantation/other commercial plantation, and iii) agriculture, where rubber plantation and rice are selected for calculation as representatives for category ii) and iii) as these are the dominant crops within the category and generate the highest benefits, which follow the equations below:

Net Present Value (NPV)= $\mathbf{NPV_{Forest} + NPV_{Rubber} + NPV_{Agriculture}}$

NPV_{Forest} = Forest area (ha) * NPV_{Forest} ($/ha)

NPV_{Rubber} = Rubber area (ha) * NPV_{Rubber} ($/ha)

$NPV_{Agriculture}$ = Agriculture area (ha) * $NPV_{Agriculture}$ ($/ha)

The vegetation areas of two scenarios compared with status quo and NPV results of the two corridor segments are presented in tables 16 and 17 below.

Table 16. Scenario Analysis of Mangao-Nabanhe BCI Corridor Segment

NPV Unit: (million USD)

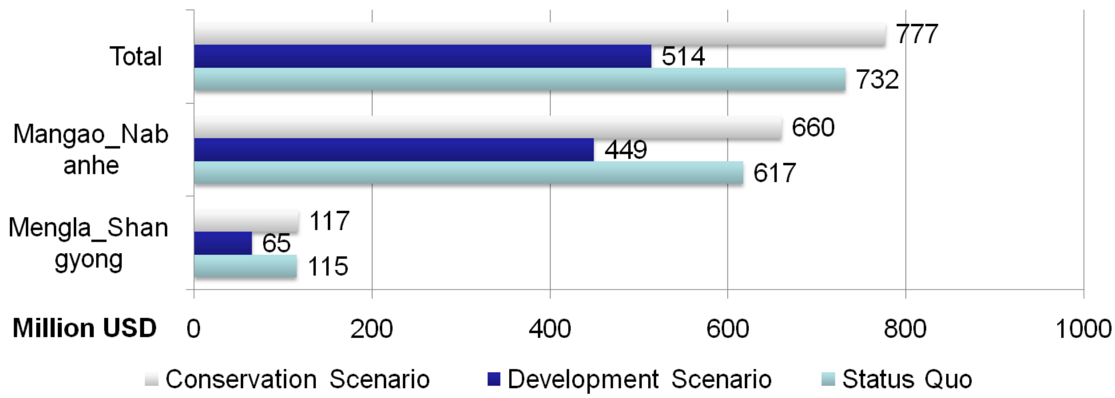
Vegetation Area	Status Quo	Development Scenario	Conservation Scenario
Forest area (ha)	7,517	4,111	10,255
Change (ha)		-3,406	+2,739
NPV_forest	511	279	591
Rubber/other commercial plantation (ha)	1,377	5,414	1,074
Change (ha)		+4,037	-303
NPV_rubber	25	97	19
Agriculture (ha)	6,380	5,749	3,944
Change (ha)		-631	-2,436
NPV_agriculture	81	73	50
Total NPV	617	449	660

Table17. Scenario Analysis of Mengla-Shangyong BCI Corridor Segment

NPV Unit: (Million USD)

Vegetation Area	Status Quo	Development Scenario	Conservation Scenario
Forest area (ha)	1409	416	1589
Change (ha)		-992	+180
NPV_forest	96	28	101
Rubber/other commercial plantation (ha)	1007	2053	838
Change (ha)		+1046	-169
NPV_rubber	18	37	15
Agriculture (ha)	64	10	53
Change (ha)		-54	-11
NPV_agriculture	0.813	0.127	0.637
Total NPV	115	65	117

Figure 11 Results of Scenario Analysis



The results of both corridor segments show that conservation scenario can better preserve the value of status quo even with further improvement, while the development scenario may incur a huge loss of value compared with status quo. NPV of the forests contribute to the biggest proportion and variance of the values under different scenarios. However, for better understanding the costs and benefits of different land use options in the corridor area at a micro level, economic analysis of rubber plantation, forest and agriculture are discussed as below.

Rubber Plantation

Rubber plantation has become the major and most commercially beneficial commodity /cash crop with rapid expansion in Xishuangbanna in recent years. Based on a Landsat Multi Spectral Scanner (MSS) image and a Landsat Enhanced Thematic Mapper (ETM) image studied by XTBG, the area of rubber plantations increased by 194,141ha (90% growth rate) from 1976 to 2003[28].

Rubber industry boosts local economy; meanwhile, it also helps local villagers to reduce poverty and become financially well-off in a very short period of time. However, uncontrolled expansion of rubber plantations also incurs many negative impacts on ecosystem services and local livelihoods. The direct impact of excessive rubber plantation is on water resources. Water sources, which were previously abundant, are gradually drying up. Availability of clean drinking water has become a major problem in some villages. There are more potential threats from excessive rubber plantation on soil erosion, destruction of biodiversity, water and soil

[28] Hongmei Li, Youxin Ma, T. Mitchell Aide, Wenjun Liu, (2007) Past, present and future land-use in Xishuangbanna, China and the implications for carbon dynamics. Forest Ecology and Management 255 (2008) p.20

contamination from fertilizers and pesticides, and negative impact on pollination and seed dispersal etc. Moreover, the other threat on local livelihood is high dependency on rubber plantation for income generation, thus reducing the previously diversified income sources, subjecting local people to increased economic and financial risks in long run.

In this analysis, we only consider the economic costs and benefits of the raw material rubber for calculation. For the establishment of rubber plantation, it normally takes 5-6 years after planting to start production. The production period often lasts up to 30-35 years according to condition of soil/land and technical skills of tapping the rubber. The rubber tapping season starts from March to November, and normally with two days of tapping followed by 1 day off; thus rubber tapping is for approximately 160 days per year. The average yield of rubber in the study area is 1.5ton/ha annually[29]. The prices of rubber had been continuously increasing from 2RMB/kg in 1990 up to 20RMB/kg in 2007 but due to the economic downturn, the price fell to around 10RMB/kg recently. The timber of the rubber tree after the production period can be sold at a price of 500-800RMB/m^3. The input and benefit flows are summarized in table 18 below.

Table 18. Input and Benefit Flows of Rubber Plantation

Items	Inputs (RMB/ha/yr)	Benefits (RMB/ha/yr)	Period (yr)
Seedling	3,000	-	Year 0
Preparation of land	2,250	-	Year 0
Planting labor	900	-	Year 0
Fertilizing labor	225	-	Year 0-Year 34
Fertilizer	1,050	-	Year 0-Year 34
Weeding labor and spraying pesticide	750	-	Year 0-Year 34
Harvesting labor	2,400	-	Year 1-Year 34
Rubber production	-	15,000-30,000	Year 7-Year 34
Timber	-	75,000	Year 35

Therefore, based on the cashflow presented above, taking 35 years as basis for calculation, with a discounting rate of 10%, which has also been used in scenario analysis, the Net Present Value (NPV) of rubber plantation per hectare ranges between $6,386 - $17,923.

Forest Restoration

If well maintained and protected, natural forest ecosystem provides a constant benefit flow of $7,047 annually based on the valuation in the previous section. However, in the conservation scenario, reforestation is required for forest ecosystem restoration in the core area and some

[29] Data is provided by Agriculture Bureau and consultation with villagers, as well as a report prepared by Julia Schmitt, *The livelihood system in Mahobung village*, May 2006.

of the shrub land in the buffer zones. There are three different approaches for reforestation: natural regeneration, enrichment, and plantation. It normally takes 8-10 years in Xishuangbanna region for a restored forest area to become intermediate-mature tropical rainforest which is able to maintain and provide the ecosystem services.

On the input side[30], i) natural regeneration costs 75RMB per ha per year according to the national standard of non-commercial forest management fee, mainly the demarcation and patrolling and public education cost; ii) enrichment involves costs of seedling, planting and maintenance, which in total approximately costs 1,000RMB per ha per year; iii) human assisted restoration (large scale replanting) requires more inputs in seedling, planting and management, with an estimated cost at 2,000RMB per ha each year. For scenario analysis, this study considers the enrichment cost for reforestation of 1,000RMB/ha/yr for calculation, considering 4 years of inputs for the restoration period with the secondary forest expected to generate benefit streams for ecosystem services after the 8th year.

Moreover, it is also necessary to consider the opportunity costs of converting rubber plantation or agricultural land back to forest, which implies that restoration in the collective forest areas might incur financial outlays for compensation and subsidy for land conversion. According to regulation and policies on Conversion of Farmland to Forests Scheme, the household which owns the user right of the land under the Scheme will get 3,600RMB/ha subsidy for the first 8 years and 1,875RMB/ha for another 8 years[31]. Therefore, the NPV for restoration (35 years, 10% discounted) is $29,294/ha, while NPV for maintaining the existing forest is $67,962/ha.

Agriculture

Except rubber plantation, the major source of income for the households in the Xishuangbanna BCI corridor area is from agricultural activities. Areas of upland farming, fruit, oil plants and traditional cash crop plantation have gradually decreased while rubber plantations have increased. However, area under paddy has remained stable. The major agriculture products are rice, corn, sugarcane, and tea. Thanks to the tropical climate and high fertility of the soil, agricultural activities are normally under two to three-cropping cycles every year. The statistics of prices, costs of production and yield are presented in table 19 below:

[30] The information on the cost of restoration is provided by Xishuangbanna Nature Reserve Administration Bureau

[31] It is stated in the Yunnan provincial Government Documents [2004] No. 130 and [2007] No. 189.

Table 19. Key Statistics of Agricultural Products in Xishuangbanna

Agricultural Products	Yield (ton/ha/yr)	Market Price (RMB/ton)	Cost (RMB/ha/yr)
Rice	5.4-9	1,800	7,200
Corn	10.5	1,600	10,500
Sugarcane	90	195	12,750
Tea	0.816	4,000-14,000	2,250

Source: Agriculture Bureau, Xishuangbanna Prefecture, Yunnan Province, China, Jan 2009, adjusted by field consultation with villagers in the corridor area.

A summary of NPV ($/ha) under a 10% discounting rate and 35-year timeframe is presented in table 20. It demonstrates that maintaining forests or even restoring the degraded forests/reforestation provides much more value than other alternative land use options. However, the values of forest ecosystem services are not well recognized and received by people due to its environmental externality, the rather high economic return of rubber plantation (IRR=23.05% - 34.91%), which drives the rapid expansion of rubber plantation in Xishuangbanna. Although the economic value of other agricultural crops is relatively lower, they still play a very important role in local livelihoods in terms of source of food and income.

Table 20. Summary of NPVs of Land Use Options in Xishuangbanna BCI Corridor Pilot Site

Land use options	**NPV ($/ha) (10% discounting rate, 35 years)**
Forest conservation	67,962
Forest restoration	29,294
Rubber Plantation	6,386 -17,923
Rice	3,558 – 12,708
Corn	8,895
Sugarcane	6,777
Tea	1,431-12,953

C. Sensitivity Analysis

A number of variables and data sources are used in the valuation and scenarios analysis, to deal with the uncertainty of the results; four key variables are selected to conduct the sensitivity analysis, which are: i) discounting rate; ii) prices of rubber selling in the primary market; iii) prices of Carbon Dioxide trading under United Nations Framework Convention on Climate Change (UNFCCC) framework; and iv) rice yields and productivity.

Table 21. Selected Variables for Sensitivity Analysis

Variable	Base case	Alternative value (range)	Descriptive
Discounting rate	10%	8%, 6%	Lower discounting rate (10% discounting rate is regarded to be high for calculation)
Rubber Prices	20 RMB/kg	10 - 25 RMB/kg	Lower bound of rubber price: 10 RMB/kg (2009); higher bound of rubber price: 25 RMB/kg (2007) [Market]
Carbon Prices	10 USD/ton	20 - 50 USD/ton	IPCC Fourth Assessment Report 2007 suggest real prices of 20 to 50 USD/ton CO_2
Rice Yields	9 ton/ha	5.4 -12 ton/ha	According to the field consultation the range of rice yield is between 5.4 -12 ton/ha

The results of the sensitivity analysis (see table 22 below) show that the value of NPVs are quite sensitive to carbon price fluctuation and discounting rate, and less sensitive to the rubber prices and rice yields. If the price of carbon dioxide is set at 50 USD/ton, the NPV values reach double the values of the base case. Six percent (6%) of the discounting rate leads to approximately 50% incremental increase in NPVs. However, the incremental changes in NPVs, by adjusting the values of selected variables, do not affect the outcomes of scenario analysis; in all cases, NPVs of conservation scenario remain the highest values in comparison to status quo and development scenarios.

Table 22. Sensitivity Analysis of Scenarios Analysis (NPV: Million USD)

Scenarios	Base case	Discounting rate		Rubber Prices		Carbon Price		Rice Yield	
		8%	6%	10 RMB/kg	25 RMB/kg	20 USD/t	50 USD/t	5.4 t/ha	12 t/ha
Mangao_Nabanhe BCI Corridor Segment									
Status Quo	617	749	938	601	624	776	1253	558	665
		21.43%	51.95%	-2.65%	1.22%	25.73%	103.10%	-9.53%	7.81%
Development Scenario	449	559	717	387	481	537	798	397	493
		24.59%	59.80%	-13.81%	7.06%	19.49%	77.64%	-11.62%	9.86%
Conservation Scenario	660	816	1038	648	667	848	1412	624	690
		23.62%	57.34%	-1.82%	1.00%	28.53%	113.92%	-5.41%	4.62%
Mengla_Shangyong BCI Corridor Segment									
Status Quo	115	142	180	103	120	144	234	114	115
		23.07%	56.58%	-10.45%	4.71%	25.61%	103.42%	-0.85%	0.08%
Development Scenario	65	85	114	42	77	74	100	65	65
		30.70%	75.17%	-36.15%	18.51%	13.85%	54.49%	0.15%	0.41%
Conservation Scenario	117	145	184	107	122	148	244	116	117
		23.52%	57.59%	-8.51%	3.88%	26.87%	108.19%	-0.66%	0.10%
Total									
Status Quo	731	891	1118	704	745	920	1487	672	780
		21.85%	52.89%	-3.74%	1.90%	25.88%	103.43%	-8.04%	6.74%
Development Scenario	515	644	831	428	558	611	898	462	559
		25.12%	61.43%	-16.80%	8.29%	18.55%	74.37%	-10.30%	8.46%
Conservation Scenario	777	960	1223	755	788	997	1655	741	808
		23.60%	57.38%	-2.82%	1.43%	28.28%	113.05%	-4.69%	3.94%

D. Stakeholder Analysis

Conservation scenario seems to be the better option in both BCI corridor segments. However, the value of ecosystem services, particularly the indirect use values, are not well reflected and factored in both individual household and governmental policy decision making, as different stakeholders own different interests, powers and positions toward benefits of ecosystem services and other incentives. Therefore, it is also important to conduct a stakeholder analysis to provide a general picture of "why and what services are important to whom", and a basis for further developing the PES framework on "how much needs to be provided by whom and to whom if we are to avoid damage cost to the ecosystem"?

Table 23. Stakeholder Analysis of Xishuangbanna BCI Pilot Site

Stakeholders	Interests	Benefits of Concern	Mandates / Power	Position*
Government	Economic, Social, Environmental	Revenue from rubber, and ecosystem services	Policy and regulation	+1
Farmers/villagers	Livelihood and welfare	Income from cash crops; water, food	Land user right	0
Rubber Industry	Economic	Profits from rubber	Capital	-1
Tourism Sector	Economic	Recreational values	Capital	+2
Processing Industry	Economic	NTFP, Agro-biodiversity	Capital	+2
Research Institutes (i.e. XTBG, TianZi etc.)	Economic, Social, Environmental	Research on plant genetics, biodiversity etc.	Science and Technology	+3
International and Regional Programs / Organizations (i.e. ADB, GMS-EOC, etc.)	Social, Environmental	Poverty reduction, VES, biodiversity conservation	Financial and technical assistance	+3
Media	Economic, Social, Environmental	All above	Publicity	+2

* Note: Possible attitudes to support (or object against) the conservation scenario with the score range from (-3. +3), based on consultation and personal judgments, may not represent any organization's point of view.

The stakeholder analysis is summarized in the table 23 above. Local government and individual villagers play a very important role as they are the key players in the game with high interests mandate, and power in hand. Meanwhile, we should not ignore the driving forces of the markets and private sector interests closely related to the ecosystem services, namely, rubber industry, tourism agencies and processing industry. Research institutes, international organizations and media may also contribute to the decision making process in their own way.

V. Conclusion and Policy Implications

A. Conclusion

The valuation results show a potential value of $1.162 billion that is estimated as being provided annually by the forest ecosystem services of Xishuangbanna BCI Pilot Site, namely, Mengla-Shangyong BCI Segment and Mangao-Nabanhe BCI Segment covering a total area of 164,913 ha. Carbon sequestration contributes the largest proportion of the benefits from ecosystem services, water regulation and nutrient cycling also provide significant benefits, while NTFP turns out to be a minor factor due to its limited collection and marketing practiced in the corridor area. However, NTFPs play a very important role in people’s lives and have the greatest potential to capture the value of the ecosystem services and improve local livelihoods. Not all the ecosystem services are included and factored in this valuation framework. Thus, the total value of ecosystem services may be higher if data and model are further developed in the future.

The scenario analysis simulates costs and benefits of the future land use options using different development assumptions. Conservation scenario stands out to be the better option in both BCI corridor segments, while development scenario causes huge invisible loss of benefits in ecosystem services. Expansion of rubber plantation is the major driver and threat to forest conversion, though it is the most beneficial option for the local people to enjoy the short-term high economic returns. However, the risk of rubber related disease and current global economy downturn shows the great vulnerability and uncertainty of the monoculture in rubber plantation.

The value of ecosystem services, particularly the indirect use values, are not well reflected and factored in both individual household and governmental policy decision making, due to its environmental externality. Therefore, it is essential to formulate corridor management policies and payment for ecosystem services (PES) scheme to provide the right incentives to secure and capture the value of ecosystem services.

B. Policy Implications

Giving a significant value of **over $1 billion annually** being provided by the tropical forest ecosystem services in Xishuangbanna BCI pilot site, **the value should be well considered and reflected in decision-making related to land use, forest management and BCI Corridor establishment /development.**

The scenario analysis shows that conservation scenario preserves the value with improvement, while development scenario causes huge invisible loss of benefits in ecosystem services. Therefore, it is essential to apply regulatory and economic instruments in the policy making for providing **i) incentives for forest conservation, restoration and watershed protection; ii) disincentives for uncontrolled expansion of rubber and forest conversion on marginal soil and steep slopes.**

In order to secure and capture the value of ecosystem services of Xishuangbanna BCI Site, several policy implications need to be considered:

3. Formulate legal framework and BCI management guidelines that include:
    a. Regulations on natural forest protection and restoration of degraded forest areas for maintaining important ecosystem services (i.e. watershed protection, soil erosion control, nutrient cycling, etc.)
    b. Zoning the corridor area
        i. Core area – reforestation and restricted development to ensure ecosystem connectivity and biodiversity conservation
        ii. Buffer zone – sustainable forest management and livelihood activities (i.e. NTFP, fuel wood, agro-forestry, livelihood plantation, etc.)
    c. Regulation on rubber plantation expansion and conversion back to forest (geographic location, slope, altitude, etc.)
4. Establish payments for ecosystem services scheme, such as:
    a. PES for watershed services
    b. PES based on carbon sequestration and deforestation avoidance (Payments for REDD - Reduced Emissions from Deforestation and Forest/Land Degradation), tradable Certified Emission Reduction (CER) carbon credits and national carbon offsets
    c. PES for NTFP (eco-certification and eco-labeling of organically produced goods
    d. PES for biodiversity and ecosystem restoration (livelihood interventions/incentives including promotion of agro-forestry and livelihood plantations in return for conservation contracts for maintaining natural forests; public reforestation program and payments, rural greening and promotion of wood based industries (i.e. The National Natural Forest Protection (NNFP) program and the Sloping Lands Reconversion Program (SLP))
    e. PES for recreation (eco-tourism / nature based tourism).

VI. Limitations and the Way Forward

There are certain limitations of this research. Some of the very important ecosystem services are excluded in the valuation framework, i.e. biodiversity, recreation/tourism, pollination and seed dispersal, social benefits (e.g. poverty reduction, employment), because of which the total value of ecosystem services presented herein may be undervalued. Additionally, the costs of negative impacts of rubber and its positive values in ecosystem service terms have not been considered/included in the valuation framework. It is estimated by experts from XTBG, that each hectare of rubber may incur soil erosion of 22.5 ton/yr and loss of underground water of 136.5 ton/yr. If certain costs and benefits can be properly estimated, it will be greatly helpful to better understand the trade-offs between rubber plantation and natural forest conservation. Also because of constraints of data availability and accessibility, most of the coefficients and values are taken from existing research findings, consultations and other secondary literature. Furthermore, valuation is based on a local framework without comparing or considering the regional and global level frameworks or values that may be higher.

In future, further research could focus on improving the valuation research framework wherever data is available and appropriate models can be applied. There is potential for incorporation of high resolution GIS data and computer simulation techniques into the valuation model and develop a robust model for calculating values at prefecture, county, administrative village and even farm levels. The valuation methods applied here can be used in other BCI pilot sites (such as in Cambodia, Lao PDR, Thailand and Viet Nam or expand the valuation research framework to cover the entire Xishuangbanna Prefecture). And a more systematic and programmatic PES mechanism for Xishuangbanna BCI site could be designed.

Appendixes

Appendix 1: BCI Pilot Sites and Biodovoerisity Landscapes in the GMS

Country	BCI Sites	Biodiversity Conservation Landscape (BCL)
Cambodia	Cardamom Mountains	Cardamom and Elephant Mountains
	Eastern Plains, Mondulkiri	Eastern Plains Dry Forest
PR China	Xishuangbanna	Mekong Headwaters
Lao PDR	Xe Pian – Dong Hua Sao –Dong Ampham	Triborder Forest – Central Annamites
Thailand	Tenasserim –Western Forest Complex	Western Forest Complex
Viet Nam	Ngoc Linh – Xe Sap	Central Annamites

Source: BCI Implementation Status Repot 2007, published Jan 2008 by GMS EOC.

Appendix 2: Valuation Techniques Commonly Used to Value the Different Value Components of a Tropical Forest

Values of Ecosystem Services	Valuation Technique
Direct Use Value	
Timber	Market analysis
NTFP	Market analysis, price of substitutes, indirect substitution approach, indirect opportunity cost approach, value of changes in productivity, barter exchange approach
Educational, recreational and cultural uses	Travel cost method, hedonic prices
Human habitat	Hedonic prices, [replacement cost]
Indirect Use Value	
Watershed protection Nutrient cycling Air pollution reduction Microclimate regulation Carbon store Biodiversity	Damage costs avoided Preventive expenditure (cost saving), Value of changes in production [Relocation costs] [Replacement costs]
Option Value	Contingent Valuation Method
Existence Value	Contingent Valuation Method

Source: The Economic Valuation of Tropical Forest Land Use Options – A Manual for Researchers (Section B, p28), EEPSEA.

Appendix 3: Vegetation Types and Area in Xishuangbanna BCI Pilot Site

Vegetation Types and Area in Mengla-Shangyong Corridor

Vegetation Types	Area (ha)
Tropical seasonal rain forest	169.64
Mountain rain forest	269.29
Coniferous seasonal rain forest	3.66
Monsoon evergreen broadleaf forest	966.78
Bamboo forest	2.55
Rubber plantation	976.57
Fruit trees	7.7
Teak forest	0.86
Cassia siamea Lam	12.55
Agricultural crops	54.59
Others	22.25
Total	2486.44

Source: Ecological assessment of Mengla-Shangyong BCI Corridor Segment, done by Xishuangban Nature Reserve, 2007

Vegetation Types and Area in Mangao-Nabanhe Corridor

Vegetation Types	Area (ha)
Monsoon evergreen broadleaf forest	6440.91
Warm coniferous forest	408.98
Shrub lands	15.3
Deciduous broadleaf forest	756.24
Grassland	1402.38
Tea	1228.47
Fruit trees	0.85
Bamboo forest	80.08
Agricultural crops	5006.13
Others	146.53
Total	15485.87

Source: Ecological assessment of Mengla-Shangyong BCI Corridor Segment, done by Xishuangban Nature Reserve and Nabanhe Nature Reserve, 2007

Appendix 4: Forest Biomass Carbon Density in Xishuangbanna

Land Use/ Land Cover	Mean Biomass Carbon Density (ton/ha)
Forest Type (Elevation range)	
Inside nature reserve (mature forest)	
Tropical seasonal rain forest (<800m)	121.74
Mountain rain forest (800-1000m)	116.24
Subtropical everygreen broadleaf forest (>1000m)	105.24
Coniferous forest	31.54
Outside nature reserve	
Tropical season rain forest and mountain rain forest	
Young	29.23
Intermediate	56.06
Mature	75.17
Mean Carbon density	49.84
Subtropical evergreen broadleaf forest	
Young	32.15
Intermediate	54.73
Mature	71.00
Mean carbon density	53.22
Coniferous forest	
Young	28.39
Intermediate	36.85
Mature	51.44
Mean carbon density	37.19
Rubber plantation (elevation range)	
<800m	61.48
800-1000m	35.09
>1000m	15.31
Mean	30.47
Shrub lands	14.26
Grassland	5.32
Tea garden	14.26
Shifting cultivation	3.81
Paddy	5.41

Source: Hongmei Li, Youxin Ma, T. Mitchell Aide, Wenjun Liu, (2007) Past, present and future land-use in Xishuangbanna, China and the implications for carbon dynamics. Forest Ecology and Management 255 (2008) p.19

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