Young rubber plantation in Xishuangbanna, Southwest China. Photo: Development Seed/Zhuang-Fang Yi

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CHAPTER 17

Can carbon-trading schemes help to protect China’s most diverse forest ecosystems?

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Highlights

- Ecosystem and biodiversity will be expensive to recover once destroyed.
- Rubber agroforestry enhances ecosystem services and biodiversity.
- Forestry carbon trade has not been prioritized in China yet.
- China has a banking system that potentially benefits forestry carbon markets.
- Better forestry carbon measurement and monitoring should be carefully designed.

17.1 Introduction

Currently Southeast Asian countries are experiencing dramatic rates of deforestation and forest degradation largely due to commercial monoculture plantations, such as rubber (*Hevea brasiliensis*), palm oil, and eucalyptus. This transition leads to severe biodiversity losses and rising carbon dioxide emissions. Carbon trading schemes are expected to drive investments for the sequestration of carbon through reforestation, afforestation and maintenance of existing forests. Mechanisms such as the Reducing Emissions from Deforestation and forest Degradation (REDD+) are being negotiated with aims not only to mitigate climate change, but also to achieve supplementary benefits, e.g. biodiversity conservation in tropical forests. China is now the world’s largest carbon dioxide emitter and is currently piloting a domestic carbon market (http://www.forestry.gov.cn) and setting emission targets for five cities (Beijing, Tianjin, Shanghai, Chongqing and Shenzhen), and two provinces (Guangdong and Hubei). Given uncertainties in the global carbon market and declining prices due to the European economic crisis, the move to generate domestic demand for carbon credits will be a timely one.

The forestry carbon trades would not only help China against the climate change but also bring other ecosystem services along with reforestation and afforestation. China as a biggest carbon dioxide, is also suffering environmental degradation because of urgent economic development and corruption. However, China has also made a big effort on environmental improvements. To achieve a greener landscape, several reforestation and afforestation programs have been implemented since 1990s, e.g. Sloping Land Conversion Program (SLCP) (also known as Conversion of Cropland to Forests Program (CCFP), and Grain for Green program) and Natural Forest Protection Program (NFPP). SLCP in China is the world's largest afforestation-based payment for ecosystem services (PES) program, about 700 billion RMB (approximately 100 billion USD) has been invested in PES only over 1998-2010 through this program. Several studies have been argued that forest coverage significantly grew...
through these programs but biodiversity loss was permanent with only man-made tree monocultures, however, the regrowth man-made forests still provide enormous carbon sequestration and other ecosystem services in China. The program also has been argued of harming the smallholders, who is not part of this program. Develop a sustainable strategy to subsidize the smallholders, who joined the program, without harming others' benefit would be the essential. The domestic carbon market, which would be fully functional in 2016, has been considered as an alternative funding source for smallholders to practice afforestation and reforestation in China. In the end, these programs would reduce China's carbon emission that helps to fight again climate change and would also improve smallholders' livelihood through carbon trading schemes nationally.

17.2 The existing national PES transference system in China

Many studies have highlighted that the correlation between land tenure security and PES efficiency are long been neglected. The afforestation and reforestation carbon sequestration programs in Africa showed that without land property clearance, institutional and policy reform, the programs are doomed to fail. Even though Chinese smallholders only have the use right of their land property instead of ownership, the smallholders still own a certificate for their property. The certificate has clarified that smallholder has 70 years of use right for their forests and 50 years for the agricultural and residential area from 1980s since the first forest reform in China. The geographic location, the boundary and the land user are listed on the certificate. Forests are ranked for three levels in China, which are state-owned, collective and individual forests. In despite of border arguments, most of land in China especially the individual forests have been registered and legally titled to smallholders. A mature PES transference system has been established through SLCP for the past, in which smallholder who participated the program could withdraw the payments with their assigned bank account through Rural Credit Cooperative of China using the land property certificate. The payment comes amount from 150 USD to 330USD/ha without/with additional provincial and county level compensation on the top of central government payment from Beijing for the SLCP. A more comprehensive capacity building at different levels of governments, multi-sectorial monitoring, planning and evaluation have been built through the program, which will profoundly benefit carbon sequestration program against climate change nationally. In this chapter, we are using a case study to demonstrate if domestic carbon market could benefit biodiversity conservation in tropical China; and also to assess if carbon finance can be competitive with rubber profitability and to help decision-makers and policy-makers to find low opportunity cost areas in Xishuangbanna, SW China (Figure 17.1A) that might serve as economically viable areas for natural forest protection and reforestation.

17.3 Biodiversity loss through rubber monoculture expansion

Xishuangbanna (XB), one of few tropical regions in China, is located within the Indo-Burma biodiversity hotspot. While XB comprises only 0.2% of China's land area, it harbors nearly 16% of plant species, 21.7% of mammals, 36.2% of birds, 15% of amphibian and reptiles found in China. XB has been promoted as one of 32-biodiversity conservation priorities by the Ministry of Environment Protection emphasized in the 2011-2030 China Biodiversity Conservation Strategy and Action Plan. Its rich biodiversity also supports substantial cultural diversity. Geographically, XB connects two global biodiversity hotspots, the Mountains of Southwest China and Indo-Burma.
Rubber was first introduced to XB in the 1950s as state-owned rubber farms and did not occupy more than 1% of XB’s land area until 1976. Rubber is not a traditional plantation species in mainland South East Asia. Rubber cultivation on a commercial scale was initiated only in the 1980s. In only seven years, from 2003 to 2010, the proportion of XB’s land area covered by rubber plantations doubled, from 11% to 22% (Figure 17.1B), respectively. The converted areas were primarily natural tropical seasonal rain forests at altitudes below 800 m a.s.l, greatly reducing plant species richness and altering plant species composition patterns. Continued expansion of rubber plantations into higher elevation forest will destroy the remaining refuges of biodiversity in XB. Rubber has now been frequently planted at elevations up to 1400 m a.s.l, even though rubber tree growth and survivability above roughly 900 m a.s.l. is greatly reduced.

Across South East Asia, a similar trend of forest conversion into rubber plantations has been observed. Rubber plantations, already occupying more than one million hectares of land in the region are predicted to quadruple in area by the year 2050, causing substantial carbon emissions. In XB alone, almost 90 million tons of biomass carbon stocks were lost from 1976 to 2003 and current rates of deforestation would lead to a further 4 million tons of carbon emissions by 2023, along with significant loss of biodiversity. To maintain biodiversity and carbon stocks in this rapidly developing region, choosing the appropriate land-use policy is important to properly balance economic growth in relation to stated conservation goals.

Given strong and sustained industrial demand for natural rubber, continued expansion of rubber plantations should be expected. Currently, the central government provides unattractive and uncompetitive levels of eco-compensation for the maintenance of natural forest, so that conversion into monoculture rubber has been financially irresistible for both local smallholders and outside investors. While market-based incentives, like Clean Development Mechanism (CDM, under Kyoto Protocol) REDD+, are an attractive idea, if the probability of rubber plantations is substantially greater than benefits provided by these markets, then market-based incentives are doomed to fail.

17.4 Spatial economic returns from rubber monocultures

XB has been considered as one of two areas with tropical climate in China. Within China, XB is one of the richest regions both culturally and biologically. The population of approximately 1.1 million encompasses 13 distinct ethnic minorities whose traditional land-use systems play a crucial role in maintaining the regions outstanding biodiversity. Before 1980, the Dai (Tai
Lue) community who lived in the lowlands grew semi-aquatic rice and winter vegetables for local consumption. The Hani (Akha), Jinuo and Miao (Hmong) people have always lived at higher elevations than the Dai, mainly relying on shifting cultivation of upland rice and vegetables. All minorities herd livestock, hunt wildlife and collect wild vegetables and fruits from the forest. But now, a strong socio-economic shift in household income has occurred across all ethnic groups with rubber monoculture and terrace tea becoming increasingly important. A large-scale household survey (1000+ families) completed by the research team of World Agroforestry Center (ICRAF) East Asia office from February to April in 2011 showed that in the lowland areas, rubber now accounts for nearly 90% of household income in the central area of XB (unpublished data), with drinking water and food being bought from the local markets.

The economic returns of rubber monoculture in XB were mapped using Net present value based on spatially explicit modeling, for more detail modelling please see our peer-reviewed paper. For more details of the calculation please see our peer-reviewed paper. Spatially explicit rubber NPV maps at the 1km² scale (Figure 17.2).

![Figure 17.2 General rubber NPV (USD/ha) for Xishuangbanna. Rubber price calculated with 3.4USD/kg and a discount rate of 8% were applied to the rubber productivity map using Equation 1 to derive this NPV map](image)

According to our model, average productivity for XB’s rubber plantations is 521kg/ha yr⁻¹ while the highest-profit plantations, all situated below 900 m a.s.l. produce more than 1000kg/ha yr⁻¹. At elevations above 900m, rubber productivity can fall below 170kg/ha yr⁻¹ and plantations cease to be profitable as fixed costs of establishment and management exceed profits. With the established rubber plantations in 2010, there are about 98million USD could be generated over 25-year plating life span. We found that as elevation increases, the microclimate and physical environment become even more important to enable cost-effective production. The best microclimate for rubber tree growth and latex flow is a southeasterly aspect where sunshine is the most direct with high humidity and low temperature in the early morning.

17.5 Using land-use scenarios to detect carbon sequestration change

In this chapter we tried to untangle: 1) how forest protection policy would impact on carbon sequestration; 2) how can carbon trading would contribute to biodiversity conservation in tropical China; and 3) also how policy and decision-makers could be prepared for coming...
domestic carbon market in China. We simulate three land-use scenarios based on land-use map in 2010.

The land-use scenarios: an Economic Oriented Scenario (EOS, Figure 17.3, B), a Conservation Emphasis Scenario (COS, Figure 17.3, C) and a Business As Usual Scenario (BAU, Figure 17.3, A). BAU was based on current rates of rubber expansion from 2010 up to elevation of 1200 m a.s.l. If BAU represents the baseline over next 25 years, then COS was assumed to be BAU with additional enforced forest protection. Whilst EOS will be assumed to have no forest protection, e.g. all sites suitable for rubber plantations will be converted and the highest elevation will up to 1400m.

The BAU scenario was simulated based on the 2010 land-use map (Figure 17.3, A), using a 1% of rubber conversion rate from other land-use types on sites with are below 1200m and suitable for rubber growth over next 25 years. 1% of land use change rate was gained from average rubber plantation growth rate from land-use map of 1988 to 2010. Twenty-five years is the average rotation of smallholder rubber monoculture in XB. Under the BAU scenario, the local governments and communities will restrict the conversion of upland area to rubber plantation. In contrast, under EOS, the assumed goal of local governments and communities is to maximize economic profit over most other considerations. So under EOS there is no policy of forest protection allowing the expansion of rubber plantations up to elevations of 1400m on land-use type except the existing residential areas, nature reserves (as China has very strict law for protected areas) or land currently under rice paddy cultivation in consideration of regional food security requirements.

Policies relating to natural forest protection and biodiversity conservation would be fully implemented under COS (Figure 17.3, C). The Biodiversity Conservation Corridor as designed by the Asian Development Bank was included into our COS for future forest recovery. In addition, low-profit rubber plantations above 900m will be reforested. We analyzed the rubber NPV and carbon finance by elevation gradients from 500 to above 2000m using an interval of 100m. For more detail land-use scenarios and simulation rules, please see.

Carbon sequestration rates and above ground biomass values were derived for XB using the regional studies of, and we applied the mean average of these findings in this study. We use a linear regress to assess carbon and assume that the land uses in each scenario will achieve the level biomass (illustrated in Table 17.3) at the end of the 25-year period. The static carbon approach is appropriate in this case given the rubber NPV model is also static in nature.
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Figure 17.3 Land-use map of 2010 and the three land-use scenarios. Land-use scenarios are lined at first row, they are Business-as-usual scenario (BAU, A), Economic Oriented Scenario (EOS, B), and Conservation Oriented Scenario (COS, C) from left to right; Carbon sequestration maps at second row also follow the order, D is carbon stock map for BAU, E is the carbon stock map for EOS and F is the carbon stock for COS. The bottom two maps are land-use map (on the left) and carbon sequestration in 2010 (on the right).

Table 17.1 Carbon sequestration rates of each land-use class

<table>
<thead>
<tr>
<th>Land-use and land cover types</th>
<th>Above ground biomass carbon over 25yrs (ton/ha)</th>
<th>Above ground Carbon sequestration rate (ton/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice paddy field</td>
<td>5.4</td>
<td>0</td>
</tr>
<tr>
<td>Residential area and other land-use</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tea plantations</td>
<td>14.3</td>
<td>0.60</td>
</tr>
<tr>
<td>High-profit rubber plantations</td>
<td>61.5</td>
<td>2.50</td>
</tr>
<tr>
<td>Low-profit rubber plantations</td>
<td>15.3</td>
<td>0.61</td>
</tr>
<tr>
<td>Lowland rainforest</td>
<td>121.7</td>
<td>4.87</td>
</tr>
<tr>
<td>Mountainous rainforest</td>
<td>116.2</td>
<td>3.27</td>
</tr>
<tr>
<td>Ever-green broad leaved forest</td>
<td>105.2</td>
<td>4.21</td>
</tr>
</tbody>
</table>

We used these locally derived figures to calculate carbon price for possible carbon finance of REDD+ program in XB. All of our calculation and modeling were carried out using R and mapped using ArcGIS v.10.
Rubber plantations contain less biomass and sequester less carbon compared to natural forests\(^7,36\) and when these natural forests are converted into rubber plantations, considerable carbon stocks are released\(^40\). Carbon stocks are greatest at mid elevations and the projected amount of carbon sequestration differed substantially among the different land-use scenarios (Figure 17.3). Because more forest is maintained, the COS will sequester 11.2 million tons of above ground biomass, more than BAU (9.0 million tons) and considerably more than the EOS (only 7.1 million tons; Supplementary Table 2). Whether these differences in carbon sequestration among the scenarios will provide sufficient incentive for conserving the remaining natural forests in XB will depend on carbon market development or increases in the carbon price. If the carbon market is the only eco-compensation mechanism being considered, an extremely high carbon price (~20 USD/ton) is required for the total NPV of the COS model to equal that in the EOS model. But, this comparison does not include the many other benefits achieved by the COS, like biodiversity conservation, increased tourism value, and watershed protection.

Figure 17.4 Carbon sequestration along the elevation classes: orange is carbon sequestration (in tons) of BAU (Business-as-usual) scenario, and green is the carbon sequestration of COS (Conservation Emphasis Scenario), red color line is the carbon sequestration of EOS (Economic Oriented Scenario)

### 17.6 Carbon finance and biodiversity conservation

While the carbon market cannot directly compete with the profitability of rubber plantations in XB, rubber profitability varies considerably across the landscape and carbon prices might be sufficient to promote reforestation in specific parts of XB, particularly the marginal areas. By comparing the potential carbon revenues against the different opportunity costs at specific locations, we can evaluate potential effectiveness of the carbon trading scheme as an incentive for local reforestation, directing the financial resources obtained from the carbon market directly at achievable targets. With 10USD/ton of carbon price, we can conserve 59% of landmass in XB from rubber expansion under COS, and 24% under BAU; however, we can only protect 7% under EOS.
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**Figure 17.5** Potential carbon price (in USD/ton) for each elevation class under the three different scenarios. The numbers in the table below the column are the actual price for each scenario by evaluation class. BAU requires highest carbon price for reforestation in Xishuangbanna (see the table), COS requires lowest among the three land-use scenarios.

Lowland seasonal rain forest areas, with favorable humidity and temperature, have been considered the best location for rubber growing, while mid-elevation seasonal rainforest and montane rain forest were second best, followed by evergreen broadleaf forest. This classification system indicates a direct conflict between rubber plantation development and biodiversity conservation in Xishuangbanna.

According to our BAU results, areas outside protected areas would be unprofitable above 1200m, so under this scenario about 1000 species of seed plants can be protected inside the remaining natural forest; compared to 1300 species of seed plants under COS and only 760 species of seed plants under EOS. COS can thus protect 71% more of biodiversity amongst the three scenarios, but the conservation of large area of remaining natural forests can also support other ecosystem services.

Politically, the XB prefectural government and the rubber industry are under pressure from both national and provincial governments to address the environmental problems cause by rubber. Maximizing economic benefits in the short term should not be the policy objective. Indeed, a landscape dominated by one single crop will be dangerously vulnerable to market fluctuations and other climatic impacts. Therefore, in 2009, the “Leadership Group for Environment-friendly Rubber” (LGEFR) was established, followed by the approval of the “Green Rubber Management in Xishuangbanna” guidelines, which clearly require the design of market-based eco-compensation/payment schemes and rewards for ecosystem services.

While carbon-trading mechanisms, either domestic or international, are currently inadequate to capture the necessary financial reward to compensate local rubber farmers for the opportunity costs of limiting rubber monoculture expansion, an affordable initial focus for reforestation and carbon sequestration schemes would be on low-profit rubber plantations. However, to reach long-term sustainability of land-use and to maintain ecosystem services, other programs, e.g. intercropping on lowland rubber monoculture, environmental education, and community-based conservation, will be necessary. Otherwise with such a lucrative crop neither REDD+ nor Chinese national eco-compensation would be sufficient to replace rubber in farmers’ income. Macadamia, teak trees, indigenous tree species with higher value in timber market and tea etc. can be slowly introduced to upland farmer to replace the low-profit plantations instead of forcing them to reforest immediately. Ecotourism of culture and nature should be promoted in these areas to distract farmers from logging natural forest to further plant rubber trees.
17.7 The future of domestic carbon markets in China

China's current carbon finance is more concentrating on carbon credit trades among energy industries; forestry carbon trading schemes is not the main focuses. However, China green carbon fund has started forestry carbon trades in Zhejiang Province, e.g. Wenzhou, Lin'an, and Chengzhou and Guangxi province under Clear Development Mechanism (CDM). The CMD is one of carbon dioxide reduction mechanisms under the Kyoto Protocol. CDM has been ceased since the Kyoto Protocol could not reach an agreement internationally in 2012. With the incentives under CDM, China has mapped national carbon sequestration, which was led by Chinese Academy of Sciences and State Forestry Administration of China. The map could be the baseline of carbon trading in the future forestry carbon trades nationally.

Besides the market demand, the seller and buyers, the successful carbon trades would rely on many other factors, e.g. the baseline carbon storage map, institutional supports on measurement, management and monitoring the carbon sequestration, legal regulations, payment transference between the sellers and buyers and also supportive governments etc. However, the existing PES transference system under SLCP has already shed the light for future payment of carbon trading in China. If the buyer in SLCP is the central government and the smallholder farmers are the sellers, the existing transference system have just linked the buyers and sellers together through the bank of Chinese Rural Credit Cooperatives. Under the payment and transference system that smallholders could withdraw their compensation from SLCP using their bank account associate with land property certificate. Therefore, they could also gain the payments through the transference system by how much carbon sequestration they preserved in their forest.

The domestic carbon market, especially the forestry carbon trades, of China will hopefully encourage the reduction of carbon emissions in China whilst restoring the balance between protecting biodiversity, environmental protection and economic development. These markets may be especially important for regions like XB, with its rich and biodiverse tropical rain forests and few alternatives for generating revenue other than intensive land conversion into rubber. However, only bamboo carbon credit is available for promoting bamboo plantation in Xishuangbanna under panda standard, and has been traded, which misled the whole point of pushing forestry carbon trade for sustainable forestry management (http://www.cbex.cn/).

No matter which scenario is considered, a very high carbon price will be required to match rubber NPV at elevations below 900 meters because of high rubber profitability and even at higher elevations, a higher carbon price will obviously be required in the EOS compared to the COS for equal compensation to the farmer. The underlying message here is that the pursuit of greater economic development in the short-term occurs at the expense of irreplaceable and hard to recover natural resources, making future conservation work difficult and expensive. Ultimately, preventing forest conversion and enforcing forest protection now, e.g. under COS, would be more cost effective in the long run. Rubber agroforestry in some area of Asia have been a subset of forest biodiversity. Rubber agroforestry is a rather complex intercropping system compare to rubber monoculture. Rubber monoculture refers to the rubber plantations that only have rubber trees, and other plant species has been killed and get rids constantly by using herbicide and manual clearance. Rubber agroforestry sustains better ecosystem services and also bring more economic returns. But the labour requirement and knowledge gaps from rubber monoculture to rubber agroforestry are the main constrains for a greener cultivation system. It means rubber farmers only need to intensively take care rubber trees in rubber monoculture system, but need other knowledge and time inputs for rubber agroforestry. However, there are about 21 intercropping systems and more than 300 farms are practicing the intercropped rubber agroforestry by the rubber farmers without
authority supports like rubber monoculture in Thailand. Other than seeking a carbon trade platform, improving understanding of land-sharing and land sparing rubber cultivation will best serve biodiversity conservation and ecosystem services enhancement are urgently needed.

References