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A Nested Land Uses–Landscapes–Livelihoods Approach to Assess the Real Costs of Land-Use Transitions: Insights from Southeast Asia

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Abstract: Reducing emissions from deforestation and forest degradation (REDD+) is viewed as an effective way to mitigate climate change by compensating stewards of forested areas for minimizing forestland conversion and protecting forest services. Opportunity costs assess the cost of foregone opportunity when preserving the forest instead of investing in an alternative activity or resource use. This paper questions the calculation method of opportunity costs using averaged economic benefits and co-benefits of different land-use transitions. We propose a nested approach to land-use transitions at the interface between landscapes and livelihoods and assessing a wide range of potential socio-ecological costs and benefits. Combining household surveys and focus groups with participatory mapping, we applied the approach in villages of Laos, Vietnam and China positioned along a broad transition trajectory from subsistence shifting cultivation to intensive commercial agriculture. By looking beyond the economics of land use, we highlight important linkages between land-use changes and livelihood differentiation, vulnerability and inequalities. Our results show the importance of addressing the impacts of land-use transitions on a wide range of potential ecological and socioeconomic costs and benefits at multiple levels.

Keywords: opportunity costs; multi-level assessment; agrarian transition; REDD+; Southeast Asia

1. Introduction

The global mechanism for reducing emissions from deforestation and forest degradation and enhancement of forest carbon stocks (REDD+) is envisaged as a form of payment for ecosystem services (PES), whereby stewards of forested areas are paid to minimize forestland conversion and protect forest services, such as carbon storage and sequestration. The direct drivers of deforestation and forest degradation determine the opportunity costs of maintaining the forest. The opportunity costs of the land use replacing the forest largely determine whether local people will prefer REDD+

payments (in the form of cash or as non-cash benefits such as subsistence use values, environmental service values, and spiritual values) to forest conversion. Opportunity costs analysis aims at assessing whether the rent on forest carbon sequestration that would reach the actors of deforestation and forest degradation can offset the foregone land-use and livelihood opportunities due to conserving forest areas or leaving degraded forests to regenerate. The accurate estimation of the economic losses and foregone livelihood assets due to forest conservation is a very strategic issue and is necessary to 1) identify low cost strategies for reducing deforestation and forest degradation, and 2) provide fair compensation to forest users and managers [1,2]. Various approaches are being used and developed for estimating opportunity costs in relation to carbon sequestration and REDD+ [3–8]. These approaches can be gathered into two main categories according to their scale of significance and their potential contribution to actual REDD+ implementation: large-scale aggregated approaches and sub-national empirical approaches.

A first type of large-scale approaches was presented in the Stern Review of the Economics of Climate Change [9]. This approach combines average national returns per hectare of different land uses (e.g., annual food crops, oil palm and rubber, cattle pasture) with estimates of the areal extent of each land use at the national and international levels. From there, it assesses REDD+ opportunity costs as the net value of returns from land uses that would be prevented as a result of avoiding all deforestation and forest degradation. A second type of approach uses global estimates of forest extent, carbon densities and/or deforestation rates as well as aggregate economic variables (e.g., distribution of land values, profits generated from timber production, agriculture and pasture). Based on these values, it assesses the global potential for REDD+ in percent of reduced deforestation and emission reductions at different carbon prices [10]. While both approaches can be useful for producing large-scale estimates of forest conservation and carbon emission reductions at specific costs to the global economy, they provide limited information on the potential of and challenges for REDD+ implementation at the national level, for example, sub-national variability in agro-ecological potential, land rent and proximate drivers of deforestation and forest degradation.

Thus, at the national and sub-national levels, generic approaches have been developed integrating the actual extent of different land-use types (including forests) with the estimated carbon stocks, economic profits and co-benefits (e.g., water provision, biodiversity) associated with each land-use type [11–13]. On this basis, projections of opportunity costs, carbon emission reductions and benefit distribution are made under different scenarios of land-use change (e.g., 'business as usual', agrarian reform, shifting returns per hectare). In turn, these projections can provide guidance for managing trade-offs (e.g., food production vs. carbon sequestration vs. biodiversity) and targeting REDD+ initiatives at the sub-national level [5,14,15]. While the latter approach has become a core component of many feasibility studies for REDD+ projects implemented at the sub-national level [16], several researchers are voicing concerns regarding the fairly narrow economic perspective that is implied [5,17–19]. As argued by Ghazoul et al. [20], opportunity costs analysis should look "beyond the purely economic implications of REDD and consider less tangible but equally important political and socioeconomic issues relating to national and local development" [20] (p. 399).

Echoing this call for more comprehensive assessments, we take the above sub-national empirical approach a step further by integrating two additional levels of analysis: the landscape and the livelihood system. The costs and benefits of land-use and REDD+ transitions for short- and long-term livelihood perspectives and food security may indeed be very different depending on the scale of analysis (e.g., mosaic landscape versus individual plot). In smallholder agriculture contexts, the costs and benefits of land conversion may also be strongly related to variables like household labor availability, access to land and water, and cultural or traditional standards, most of which have no direct monetary value—only qualitative or scarcity values that vary from one household and/or individual to another [5]. A multi-level approach at the interface between landscapes and livelihoods as depicted in Figure 1 is thus necessary to assess, at different scales, this wide range of potential ecological and socio-political costs and benefits of land-use transitions.

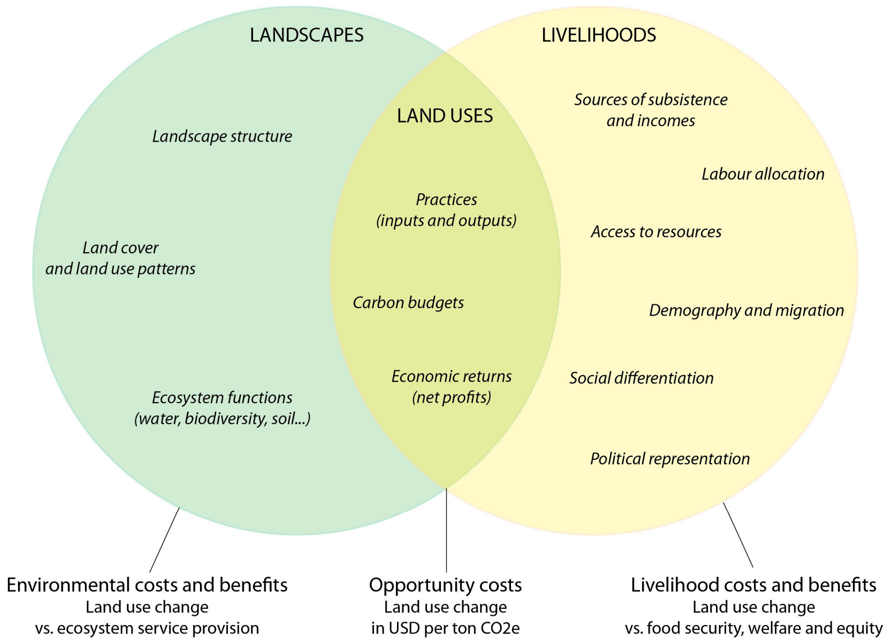


Figure 1. Nested approach to the opportunity costs of reducing emissions from deforestation and forest degradation and enhancement of forest carbon stocks (REDD+) transitions (the authors).

In this paper, we apply this framework with a comprehensive cost-benefit analysis framework as well as analysis of land uses, landscapes and livelihoods based on expert knowledge, systematic surveys and participatory exercises with local communities. We experimented with this hybrid approach to opportunity cost analysis in Laos, Vietnam and China, in two research sites per country (Figure 2) with the objective of illustrating the use of this approach across various landscapes and governance contexts. The next section provides a detailed overview of the field surveys conducted and the data processing methods and tools used for comparative analysis across sites. The following sections then present the main results of this experiment in terms of identifying recent land-use transitions across the target sites and assessing their opportunity costs and impacts on ecosystem services and local livelihoods. The paper concludes by a discussion of the implications of the latter costs and impacts for potential REDD+ initiatives in the study region.

2. Materials and Methods

We experimented the approach in three Asian countries in two communities each: one inside the park and one in the buffer zone of the Nam Et-Phou Loey National Protected Area in Huaphan Province, Laos; two in Xishuangbanna Prefecture in southwestern China; and two in Con Cuong District, Nghe An Province, near Pu Mat National Park in Vietnam (Figure 2). These sites were selected in areas where REDD+ (or, in the case of China, REDD+-like) programs were implemented or under consideration [21,22]. These landscapes also represent diverse situations in terms of forest-dependence of local populations and forest governance by local authorities (Appendix A).

Table 1 summarizes the different data collection and analysis steps employed to characterize the recent land-use transitions in the research sites. In each target village, a quantitative household survey was administered in 2012 to a random sample of 50 households (selected in local family registers), with questions covering various aspects of the household structure and economics, including family composition, labor force, productive and nonproductive assets, land tenure, plot location and land-use history, crop and livestock production and off- and non-farm activities. The household survey provided statistically representative data at the site-level that were used to triangulate the information collected with the qualitative data elicitation techniques. Focus group discussions were organized in all of the communities with groups of eight to 15 villagers of different ages, sex and social status. We specifically investigated socioeconomic differentiation patterns (household typologies and poverty indicators) and economics of land use (work calendar, labor force, production costs and income for past and current land use types). Groups of eight to 12 key informants were then engaged in participatory mapping of 2012 and 2000 land uses on a 3D model of the village [23,24], in order to characterize land use transitions over this key decade (Figure 3). We adjusted land-use maps with available high-resolution satellite images (RapidEye and Google Earth images from different years) so that areas of the different land uses could be assessed at the landscape level.

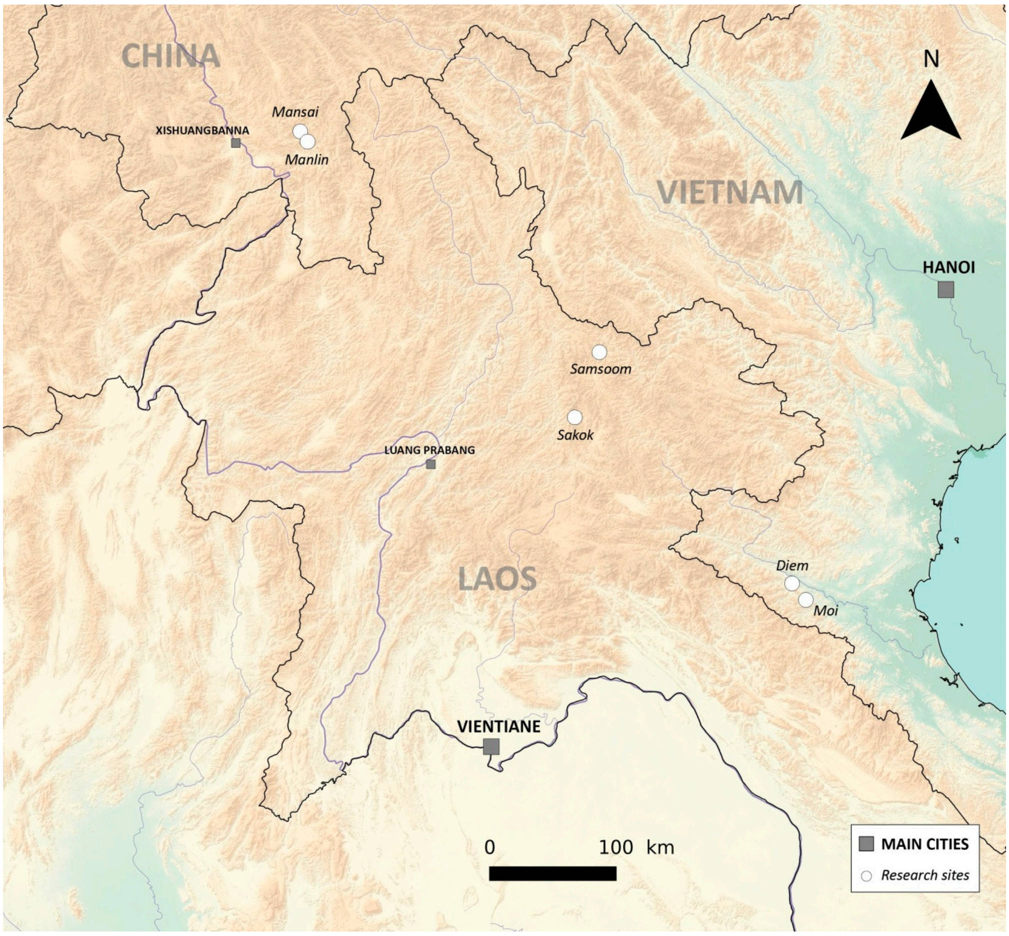


Figure 2. Location of the six villages chosen as research sites.

Table 1. Data collection and analysis related to land uses, landscapes and livelihoods.

Land uses	Landscapes—Livelihoods
Estimation of the opportunity costs associated with potential land use change (e.g., annual food crop to secondary forest, tree monoculture to agro-forestry) in three steps: 1. Characterization of land uses transitions and practices, inputs and outputs associated with each land-use type in target sites; 2. Assessment of the economic returns per land use type (i.e., expenses, revenues and net profits in US$ per ha); 3. Definition of appropriate time horizons and discount rates, estimation of the net present value (NPV) of the different land use types, and quantitative assessment of the opportunity costs associated with land-use transitions in US$ per ton of CO_2e (CO_2 equivalents).	The landscape-livelihood analysis is implemented in three steps: 1. 300 household surveyed, 50 randomly selected in each community, on current livelihood systems in target sites (village and household level information on e.g., livelihood activities, time and labour allocation, access to resources, demographic trends and socioeconomic differentiation); 2. Participatory mapping of land cover and land-use patterns in target sites in 2000 and 2012; 3. Landscape level carbon sequestration assessed by extrapolating carbon densities, in ton of CO_2e per ha, from land uses to the landscape level.

N.B.: In this study, the time-averaged carbon densities (in ton of CO_2e per ha) under different land uses are taken from the literature but they may as well be derived from actual field measurements as such data were collected in the framework of the I-REDD+ project [25].

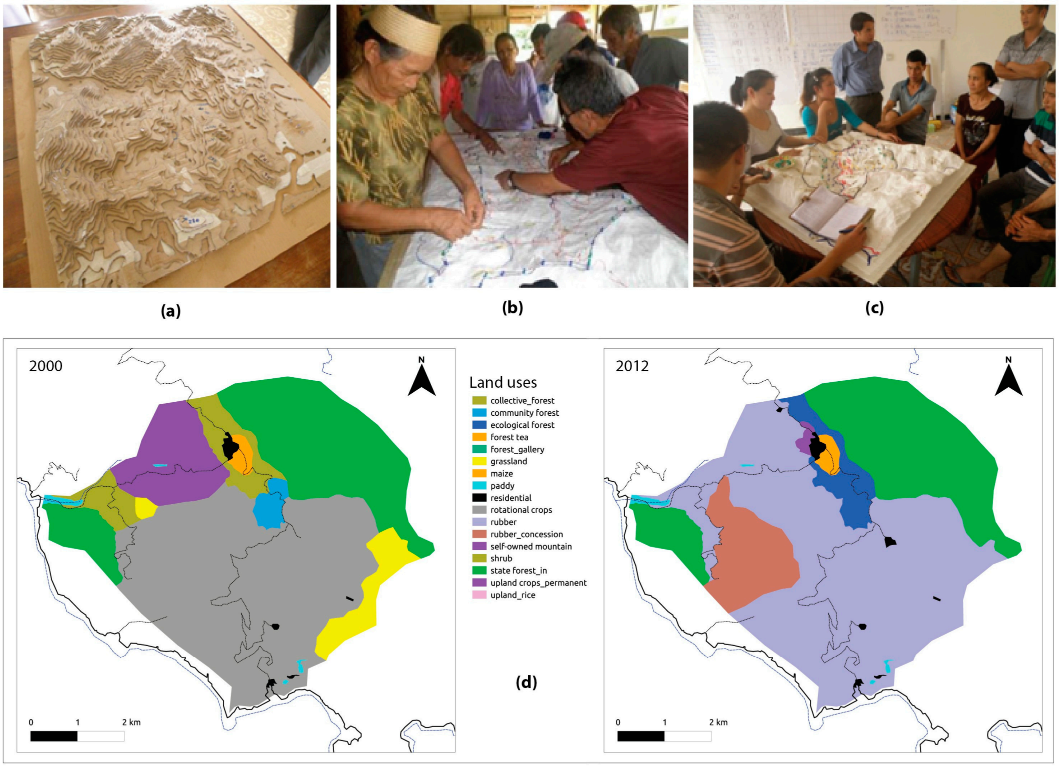


Figure 3. Participatory mapping using 3D models of the villages and land-use maps 2000 and 2012 in Manlin Village, China: (**a**) Construction of a 3D model; (**b**) delineation of land uses by villagers; (**c**) discussion on land use changes; (**d**) resulting participatory land use maps for 2000 and 2012.

Villagers identified major land-use categories: e.g., dense forest, secondary forest, plantation crops, shifting cultivation and arable land. We used the sketch maps as a visual aid and basis to delineate and discuss the changes of land-use categories that had occurred over the past 50 years. We obtained long-term land-use transition curves for all sites as reported in Müller et al. [21].

Once land-use transitions had been identified, we computed the opportunity costs associated with each land use transition (Table A1 in Appendix B). Most of the forest conversions driven by local people, such as shifting cultivation, are informal without taxes being paid to the government. Therefore, the total benefit from these land uses equals the benefit captured by local people. Although the per-hectare opportunity cost gives an indication of whether REDD+ would be preferred to forest conversion, it is reasonable to assume that opportunity costs will increase over time as land becomes increasingly scarce.

Household data collected from the 50 households surveyed in each study village were used to identify the four household types commonly found in shifting cultivation landscapes: A, B, C and D [26]. Each household type relies on similar land resources and/or shares similar land management strategies (e.g., shifting cultivators, livestock farmers, tree plantation manager, part-time farmers with off farm activities). The relative proportion of these household types within study villages were used to characterize different stages in the agrarian transition [26]. The household typology was also built upon wealth ranking criteria commonly used by local villagers. These criteria were formalized during separate focus group discussions with men and women. They pertained for example to the housing quality, family labor, social status in the village, assets (e.g., hand tractor, motorcycle, etc.), land tenure, indebtedness, capacity to pay for children education, etc. These criteria were incorporated into the survey questionnaires so that household classifications would reflect local contexts.

Data derived from the different sources and scales were combined to link land-use transitions with carbon stock variations (using carbon stock estimates, as available in the literature specific to the target sites) and local socioeconomic differentiation patterns. We used two main approaches:

(1) 'Conventional' values for opportunity costs were generated using REDD Abacus SP software [27]. These were calculated using matrices of land use transitions derived from participatory land use maps and the differences in net present value (NPV, in USD per ha) and time-averaged carbon densities (CO_2e per ha) for each land use change between 2000 and 2012 (Tables A1–A4 in Appendix B). Corresponding trade-offs and abatement cost curves were generated to characterize changes in land use systems, their impacts on economic returns and carbon sequestration, and the feasibility of a REDD+ intervention at a given carbon price.

(2) The differential impacts of land use transitions on local livelihoods were investigated by looking at how household types identified in each study village rely differently on land resources, to what extent household types have been shaped by past land-use transitions, and how they may evolve in the future. The percentage of village area under each specific land use and managed by the different household types was used as an indicator of the impact of land-use transitions on the local economy.

3. Results

3.1. Rapid Transitions, Similar Trajectories

Until the 1990s, the main land use in all study villages was shifting cultivation, practiced by subsistence farmers of different ethnic groups using similar resources and agroecological knowledge (Appendix A). Upland rice combined with cassava, taro, chili, eggplant, and vegetables for family consumption have been grown for centuries as part of long rotations, which included 12 to 15-year fallows. In China's Xishuangbanna region, like in Laos and Vietnam, villagers also engaged in animal husbandry, including cattle, pig and poultry, for subsistence. Wherever alluvial land could be terraced to grow lowland rice, farmers would intensify rice production in paddies. Agriculture was practiced within complex landscape mosaics characterized by decreasing land-use intensity with the distance to the settlement areas. The villages were embedded in a forest matrix and their boundaries were not clearly defined. Villagers relied to a large extent on non-timber forest products for their livelihoods and food security in case of bad harvests. The customary land tenure system (i.e., right of clearance or 'axe rights') temporarily allocated the land-use rights to the villagers who first cleared the forest, while forest resources were open-access.

In all study sites, the 2000-2010 decade constituted a period of rapid and wide-ranging changes in the structure of local landscapes. These changes, described for each country in more detail in the supplementary material (Appendix A), and also illustrated by Müller et al. [21], have been driven by two main forces: (i) land policies and tenure reforms in the 1990s and (ii) fast integration in the market economy in the 2000s. These drivers led to a rapid expansion of commercial agriculture, a competition with former subsistence agriculture and a gradual reduction, intensification or abandonment of traditional shifting cultivation practices. The process of land-use intensification, i.e., shortening of fallow periods and/or lengthening of cropping periods up to annual or permanent cropping has generally resulted in higher return to land and/or labor as revealed by the land-use transitions in Table A1 (Appendix B).

3.2. Impacts on Economic Returns and Carbon Sequestration

3.2.1. Carbon vs. Profitability Trade-Off Curves

The land-use transitions described in the previous section (see also the supplementary material) were analyzed in terms of their economic impacts, i.e., return to land and labor, and potential for carbon sequestration. As shown by the trade-off curves (Figure 4), most of the existing land-use systems in the study villages fall into "low carbon stock-high profits" and "low carbon stock-low profits" clusters. Protected forests are the only component of a "high carbon stock-low profits" cluster. The analysis of land-use changes over the 2000s decade reveals a general transition away from shifting cultivation systems towards land uses with higher profitability. A noticeable exception is the transition from rice swidden to acacia in Vietnam that can be explained by a national ban on swidden and public incentives to develop acacia plantations.

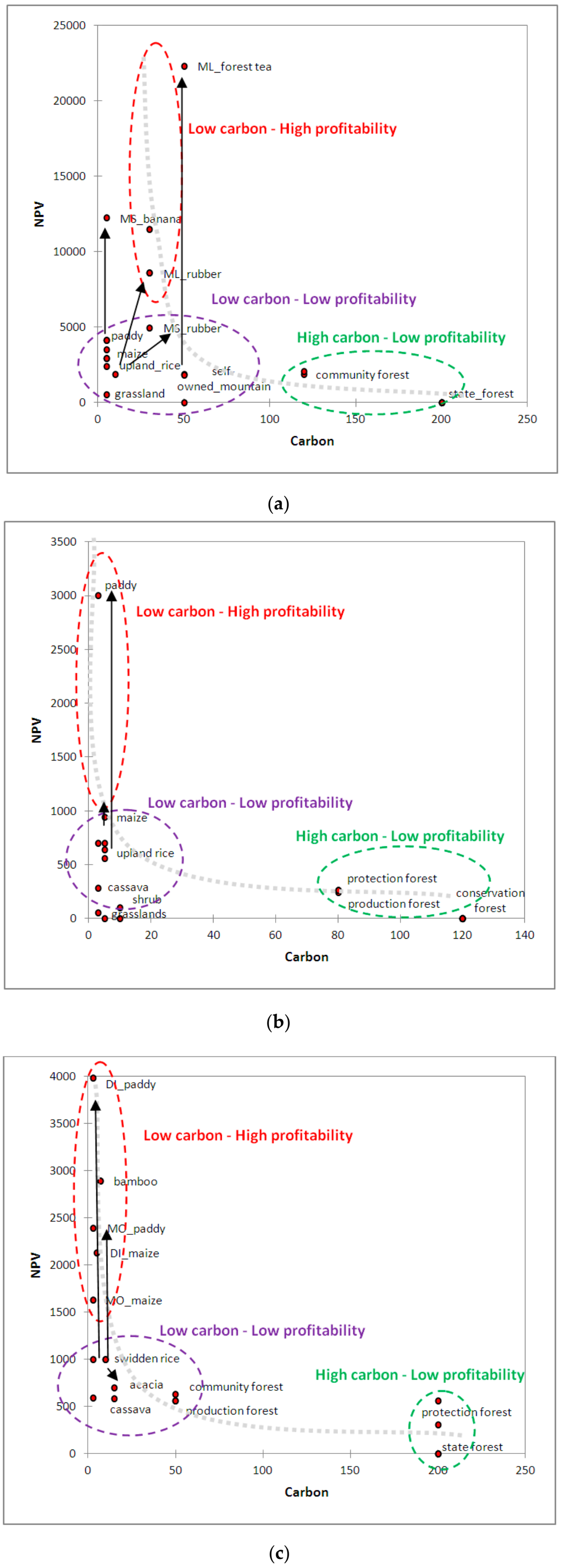


Figure 4. Trade-off curves of land-use systems in the three research sites: (**a**) China; (**b**) Laos; (**c**) Vietnam.

The comparison across the three study sites exemplifies the successive steps in a general process of agricultural intensification:

On the hillsides, the intensification process first takes the form of a shortening of the shifting cultivation cycle, then a conversion to cash crops (e.g., maize) with shortened fallow periods and finally annual cropping relying on the use of chemical inputs (i.e., herbicides, insecticides, fertilizers). The last stage consists in shifting from annual crops to tree plantations, either by incorporating tree species in the fallows towards complex agroforests (e.g., forest tea in China) or converting the fallows to monoculture tree plantations (e.g., rubber). Only the conversion from grasslands or permanent crops to agroforests or tree plantations leads to carbon sequestration. The conversion from swidden systems to agroforests and tree plantations are associated with carbon sequestration only in the case of short rotations of the initial land use and reconstitution of biomass and carbon stocks in the final land use [25].

In the valley bottoms, land use is also intensified through an increase in the number of crop cycles, i.e., from one rice crop to two cycles thanks to irrigation systems, or by adding one cycle of maize in the spring and winter crops such as watermelon. Then, the conversion to more intensive systems takes the form of 'industrial' banana plantations introduced by external investors in the case of China (Appendix A). All these changes are usually carbon neutral.

3.2.2. Abatement Cost Curves

The calculation of the foregone financial benefits for local populations, if carbon emitting land use transitions would have been avoided, provided an indication of avoidable emissions if a REDD+ project would have been in place during the last decade. Table 2 summarizes the results for the eight study sites. Village areas and population densities have been added to facilitate interpretation of the results.

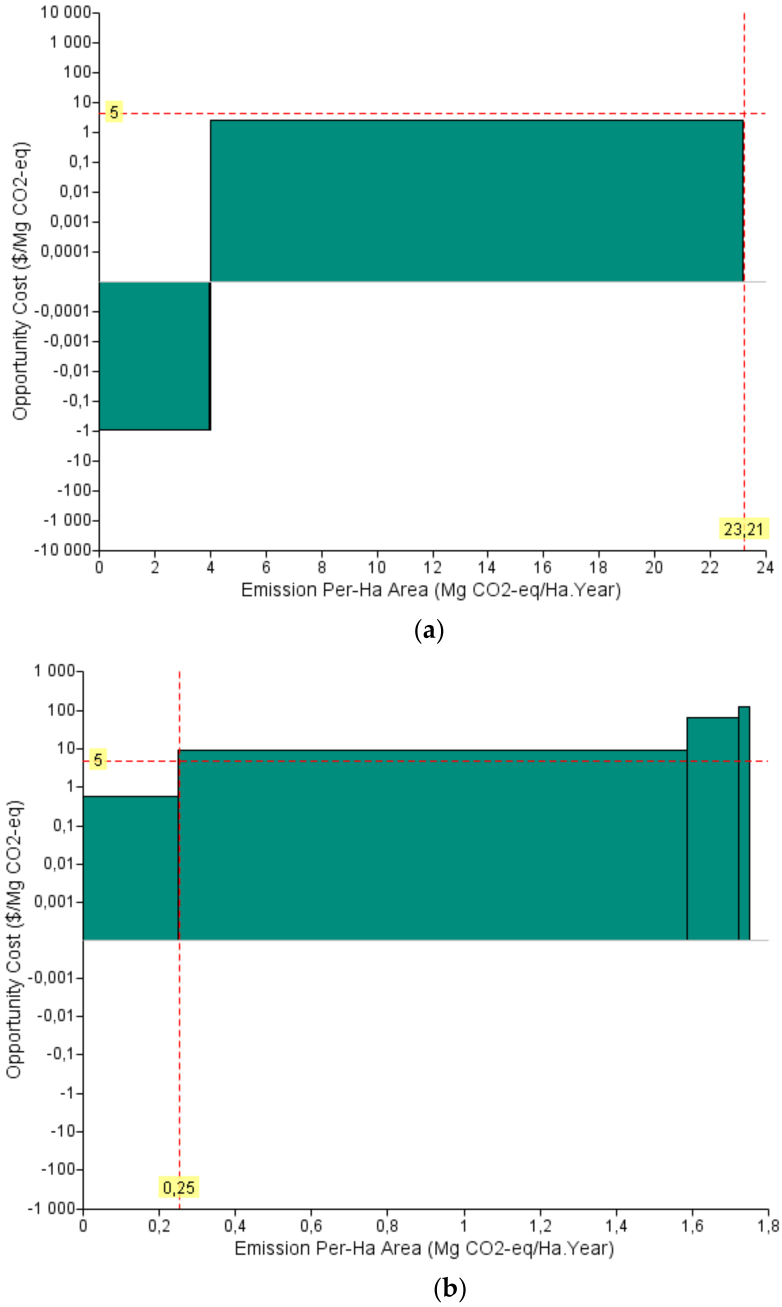
Table 2. Outputs of the REDD Abacus software for the six study sites over the period 2000–2012.

Country	Study Sites	Emissions per-Ha Area (Mg CO_2 /ha,year)	Sequestration per-ha area (Mg CO_2/ ha,year)	Cost-Benefit per-Ha Area ($/ha,year)	Emission (Mg CO_2 /year)	Sequestration (Mg CO_2 /year)	Cost-Benefit (x1000$/year)	Village Area (ha)	Population Density 2011 (inhab./sq.km)
China	Manlin	0	76	3 913	91	265 323	13 740	3 511	8.1
	Mansai	6	66	4 920	13 773	144 887	10 780	2 191	14.7
Laos	Sakok	0	153	−222	651	344 955	−500	2 252	14.3
	Samsoom	23	0	−143	160 615	147	−988	6 921	5.3
Vietnam	Diem	2	290	−395	4 700	779 325	−1 059	2 683	25.4
	Moi	113	21	−31	138 960	25 930	−38	1 231	57.8

These results confirm that recent land-use transitions in the two Chinese sites, Manlin and Mansai, were not associated with carbon emissions (except for limited areas of agricultural land that was converted to residential areas) and that the opportunity costs associated with massive expansion of rubber plantations are so high that they could not be compensated by carbon at the current market price (USD 5 per Mg CO_2-eq is used here as a conservative value to account for additional transaction costs).

As Sakok is located in the core zone of the Nam Et–Phou Loey National Protected Area (NEPL–NPA), the village has been under high pressure from local authorities to preserve its forests. Demarcation of the NPA combined with strict application of land policies prevented carbon emissions and allowed sequestration of approximately 153 Mg CO_2/ha/year. However, this remarkable result was achieved at the expense of local livelihoods as the cost of land conversion for the village population is estimated at 222 USD/ha/year. With less pressure to preserve forest, carbon emissions in Samsoom have been more important and related to the conversion of swidden to intensive maize cultivation. The abatement curve of Figure 5a shows that conversion could have been avoided if REDD+ compensation mechanisms would have been in place. The reduced benefit from land-use conversion observed in Samsoom is related to the abandonment of opium poppy cultivation since 2000. While the income loss was partly compensated by maize expansion, experience from other regions in

Laos shows that increasing poverty due to strict application of environmental regulations may revive poppy cultivation. Therefore, compensation mechanisms for lost income generation opportunities should be systematically explored with local communities [26].



(**a**)

(**b**)

Figure 5. Abatement cost curves 2000–2012 processed with the REDD Abacus [27]: (**a**) Samsoom village, Laos; (**b**) Diem village, Vietnam.

In Diem, restrictions on shifting cultivation imposed by the local authorities led to important carbon sequestration (290 Mg CO_2/ha/year) despite a high population density. This positive environmental impact is associated with negative consequences for livelihoods and high economic costs per ha (–395 USD/ha/year). At the carbon price of the 2010s, only limited additional carbon emission could be offset with the conversion of production forests to bamboo and acacia plantations (Figure 5b). In Moi, the allocation of 200 ha of the southern part of the village territory to the neighboring Pu Mat national park led to a reclassification by local villagers of the remaining part of their protected dense forest into production forest (219 ha). This conversion is associated with high carbon emission values in the REDD Abacus calculations that may not fully reflect the real status of the forest cover.

In summary, REDD+ may not have been an option in the Chinese sites as it could not compete with the high opportunity costs of conversion to rubber plantation. REDD+ may arrive too late to invert the mega-trends in land use changes in places where conversion to plantations is already taking place. In the case of Vietnam and, to a lesser extent than Laos, villagers have already been under significant government pressure to abandon shifting cultivation, preserve forests and intensify agriculture although these policies may have contradictory outcomes [28]. Thus, the room for maneuver is very limited in terms of additional carbon sequestration [25]. In such contexts, REDD+ projects provide limited additionality. They may also not be financially viable. With the high population densities encountered in Vietnam for instance, forestlands are often heavily degraded and their carbon value may not justify (i.e., cover the transaction costs) implementation of REDD+ mechanisms.

3.3. Impacts on Local Livelihoods

The four household types: A, B, C, D are consistent for the two villages in each country but are different between countries, which prevent from full comparison of a given type across countries. In general, the different types correspond to a gradient of capital accumulation from Type A farmers who are often the poorest in the village, food insecure, with very limited land and assets to Type D farmers who have accumulated enough land and capital to be considered as the better-off households [26]:

Type A households were identified as the once-dominant class of shifting cultivators (Laos, Vietnam) or, in places where shifting cultivation has disappeared, as households with limited access to land (China) who engage mainly in annual crops and seek additional income from NTFP collection or off-farm activities, i.e., daily laborer in other farmers' fields. Young families who did not inherit land from their parents usually belong to that type.

Type B households can reach food security thanks to access to paddy land, livestock breeding or other 'low investment' agricultural activity such as agroforestry.

Type C households have accumulated sufficient capital to engage in tree plantations. They are usually old settlers who have access to large tracts of upland fields that they plant in rubber (China) or bamboo and acacia (Vietnam). Their current income level may not reflect their livelihood quality as most plantations were still young in most study villages at the time of the surveys and the benefits do not yet cover the large investments they have made since the early 2000s. But their assets and land ownership are key criteria of classification for this household type besides their investment in tree plantation.

Type D households have reached a level of capital accumulation that allows them to diversity their activities outside the agricultural sector. They may invest in local trade or become entrepreneurs. They rely less on forestland for their livelihoods and most of their income come from off-farm activities.

As indicated above, we found large variations between countries. One of the main reasons is the existence of very different levels of integration into the market economy, which in turn determines local opportunities for off-farm activities. Another important factor of variation across research sites relates to population density and the impacts of land regulation. The Vietnamese sites for instance present population densities that are much higher than in other sites (Table 2) with important consequences for local livelihoods. Villagers' incomes in the study sites in Vietnam and Laos are below the international poverty line of 1.9 USD/day/person updated by the World Bank in 2015, while in the sites in China villagers have higher income despite development trajectories that came at the expense of the forest cover (Figure 6). Agricultural intensification is promoted in Vietnam and Laos to lift households out of poverty and farmers are eager to convert their upland fields to more lucrative tree plantations. Market access is the main constraint so far for these remote villages, close to national parks.

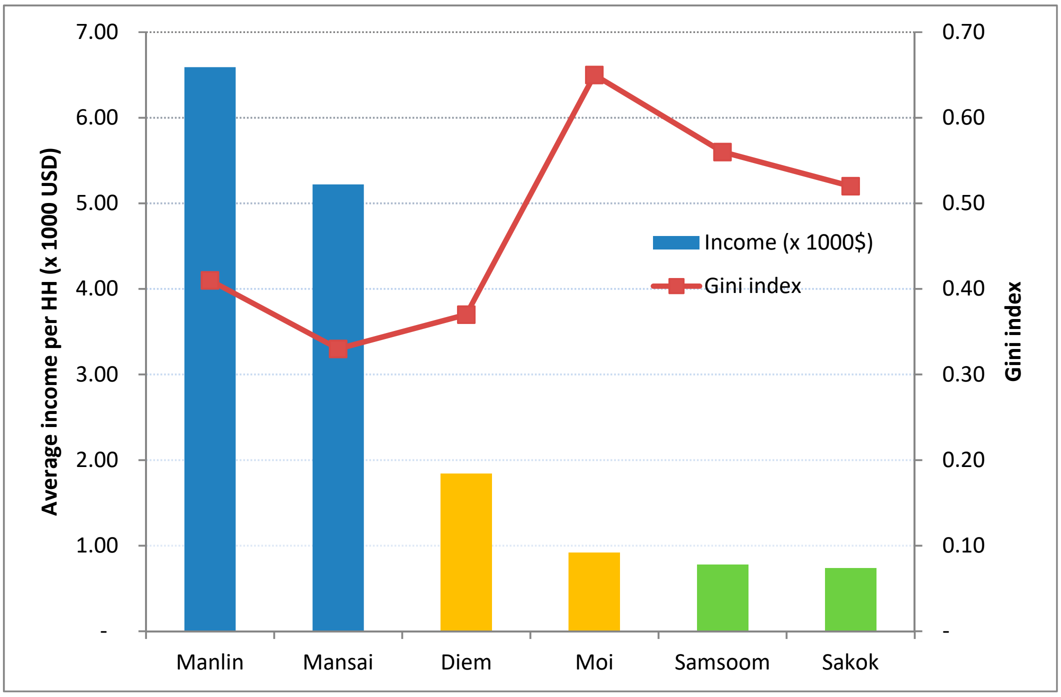


Figure 6. Average annual household income in study sites and Gini index.

When analyzing village-level income disparities among households, we found that economic development was associated with decreasing Gini coefficients (Figure 6). As the Gini index ranges from 0% (equal distribution of income) to 100% (total concentration of income), this means that agricultural intensification combined with access to off-farm activities tend to decrease income inequalities that are found in villages that rely on extensive shifting cultivation systems (e.g., Moi village). This counterintuitive result may be explained by a gradual change in household type composition within the villages: from a majority of subsistence farmers (i.e., balanced income distribution), to a coexistence of subsistence and market-oriented farming systems (i.e., income inequalities) and finally a majority of commercial farmers (i.e., balanced income distribution). While further analysis of a larger sample of villages would be needed to confirm these results, information collected through focus group discussion in the study villages tends to corroborate the idea that most households in the villages benefit from the new income opportunities.

However, the relative homogenization of household incomes can hide increasing social and economic disparities. In the Chinese research sites, for instance, most of the officially registered landowners have benefited from the rubber boom. Yet, rubber expansion is also associated with a very significant influx of migrant workers. The latter live in miserable conditions with no status or local registration and very low income. The worst-case land-use transition scenario appears to be in Vietnam where a significant reduction of the village territory, combined with strong environmental regulation, has seriously degraded local livelihoods. Farmers have lost access to about one third of their village territory due to the enlargement of national protected area combined with individual forestland allocation. Land-use intensity has suddenly increased as a reaction to the shrinking agricultural area. Compensation mechanisms provided by the government were not sufficient to cover the lost opportunities. In Laos, forest conservation policies are also associated with negative impacts on livelihoods [21,26].

4. Discussion

4.1. Closing Opportunity Windows for REDD+?

Our results show that REDD+ like payments would have a very limited influence on land-use transitions in the case of China where the village landscapes are already fully converted to perennial cash crops or in Laos where policy driven land-use restrictions have already played the role that would be assigned to a REDD+ project without adequate compensations to maintain livelihood standards of the forest dependent populations living in the vicinity of national parks. Consequently, there would be no additionality of a REDD+ project in such a location as has also been shown in a remote sensing-based study as well [29]. In the case of Vietnam and to some extent Laos, villagers have already been under significant pressure from the government to abandon shifting cultivation, preserve forests and intensify agriculture [30]. The government policies, already implemented in the 1990s and early 2000s combining individual land allocation and delineation of forest protected areas, also acted as a REDD+ activity, reducing the relevance of an additional REDD+ project that would rely on very limited carbon credits because of the low carbon content of the heavily degraded remaining forest [31].

In all sites, a REDD+ project would result in reduced village income that would be extremely difficult to compensate through the only use of carbon credits given the limited forest biomass involved in the Vietnam case, the high opportunity costs of alternative crops in China, the absence of additionality in the Laos and Vietnam cases where REDD+-like policies have already been implemented. In short, the windows of opportunity for REDD+ are closing very rapidly in the study areas [22,30]. Moreover, governance issues and high transaction costs in these locations [32] provide limited prospects for REDD+ even without considering opportunity costs.

4.2. Is REDD+ a Good Idea, yet Unworkable on the Ground?

REDD+ may arrive too late to invert the mega-trends in land use changes as described here and in other studies [21]. In other contexts, with low population densities, low opportunity costs of alternative crops, high deforestation risk of local agricultural and resource management practices (e.g., measured by baseline/reference levels), it may be possible to use REDD+ compensation mechanisms to promote the transition towards multifunctional landscapes. But only few places actually satisfy both criteria (i.e., low opportunity costs and high deforestation risk) as they rarely go together [33]. In addition, a certified REDD+ project would require one third of the area as a project and two thirds as reference, which would de facto exclude two third of potential REDD+ areas.

One way to resolve these issues has been to use jurisdictional approaches to REDD+ with results-based payments for reducing deforestation across an entire jurisdiction. This novel mechanism incorporates all components of REDD+ (i.e., carbon off-setting, social safeguards, etc.) at subnational level for accounting and implementation. However, jurisdictional approaches to REDD+ implementation are also entangled in high transaction costs related to recurring governance problems [28], tenure insecurity that leads to unclear benefit distribution mechanisms [32], and uncertain carbon markets and agreements. Taking into account expected co-benefits in terms of adaptive capacity to climate change (e.g., biodiversity, food security and poverty alleviation) would make the REDD+ equation even more complex. Reconciling multiple goals of REDD+ across local, national, and global priorities becomes challenging [33].

A key lesson from our study is that REDD+ feasibility assessment is much more than investigating potential offsetting of opportunity costs. Looking at opportunity costs only, REDD+ would be only feasible in very limited areas of Southeast Asia and would therefore have a very little impacts on climate change and on livelihoods. Adding the transaction costs, expected co-benefits and governance issues across scales, REDD+ becomes unmanageable. As pointed out by Arild Angelsen during the Carbon-Property Conference in Copenhagen in July 2014, we may ask too much from REDD+. The initially good idea of providing economic incentives to countries, which would commit to avoid tropical deforestation through a multi-level PES system based on selling carbon credits, has gradually expanded since it was launched in 2007 [34,35]. The same mechanism is expected to work at all scales below the initial national level and to address a much larger scope than just carbon sequestration for climate change mitigation, including multiple co-benefits and safeguards contributing to climate change adaptation, biodiversity conservation, land reform and several other important societal processes. Consequently, the REDD+ mechanism is often perceived by local stakeholders as just one more additional sustainable development effort [28,30], and although being increasingly complicated, REDD+ probably would never have materialized as far as it has without integrating these concerns.

REDD+ or other PES-like initiatives have already been implemented in China [36] and Vietnam [37] and they clearly rely on a combination of government policies applied as a top-down process and local adaptations. In the political context that prevails in Laos, Vietnam or China, there is little prospect for a bottom-up process or decentralized PES management schemes. However, contrasting REDD+ architectures may emerge from this diversity of local contexts. Laos still has high forest cover and low population density, meaning that the per capita payment is likely to be more substantial. Opportunity costs for local people are relatively low compared with the payments they could receive for carbon. However, these sites tend to have the most poorly defined tenure rights and fewer structures through which payments could be redistributed. In countries like China and Vietnam to a lesser extent, land-use planning and restricted access to some forest resources are key components of carbon stock regeneration strategies. In such cases, REDD+ funds could be used to compensate forest-dependent populations for restricted access to natural forest resources and reduced income-generation opportunities, and provide incentives for continuing forest conservation in the future. This is already happening in China, with compensation being delivered to people affected by the national logging ban [36]. It is possible that the REDD+ funds could be used to provide additional subsidies, or to strengthen local forestry bureaus' enforcement or other capacities.

5. Conclusions

Although this hybrid approach certainly has trade-offs in terms of data accuracy and reliability, it allows a rapid capture of contextual social-ecological information that is necessary to understand local practices, livelihood–landscape interactions and how they may be affected by specific land-use transitions. In practice, it can also contribute to empower local actors and engage them in the design of local REDD+ architectures from the outset of feasibility studies. Our results confirm the importance to address the impacts of land-use transitions on livelihoods at the local level [5]. A good understanding of household constraints and strategies is essential to design compensation mechanisms for lost opportunities that are adapted to the local development trajectories. By looking beyond the economics of land use at the plot level, we were able to highlight important linkages between current dynamics of land-use change and trajectories of socioeconomic differentiation.

However, the results also raise serious questions as to whether there is a real potential for REDD+ in rural southeast Asia. Documented additionality may be difficult to achieve in cases where environmental regulations were already in place before the REDD+ era with a strong impact on reducing deforestation despite the small compensations received by local communities. Moreover, forest degradation potentially accounts for much larger emissions in many of these areas than deforestation. As long as measurement of degradation is still too complex for national measurement, reporting and verification systems [22], REDD+ activities may not be relevant.

In China, like in other countries of the region, where commercial plantations expanded rapidly in recent years, the opportunity costs of rubber will be extremely difficult for REDD+ or other PES mechanisms to compete with on economic terms. It is doubtful that REDD+, as a financial mechanism, can counter forest conversion. Strong government intervention is necessary to prevent further deforestation. On the other hand, there is little prospect for communities to benefit and participate as will probably be required if an international REDD+ mechanism is finally agreed upon. Other compensation mechanisms for lost opportunities of local communities due to land and forest policies of the early 2000s may be developed to buffer adverse impacts on local livelihoods. Clear and transparent benefit-sharing mechanisms will be required to ensure that REDD+ projects do not harm the poorest households who rely the most on forest resources and have limited power.

It is thus essential to identify windows of opportunity—both in the temporal and spatial sense—where the REDD+ potential is high, for example in areas with low opportunity costs of current land uses, dense forests and low population, but high risk of future deforestation and forest degradation. This reiterates the findings of Pasgaard and Mertz [38], but such areas are rapidly disappearing in southeast Asia and the window of opportunity is, therefore, closing fast. Finally, if such opportunities are identified, there is a need for flexible local REDD+ architectures that adapt to highly variable local contexts and a mix of market incentives and command and control (law-regulation enforcement) will be needed alongside local participation.

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Appendix A. Main Land-Use Transitions in the Study Sites

Manlin and Mansai Villages in Xishuangbanna, China

During the 1990s, villagers were practicing shifting cultivation of upland rice (1 year cropping/7 to 8-year fallow) and maize (2 to 3-year cropping/3 to 4-year fallow), raising livestock (about 1500 heads of cattle and buffaloes in Manlin, 210 heads in Mansai) in the grasslands and collecting firewood and non-timber forest products (NTFPs) in community forests. One cycle of paddy rice per year was grown in both villages but the area was not sufficient to cover the rice consumption of the whole village. Ancient tea was grown in the high altitude forests but the market prices were so low that farmers used it mainly for their own consumption. Maize was used to feed the pigs, 50 heads per household on average. Horses were used to carry goods for sale outside the village.

Road construction in 1997 in Mansai village and in 2000 in Manlin village opened the area to the market and triggered major changes in the local land-use systems. This coincided with the first rubber plantations entering into production in the area and providing substantial benefit to the early adopters who were initially supported by a government project. In the following years, almost all villagers, attracted by the increasing prices (from 1.2USD/kg in 1998 to 4.5USD/kg in 2011) and perspectives of high economic return, planted rubber. Maize was grown the first three years as intercrop in the rubber plantations, but it gradually disappeared from the landscape as the plantations became older and saturated the whole landscape. Consequently, pigs have also almost completely disappeared, households raising 2 or 3 pigs only for consumption. As large livestock were damaging the young rubber plantations, villagers decided to sell their herds in the mid-2000s. In 2008 all large livestock had been sold. Grassland and shifting cultivation areas had been replaced by rubber plantations. The sudden increase in tea prices boosted the renewal and expansion of forest tea in high altitude areas that were not suitable to rubber. Most of the so-called 'self-owned mountain', allocated to individual households in 1983, and collective forests were turned into forest tea. And more recently, tea is also grown in forests designated as 'Ecological Forest', which is a government program that pays a small compensation for forest conservation to the villagers. Today, most villagers consider that ancient forest tea, ecological forests and self-owned mountain do not need to be considered differently. They are used the same way for tea production and firewood collection. The only difference for ecological forests is that timber extraction requires an official permission from the forestry department.

The rapid economic development of the area attracted outside investors. In 2003, the investors started to contact local authorities and villagers to rent land for planting rubber. Their plots are managed by migrant workers, often ethnic Hani people, who have few relations with the local population. Social relations have been transformed by this increasing reliance on hired labor to manage intensive cultivation systems. The influx of off-farm wage laborer from neighboring provinces is expected to increase in the coming years when most of the currently young rubber plantations will become productive. Local villagers have no idea of the total area rented to outsiders as the contracts are signed between individuals. In 2009–10, investors also started to rent lowland paddy fields to grow banana in Mansai village. About 27 ha of paddy land were rented out by Mansai villagers. Following the example of the investors, in 2010, some villagers started to plant banana on their own paddy land. They were supported by investors who provided technical training as a reward mechanism for people who facilitated their establishment there. Paddy land is now also rented out to investors to grow winter crops such as sweet corn, beans, watermelon, pumpkins, etc.

Sakok and Samsoom Villages in Laos

The study villages in Laos represent two stages in a process of agricultural intensification from traditional collective shifting cultivation in Samsoom to shortening of the fallow period due to relative land scarcity in Sakok. In Sakok, cropping systems are highly constrained by their location in the core zone of the NEPL–NPA. Before land-use planning and land allocation (LUPLA) in 2000, villagers in Sakok practiced shifting cultivation with 10-year fallows or more. Village population was low because of insecurity in the area (counter-revolutionary activities) that pushed many families to out-migrate from 1988 to 1998. The land allocation program implemented in 2000 considerably reduced the agricultural area of the village so as to increase forest protection in the core zone of the NEPL–NPA. This led to a shortening of the crop rotation cycle from 10 years to 3 years, which was not enough to maintain upland rice productivity. Villagers developed alternative strategies to secure their livelihood, such as using chemical inputs to maintain soil fertility on the slopes, intensifying their land use in the lowland by expanding terraced paddy areas, diversifying crop production by growing hybrid maize, diversifying income generating activities through NTFP collection for the market or off-farm activities.

People in Samsoom village rely on upland rice cultivation for their livelihoods as there is no paddy area in their village. Since the enforcement of the boundary of the NEPL–NPA in 2005, villagers have shortened their fallows from 10–15 years to 7–8 years. The swidden intensification process is delayed in Samsoom as compared to Sakok but it follows the same pattern. This trend has been actively promoted by the Lao government in an attempt to convert subsistence based agriculture to commercial agriculture.

Besides rice cultivation for household sufficiency, villagers raise large livestock through extensive management practices. Cattle and buffaloes are basically left roaming freely in the village territory most of the year. Their owner would just locate them once in a while (i.e., every week or two weeks) and make sure they do not get close to the swidden fields during the cropping season. But with the intensification of shifting cultivation systems, the grazing quality of the fallows has decreased and the livestock production system is under pressure. As a result, villagers in Sakok raise less livestock than they did before LUPLA. NTFPs, which were also mainly collected in the fallows, have also gradually decreased in the recent years.

In 2007, hybrid maize was introduced in Samsoom by a local trader (and exported to Vietnam). Since then, hybrid maize cultivation has expanded into former poppy cultivation areas (for opium), which had been the main source of cash income until it was eradicated by the government in the early 2000s. In 2009, Sakok villagers also began to convert some of their swidden to hybrid maize cultivation. Households who owned less than 3 plots started growing maize on their plot the year after upland rice and then maize every year as upland rice could not be grown anymore in the absence of fallow. The rapid expansion of hybrid maize in the study area is consistent with the government's promotion of commercial agriculture. Increased production costs in turn increase the economic vulnerability of farmers and land degradation due to increased erosion in upland cropping systems without fallow, and also increases their ecological vulnerability. To reduce the economic risks, some household diversify their production by growing traditional maize and tobacco into the hybrid maize cultivation areas. Traditional maize is used for household consumption and for feeding pig, while tobacco is for sale.

The main drivers of recent land-use changes include the establishment of the national protected area, policies towards the reduction of shifting cultivation, the eradication of poppy, and the implementation of LUPLA. In addition, the booming hybrid maize production led to the rapid conversion of upland swidden rice fields to hybrid maize cultivation.

Diem and Moi Villages in Vietnam

Diem and Moi villagers have stopped shifting cultivation after implementation of the forest land allocation (FLA) programme in 1999. Before that period, the main land use was shifting cultivation (7 to 8 years rotation) of upland rice, cassava and taros. Villagers also engaged in animal husbandry, including cattle, pig and poultry, for subsistence only. FLA was undertaken through land zoning and allocation of upland fields and secondary forestlands to villagers. By allocating land to individual households, the government hoped to restrict villagers' access to hillsides and forested areas and, thereby, put an end to shifting cultivation. Paddy land had been previously allocated to individual households. In Moi, each household received 200 square meters of paddy land in 1993. Since 2001, "green books" (temporary land-use titles) are progressively replaced by "red books" (permanent land use titles) for agriculture areas in both villages, and for forest land in Moi (not yet in Diem).

Land allocation has been accompanied by a ban on the clearing and burning of forest land. This forest protection policy deeply affected local livelihoods. In Moi, rice production does not cover the consumption needs anymore. On average, Moi households have to face 6- to 8-month rice shortages. As a result, crops like cassava and hybrid maize generally serve of substitutes for rice, not as feed for livestock. Villagers rely very strongly on government-subsidized rice (10–13 kg of rice per villager in 2012), a support that they have received since the land allocation was done in 1999. Compared to Diem, Moi has less opportunity for economic development due to poor road conditions and limited market access.

Plantations of bamboo and acacia trees have rapidly developed in Diem village since 2000s. Over the past decade, maize (hybrid variety) and cassava have become the main crops planted in rainfed areas while paddy rice is grown along to the river banks. According to the villagers, crops play a very important role for food security (mainly for consumption) and cattle (cows and buffaloes) represent the main source of cash incomes. Cattle are raised through a free roaming system in secondary forests and bush lands. Since 2006, off-farm activities have also rapidly developed. Off-farm job opportunities have in part been promoted by officials from the commune after advertising from entrepreneurs on job offers (e.g., garment, industrial plantations). Bamboo and acacia plantations have also developed in Moi village, but, contrary to Diem, these engage only a small share of the population (2 households for acacia and 5 households for bamboo). Limited road access and traffic result in very low incomes from bamboo and acacia plantations. Villagers do not have many cattle (1 per household in average) and concentrate generally on buffaloes. Forest products (mainly bamboo shoots, medicinal plants and timber) represent an important source of income for the villagers. Off-farm activities represent also a key source of cash incomes and about 50 villagers are working off-farm outside the village.

Beside the 1999 FLA program, the redefinition of the village boundaries has been an important driver of land-use change in Diem and Moi. Large tracts of land located in peripheral areas of Diem were redistributed to neighboring villages. In Moi, around 200 hectares of primary forest in the southern part of the village were classified as buffer zone for the Pu Mat National Park and put under the authority of the Con Cuong district forestry company. Thus, the village land was downsized from 1,230 to less than 1,000 hectares. The process was even more dramatic in Diem as village boundary redefinition led to a downsizing of the village territory from 2,680 to 1,550 hectares. In recent years, many villagers have engaged in bamboo and acacia plantation and have additional paddy land in order to make up for the lost agricultural opportunities.

Appendix B. Example of data Analysis and Calculation Methods in the Case of Diem Village (Vietnam); Data from All Other Sites were Analyzed the Same Way

Table A1. Economic calculations per land use type; based on focus group discussions and survey of 50 households.

Land uses	Average production (kg/ha/year)	Incomes (USD/ha/year)	Expenses (USD/ha/year)		Net incomes (USD/ha/year)
			Inputs	Labour (man.day)	
Paddy rice year 1	0	0	0	500	−1500
Paddy rice year 2-30	4000	1400	575	150	375
Maize (3 y crop - 2 y fallow)	2400	720	80	140	220
Cassava year 1	0	0	0	130	−390
Cassava year 2	0	0	0	70	−210
Cassava year 3-5	12500	625	0	100	325
Bamboo year 1	0	0	0	18	−54
Bamboo year 2-6	0	0	0	11	−33
Bamboo year 7-30	700	350	0	17	299
Acacia year 1	0	0	40	23	−109
Acacia year 2	0	0	4	5	−19
Acacia year 7	1100	550	0	21	487
Secondary forest	0	140	0	33	41
Protection forest	0	50	0	10	20
Land uses	**NPV (Discount rate 5%) USD/ha**	**Agricultural income (USD/ha)**	**NTFP income (USD/ha)**	**Labour force (man. day/ha/year)**	**Labour productivity (USD/man.day)**
Paddy rice	3979	825	0	150	5.3
Maize (3 y crop - 2 y fallow)	2127	492	0	84	4.55
Cassava	589	300	0	65	3.75
Secondary forest	630	0	225	41	4.25
Protection forest	307	0	50	10	5
Bamboo (cassava first 4 years)	4044	305	0	26	17.3
Acacia (cassava first 2 years)	1154	150	0	36	12.25
Livestock	**Average production (# sold/year)**	**Incomes (USD/year)**	**Expenses (VND/year)**		**Net incomes (USD/#/year)**
			Investment (USD)	**Labour (man.day)**	
Cows	0,5	250	0	2	240
Buffalos	0,2	120	0	2	110
Pigs	950	1900	1450	75	75

Table A2. Village area of the different land-use types; based on participatory mapping on 3D maps.

Land-Use Type	Land Use 2012 (ha)	Land Use 2000 (ha)	Change 2000-2012 (ha)
Protection forest	93	32	61
Production forest	1338	1764	0
Acacia	21	0	21
Bamboo	24	72	48
Grassland	0	0	0
Cassava	5	257	252
Paddy	25	22	3
Maize rotational	42	531	489
Settlement area	3	3	0
Total	1551	2681	874

Table A3. Land-use change matrix; based on participatory mapping on 3D maps for the years 2000 and 2012.

Diem	Bamboo	Bamboo + Acacia	Cassava	Cassava + Maize	Maize	Paddy	Production Forest	Protection Forest	Settlement	State Forest Out	Swidden	Total
Bamboo	24	16					33					72
Bamboo+Acacia		-										
Cassava			-									
Cassava+Maize		3	2	-			241			11		257
Maize					-							
Paddy						22						22
Production Forest		5			22		634	54		1050		1764
Protection Forest								32				32
Settlement									3			3
State Forest out										-		
Swidden					20	3	430	7		70	-	531
Total	24	24	2		42	25	1338	93	3	1131		2683

Table A4. Abatement cost curve obtained from REDD+ Abacus software.

Fields	Value
Emission Per-Ha Area (Mg CO_2-eq/Ha,Year)	1.75
Sequestration Per-Ha Area (Mg CO_2-eq/Ha,Year)	290.49
Emission Total (Mg CO_2-eq/Year)	4700.37
Sequestration Total (Mg CO_2-eq/Year)	779,325.40
Private - Total Cost-Benefit Per-Ha Area ($/Ha,Year)	−394.68
Private - Total Cost-Benefit ($/Year)	−1,058,867.10

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