Carbon Pools and Poverty Peaks in Lao PDR

Author(s): Cornelia Hett , Andreas Heinimann , Michael Epprecht , Peter Messerli , and Kaspar Hurni
Source: Mountain Research and Development, 32(4):390-399. 2012.
Published By: International Mountain Society
DOI: http://dx.doi.org/10.1659/MRD-JOURNAL-D-12-00065.1
URL: http://www.bioone.org/doi/full/10.1659/MRD-JOURNAL-D-12-00065.1

Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
www.mrd-journal.org

MountainDevelopment
Transformation knowledge

Carbon Pools and Poverty Peaks in Lao PDR

Spatial Data Inform Policy-making for REDD+ at the National Level

Cornelia Hett[1,2], Andreas Heinimann[1,2], Michael Epprecht[1,2], Peter Messerli[1], and Kaspar Hurni[1,2]*

** Corresponding author: cornelia.hett@cde.unibe.ch*

[1] Swiss National Centre of Competence in Research North–South, Centre for Development and Environment, Institute of Geography, University of Bern, Switzerland

[2] Swiss National Centre of Competence in Research North–South, c/o Ministry of Natural Resources and Environment, Prime Minister's Office Compound, Lanexang Avenue, Vientiane, Lao PDR

Reducing Emissions from Deforestation and forest Degradation and enhancing forest carbon stocks in developing countries (REDD+) is heavily promoted in Laos. REDD+ is often perceived as an opportunity to jointly address climate change and poverty and, therefore, could come timely for Laos to combine its prominent national target of poverty eradication with global climate mitigation efforts. Countrywide planning of the right approaches to REDD+ combined with poverty alleviation requires knowledge of the spatial combination of poverty and carbon stocks at the national level. This study combined spatial information on carbon stored in vegetation and on poverty and created carbon-poverty typologies for the whole country at the village level. We found that 11% of the villages of Laos have high to very high average village-level carbon stock densities and a predominantly poor population. These villages cover 20% of the territory and are characterized by low population density. Shifting cultivation areas in the northwestern parts of the country have a higher carbon mitigation potential than areas in the central and eastern highlands due to a more favorable climate. Finally, we found that in Laos the majority (58%) of poor people live in areas with low carbon stock densities without major potential to store carbon. Accordingly, REDD+ cannot be considered a core instrument for poverty alleviation. The carbon-poverty typologies presented here provide answers to basic questions related to planning and managing of REDD+. They could serve as a starting point for the design of systems to monitor both socioeconomic and environmental development at the national level.

Keywords: *Carbon stocks; REDD+; poverty alleviation; cobenefit; Lao PDR; spatial analysis; shifting cultivation.*

Peer-reviewed: *August 2012* **Accepted:** *September 2012*

REDD+: a green opportunity for poverty reduction?

Reducing Emissions from Deforestation and forest Degradation and enhancing forest carbon stocks in developing countries (REDD+) is a global initiative likely to become an important building block for a post-2012 climate regime. The aim of REDD+ is to mitigate worldwide the severity of climate change. Its approach is twofold: it prevents the destruction of forests and thus the further release of carbon dioxide (CO_2) into the atmosphere, and it raises the quality of existing forests to enable the storage of more carbon in their vegetation per hectare and hence the abstraction of CO_2 from the atmosphere. The details of a REDD+ agreement are not yet formally agreed on. Nevertheless, it is regarded as one of the least expensive and most immediate ways to reduce the rate of increase of CO_2 in the atmosphere (Baker et al 2010). The highest gains can be achieved by focusing on tropical forest areas because they are the best carbon sinks and can take up and store the highest quantities of carbon (Stephens et al 2007; Luyssaert et al 2008). Tropical forests contain nearly one fourth of the carbon in the terrestrial biosphere (Parker et al 2008). At the same time, deforestation and forest degradation rank second among the human-induced sources of greenhouse gas emissions, just after the burning of fossil fuels (van der Werf et al 2009).

Although the primary aim of REDD+ is climate change mitigation, it was recognized in 2007 in the Bali Action Plan that REDD+ should reach beyond this target and deliver "cobenefits" by complementing the aims and objectives of other relevant international conventions and agreements (UNFCCC 2007). Besides environmental cobenefits and improvement of forest governance, social cobenefits associated with pro-poor development are most prominent (Brown et al 2007). A major debate has arisen as to how to design REDD+ so that it safeguards and, ideally, enhances the welfare of poor people (Peskett et al 2008).

Forest change and poverty are closely related. Rural people often rely heavily on forest resources as a basis for their livelihoods, both for direct use for food and fiber, and to generate income (Vedeld et al 2007). In areas where natural forests exist and thus the highest carbon

stocks dominate the landscape, the incidence of poverty often peaks (Sunderlin et al 2008). Remote forest areas, particularly in mountainous regions, are often characterized by low market access, poor infrastructure, and scarcity of options for agricultural production, and have thus been called poverty traps (Price et al 2011). Overuse of forest resources driven by poverty is seen as a major cause of deforestation and forest degradation. However, externally driven destruction and degradation of forests often create more poverty in local communities (Sunderlin et al 2003).

Reducing poverty is the primary development goal of many tropical countries today. At the same time, the reduction of deforestation and forest degradation, and the reduction of poverty rank highly on the international agenda, and it has been realized that both these goals are essential for sustainable development, particularly in mountainous regions (UN 2012). Through REDD+, attempts are undertaken to link these goals. As the linkages between deforestation, development, and poverty are complex, there is a need to address ecological and socioeconomic problems jointly. However, to date it seems that only a small percentage of the research on mountains has sought to explore comprehensively the interaction of social and ecological systems (Björnsen Gurung et al 2012). This is particularly true for mountainous regions in developing countries.

In Lao PDR, which serves as a case study for this article, most of the territory is mountainous. For the national government of this developing country in Southeast Asia, preserving the natural resource base while alleviating poverty is of top priority (Bourgoin and Castella 2011). REDD+ could offer both a high potential and high risks for poor people in Lao PDR. It could be a mechanism for diversifying incomes in areas with low agricultural potential and lack of market access; rewarding carbon sequestration services has the advantage that the output does not need to be transported (Campbell 2009). Conversely, if REDD+ is not effectively implemented, new risks for poor people could arise, such as loss of access to forests (Peskett et al 2008).

REDD+ is likely to involve national-level approaches. Financing will be supplied by developed countries in return for the performance of national-level progress from developing countries to reduce deforestation and degradation (Angelsen et al 2009). One major knowledge gap at the national level is about how the potential for REDD+ relates to poverty. Today policymakers are forced to make decisions on how to implement REDD+ and define national priority areas, whereas key questions remain unanswered. These include the following: Where are the highest carbon densities? Are they found in areas where people are predominantly poor? How do mountainous areas perform in terms of carbon stock conservation and enhancement compared with the lowland areas? How many people live in carbon-rich landscapes and would be potential beneficiaries of a REDD+ scheme? And how many of the people living in these areas are poor?

Research is expected to provide basic, policy-relevant knowledge to help REDD+ reconcile these human and environmental considerations, but it faces major challenges in this respect. One key challenge is that the necessary environmental and socioeconomic data often do not exist, let alone in a consistent form over time (Baker et al 2010; Björnsen Gurung et al 2012). In this article, we propose a new combination of spatial information on the status of carbon stored in vegetation and of poverty at the national level. Lao PDR, a target country for REDD+ in Southeast Asia, serves to demonstrate how these data can provide answers to basic questions for planning and managing REDD+. We hope to contribute a first step toward an effective achievement of the synergetic goals of climate mitigation and poverty alleviation by providing important base information for policy-making on REDD+ and discussing what this could mean for different parts of the country, particularly the mountainous areas.

Lao PDR: REDD+ jewel of the Mekong

Lao PDR is often described as "the green jewel of the Mekong," a reference to Southeast Asia's most pristine environment. Forests are a dominant landscape element in Lao PDR (Hett et al 2011), but significant deforestation and forest degradation have taken place during the past decades. In a quest to catch up with its economically more developed neighbors, Thailand, China, and Vietnam, Lao PDR loses forests of an area equivalent to approximately 70,000 soccer fields per year (World Bank 2007). Forests are an important part of traditional agricultural systems, including both shifting cultivation and permanent agriculture. They are crucial for local people's livelihoods through the provision of wood and a wide range of non-timber forest products (Foppes and Ketphanh 2004).

Although the most important causes of deforestation are intensification of agricultural systems, transformation of natural forest land into industrial farming, and clear-cutting for earth metal mining or hydropower development, forest degradation is often blamed on the livelihood activities of these smallholder systems (Thomas et al 2009). Lao PDR has a predominantly rural society in which most of the population depends on agriculture (Messerli et al 2009). Most parts of Lao PDR (75%) are mountainous with steep slopes and limited flat areas in the valley bottoms. Permanent agriculture is limited to these flat areas. As shown in Figure 1, the predominant hilly terrain, particularly in the northern uplands, is used for shifting cultivation (Thongmanivong and Fujita 2006). Shifting cultivation remains a widespread agricultural practice in the uplands of Lao PDR (Hurni et al 2012).

FIGURE 1 A typical mountainous landscape of northern Laos where people live mainly in small villages and lead a rural life based on subsistence farming through shifting cultivation. (Photo by Cornelia Hett, 2010)

Lao PDR is one of the poorest countries in Southeast Asia. With a national poverty rate estimated at 34.7% in 2005 (Messerli et al 2008), it relies heavily on donor assistance. One of the key goals of the national government is to achieve the first Millennium Development Goal, namely to halve the number of poor people in the population between 1990 and 2015. The government thus places a high priority on reducing poverty and is keen to use every available instrument, including REDD+, to advance this goal.

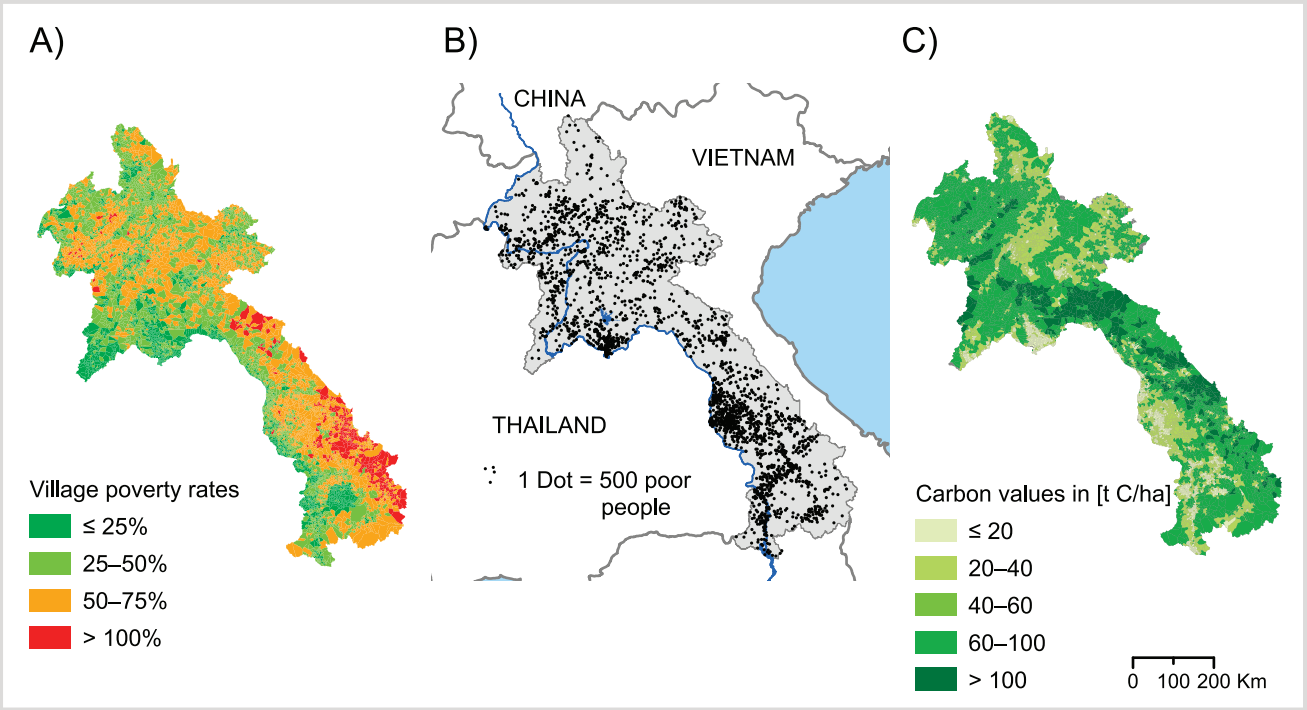
Methods

As a starting point for the spatial analysis, we used official national-level data provided by the Lao government. Using official data facilitates the acceptance of the results of the study by Lao officials and policymakers. We chose the national level for our assessment to match the scale of our analysis with most relevant decision-making processes in the field of REDD+ in Lao PDR at this time. We used spatial data on population presented in the *Socio-economic Atlas of the Lao PDR* (Messerli et al 2008) that were derived from the 2005 Lao Population and Housing Census, along with poverty estimates generated by combining household-level information from the Lao Population and Housing Census of 2005 and the Lao Expenditure and Consumption Survey of 2003 (Epprecht et al 2008). In our analysis, we used the following data:

1. Poverty rate (see Figure 2A). This measures the percentage of a given population that lives below the poverty line. The poverty line in turn corresponds to the per capita expenditure required to purchase 2100 kilocalories per person per day by using both the food basket of households of the third quintile and a nonfood allowance equal to what these households spend on nonfood items (Epprecht et al 2008).
2. Absolute number of poor people. This enumerates the spatial distribution of the absolute number of people in a given area that live below the poverty line (Epprecht et al 2008). The distribution of poor people in Lao PDR is shown in Figure 2B.
3. Carbon stock densities for the entire Lao territory. These data were created in a previous study by the authors (Hett et al 2011). The data were based on the official Lao national land cover map and approximate the amount and spatial distribution of carbon stored in vegetation measured per hectare of land.

To relate the carbon stored in the vegetation of Lao landscapes to the country's poverty situation, a common basic spatial unit or geometry was required for all the data

FIGURE 2 Overview of base data for the analysis. (A) Poverty rates at the village level; (B) poverty density, the number of poor people in a village; (C) village carbon values. This measure describes the average amount of carbon stored on one hectare of land in a given village in tC/ha. (Map by authors)



sets. Given that geographic targeting is most effective when the geographic units are quite small, the village level seemed ideal: it is the smallest official administrative unit and thus renders the highest spatial resolution for analysis. As official village boundaries do not yet exist in Lao PDR, we used village polygons that were calculated by using a concept of equal travel time between the 2 closest village centers (Epprecht et al 2008). These village polygons were used to calculate carbon values at the village level, which we refer to as village carbon values. This measure describes the average amount of carbon stored on one hectare of land in a given village (tC/ha). The map in Figure 2C depicts these village carbon values. The carbon values at village level could then be related to the socioeconomic information at that level.

By bringing together data on where poverty is most prevalent and where different quantities of carbon are stored, we have created a new typology of areas, such as "high poverty/high carbon stock" versus "high poverty/low carbon stock." In this way, the Lao territory can be divided into different categories for REDD+ actions, creating an overview of how poverty and carbon coexist.

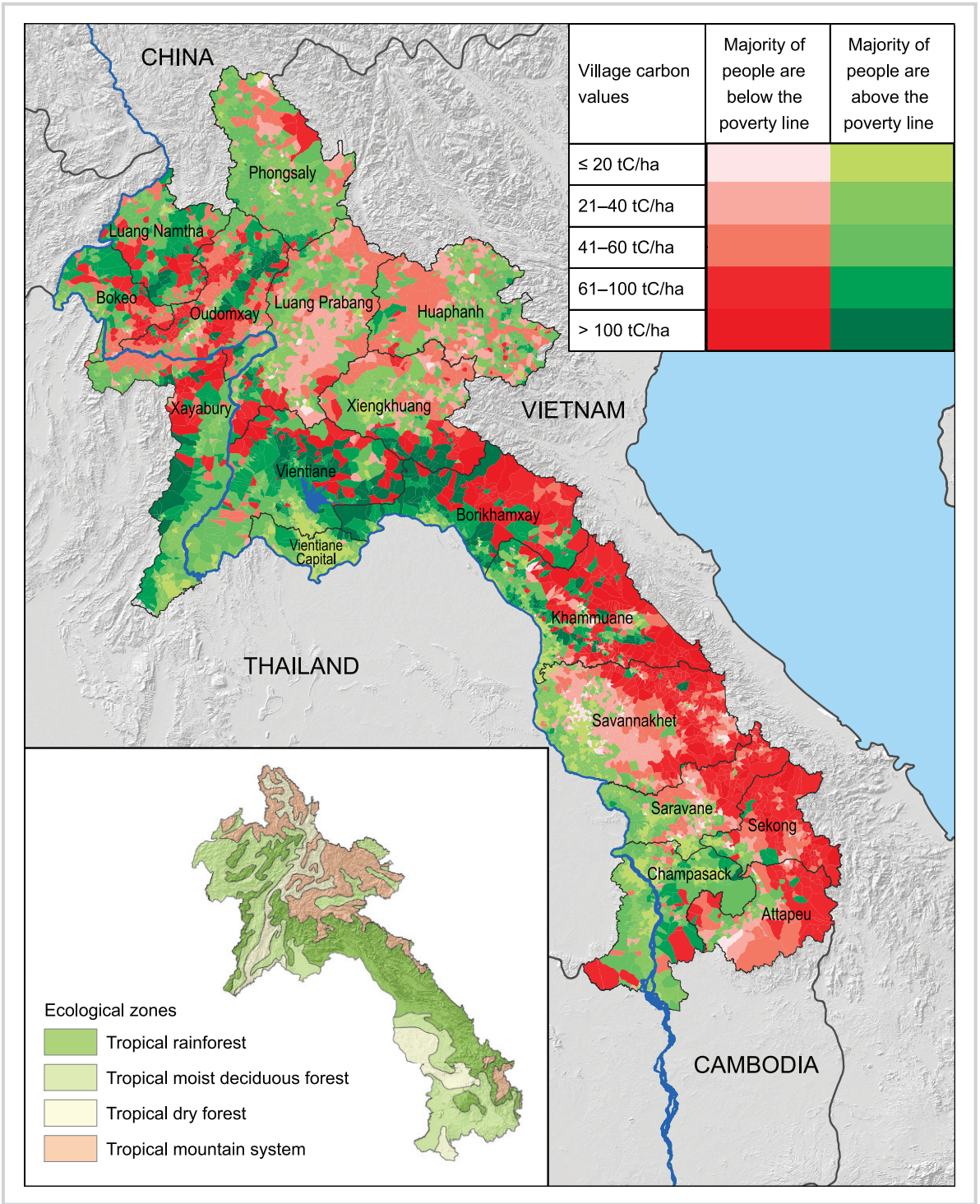
Results: A need for differentiated REDD+ approaches

The spatial combination or overlay of poverty rates and village carbon values is presented in Figure 3. We distinguished between villages where the majority of the population lives below the poverty line (red) and villages where the majority lives above the poverty line (green). The different shadings within each color show a gradient from low to high village carbon values.

Pro-poor REDD+ and no-harm REDD+ approaches

The combination of high and very high village carbon values with high poverty rates (bright red in Figure 3) is what we commonly expect; results of previous studies have shown that, in many tropical countries, there is a positive correlation between high natural forest cover, a proxy for high carbon values, and high poverty rates (Sunderlin et al 2008). In Lao PDR, this combination applies to 1052 villages, only 11% of all villages. However, these villages have large territories, altogether covering 20% of the territory, and are characterized by low population density. These "high poverty/high to very high carbon stock density" villages are predominantly found in the mountainous areas of northwestern Lao PDR and in the Annamite mountain range along the border with Vietnam and reaching down to the southeastern part of Lao PDR. These areas may well be poverty traps because they are remote and the local population has limited access to services and markets (Price et al 2011). The hopes for REDD+ as a new mechanism to tackle poverty alleviation here are high, because other funding opportunities for socioeconomic development are limited. The "high poverty/high carbon stock" villages

FIGURE 3 Spatial overlay of village carbon values and poverty rates. (Map by authors)



require a "pro-poor" REDD+ scheme, which actively seeks to deliver benefits to the poor, such as increasing income and growth potential for the region through forest preservation.

In contrast to the intensely red areas of Figure 3 discussed above, there are quite a few villages where carbon values are high to very high and the majority of the population is above the poverty line. These villages

are depicted in dark green in Figure 3. They are found mostly in the central parts of Lao PDR to the north and east of the capital, Vientiane. Where forests are carbon rich and intact, and the majority of the people are above the poverty line, the overall direct dependence of the population on forest goods seems limited. Hence, these villages seem to be the easy options for the implementation of REDD+. Here, the main focus need not be on poverty alleviation; instead a "no-harm" REDD+ scheme, which aims to avoid increased threats to the people in the area, could be sufficient.

Factoring in climatic conditions and land use

Both climatic conditions and land use influence how much carbon is stored in the landscape and, therefore, influence the carbon values at the village level. In hot and moist areas, as are found in the lowlands of Lao PDR in the tropical rainforest zone (see Figure 3), greater amounts of carbon can be taken up by vegetation than in the tropical moist deciduous, dry, and mountain zones where the potential to take up carbon is lower due to constraints imposed by temperature and rainfall. In the tropical mountain zone, yearly carbon accumulation rates in vegetation are nearly 3 times lower than in the lowlands (Hett et al 2011). The climatic constraints on carbon are reflected in the main map in Figure 3: the northeastern and central northern regions of Lao PDR that belong to the tropical mountainous zone are generally less favorable for carbon stock accumulation in vegetation. For any REDD+ scheme, these regions lose out compared with the tropical lowlands or areas in the northwest of the country dominated by a tropical moist climate, which permits more carbon uptake and storage in the vegetation.

Besides the climate effects mentioned above, village carbon values are also influenced by land use. They are generally lower where the areal share of natural forest within a village is low and intensity of land use is high. Medium carbon values can indicate that, in a village, there are still considerable shares of natural forested areas with high carbon stock densities combined with other types of land cover of low carbon stock densities, for example, permanent agriculture. In areas where permanent agriculture dominates and there are almost no forest patches left, the village carbon values are low to very low. This is the case in the southern regions of the country (Savannakhet, Saravane, Champasack). In the flat alluvial plains of the Mekong and its tributaries paddy rice farming intermixed with patches of natural forests dominates the landscape (Messerli et al 2009).The mix of these land uses causes medium-to-low levels of village carbon values.

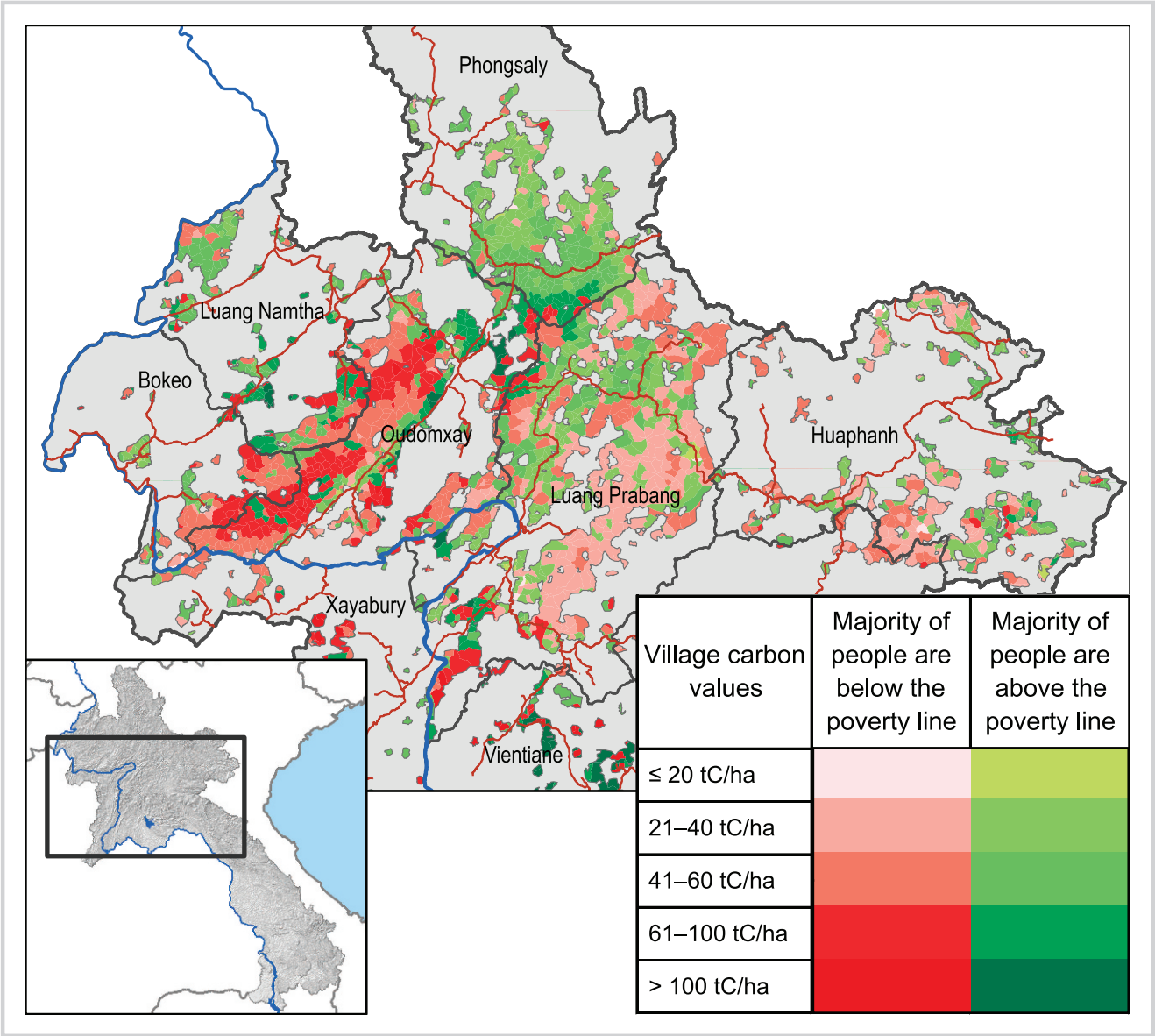
In the uplands of Lao PDR, village carbon values are reduced by the presence of degraded vegetation. This is commonly caused by another form of land use: shifting cultivation. In this traditional way of farming, a plot is cultivated for a short period of time and afterward left fallow for several years so that the vegetation and soil fertility can regenerate. The plot then is cleared and the fallow vegetation burned to prepare for the next cultivation cycle (Roder 2001). In Southeast Asia in general and in Lao PDR in particular, shifting cultivation is intensifying, from long crop-fallow cycles to shorter cycles, and formerly cultivated land is rapidly being transformed to other uses (Mertz 2009; Hett et al 2012). This development leads to decreasing carbon stocks over time.

The Lao government has especially targeted the shifting cultivation areas of the northern uplands for REDD+ (GoL 2008). In a recent study, Heinimann et al (2012) showed that the poverty rate in shifting cultivation areas in northern Lao PDR is considerably higher than the national average. The village carbon values/poverty rate typology for these upland areas under shifting cultivation when using the geometries for shifting cultivation areas proposed by Hurni et al (2012) are shown in Figure 4. In these mountainous areas, villages with the majority of people living below the poverty line (red) dominate, particularly in the remote regions away from the main roads. From the carbon perspective, these villages predominantly have high to very high carbon values in Oudomxay Province, whereas in Luang Prabang Province, medium-to-low village carbon values prevail.

In these mountainous hinterlands of Lao PDR, with few livelihood options other than shifting cultivation due to a general lack of opportunities to diversify economic activities, REDD+ could be used in 2 ways. First, it could help to preserve the existing carbon stocks by maintaining the current intensity of shifting cultivation. Preservation of existing high carbon stocks in combination with poverty alleviation measures would be of particular interest in the large shifting cultivation area covering mainly the provinces of Oudomxay and small parts of Bokeo and Luangnamtha. Alternatively, REDD+ could serve as an instrument to encourage farmers to revert to longer fallow cycles with the effect that more carbon could be accumulated in the landscape (Mertz 2009). This strategy, with a strong focus on poverty alleviation, could be followed in the upland areas of Luang Prabang. Finally, a large area of shifting cultivation in which the majority of the village population lives above the poverty line is found in Phongsaly with a north–south gradient of low to high village carbon values. Again, the most inaccessible villages, off the main road, show the highest village carbon values.

The lack of large continuous areas with the same combination of poverty rates and village carbon values in Lao PDR makes it hard for REDD+ projects to operate at a large scale by using the same project practices and components. In particular, this is a major challenge in the northeastern region of the country, where the poverty

FIGURE 4 Typology of village carbon values and poverty rates in shifting cultivation areas after Hurni et al (2012). (Map by authors)



rates vary considerably, leaving behind a fine mosaic of light red and light green patches in the map in Figure 3.

The definition of the optimal REDD+ approach in a given village requires further investigation of the linkages between carbon stocks and land-use types and dynamics, climatic conditions, and other important factors (eg village accessibility and ethnicity) at the local level. Here we can only show the general picture of spatial patterns of poverty and carbon stock density.

Integrating poverty alleviation into REDD+ schemes

The previous section summarized the patterns of poverty rates and village carbon values across Lao PDR and interpreted the different combinations with regard to REDD+ challenges and opportunities. For national-level decision-making on REDD+, the knowledge of where the largest quantities of carbon are stored in relation to poverty rates is another key asset to successful planning. As shown in Table 1, the highest carbon stocks in Lao PDR (44% of the total) are found in villages with poverty rates of 50–75%. Another 36% are found in villages with poverty rates of 25–50%. In containing up to 80% of the overall carbon stock, these 2 village categories should be at the center of planning for REDD+, and, clearly, poverty alleviation should be a part of REDD+ schemes in these villages. Lao PDR should certainly not limit its REDD+ activities to villages with very high (more than 75%) or very low (less than 25%) poverty rates. In both these

TABLE 1 Shares of carbon stocks along a gradient of poverty rates.

Poverty rate classes, %	Carbon stock, % of total
0–25	9.9
25–50	36.1
50–75	44.4
75–100	9.6

categories, less than 10% of the overall carbon stock is found, and, hence, the overall national effect of carbon stock conservation or enhancement would be rather limited.

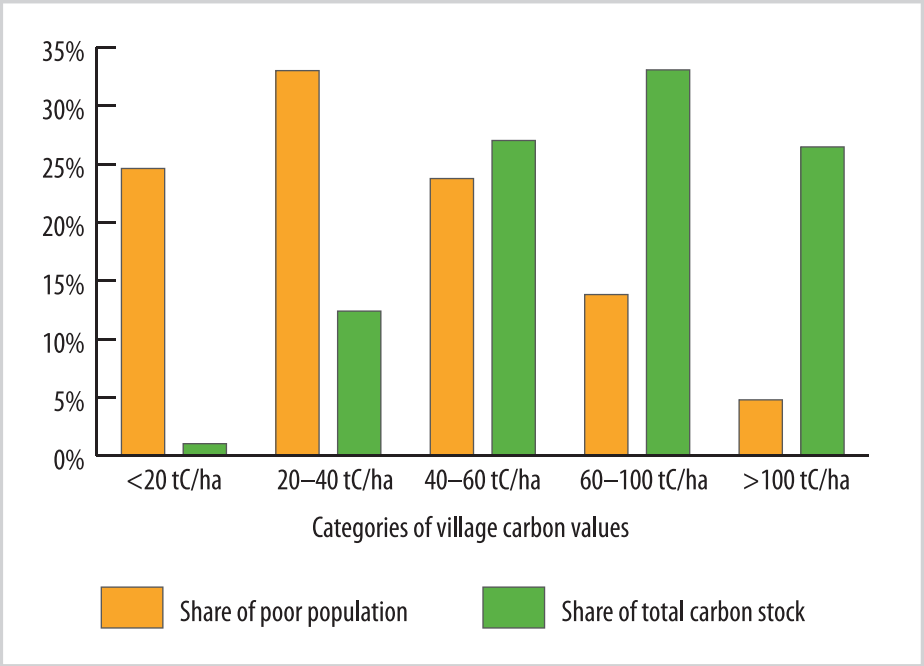
REDD+'s limited value for achieving Millennium Development Goal 1 in Lao PDR

Changing the viewing angle from poverty rates to absolute numbers of people in poverty, again along a gradient of village carbon values, spatial analysis of our data reveals the following interesting fact: most poor people live outside the primary target areas for REDD+. As shown in Figure 5, almost 60% of all the people living below the poverty line can be found in villages with low (20–40 tC/ha) or very low (<20 tC/ha) carbon values. These villages are dominated by permanent agriculture and are not target areas for REDD+ as the potential for conserving or enhancing carbon stocks is low. This finding makes it hard to link REDD+ directly to Millennium Development Goal 1, which ranks high on the political agenda in Lao PDR. To achieve this goal, Lao PDR must primarily focus on areas where high absolute numbers of poor people prevail. All together, the villages with very low and low village carbon values (0–40 tC/ha) store less than 15% of the overall carbon found in the vegetation of Lao PDR. Hence, the avoidance of further carbon stock depletion when using REDD+ as an instrument would be rather insignificant from a national carbon perspective. The villages that are most interesting for carbon conservation, and thus REDD+ target areas, have carbon values of 60–100 tC/ha and more than 100 tC/ha. These 2 categories, however, have low shares of the total Lao population living below the poverty line, 13.8% and 4.8%, respectively.

Nearly a fourth of all poor people in Lao PDR live in villages with medium carbon values (40–60 tC/ha; see Figure 5). As discussed above, these villages are potential target areas for enhancement of carbon stocks if they are in the degraded swidden areas of the Lao uplands. They are of utmost importance for a national-level REDD+ strategy as a large share of people classified as poor live in this environment, and, at the same time, 27% of the overall carbon stock of the country is found there.

Our analyses are based on simplifications that do not capture the full complexity of carbon/poverty landscapes in Lao PDR. Such simplifications include the chosen poverty measure and the level of assessment. Poor households were defined as those living below the Lao PDR poverty line, and poverty rates at the village level were based on that measure. However, even in villages with low poverty rates, villagers are by no means wealthy,

FIGURE 5 Shares of carbon stocks and poor people along a gradient of village carbon values.



and there is still great potential for poverty alleviation. Furthermore, there might be significant disparities of wealth at the subvillage level. Consequently, in a village with a low poverty rate, there may well be people who could profit from or rely on REDD+ incentives to improve their livelihood situation.

Conclusions

This study has shown how national-level spatial data on carbon stocks can be combined with population and poverty data. Knowledge of the combination of environmental status and poverty is a key asset for decision-making for REDD+. The study results help answer key questions about managing REDD+ in Lao PDR. REDD+ policies represent promising avenues in Lao PDR for climate change mitigation with a contribution to poverty alleviation. This is particularly the case in the mountainous, remote areas where shifting cultivation is practiced. But, even in these areas, poverty rates and carbon stock densities occur in different combinations. Consequently, there is no single best approach to REDD+; rather, different approaches are needed depending on the spatial combination of carbon stock densities and poverty.

Concretely, in northern Lao PDR, Oudomxay Province should be a priority for implementation of REDD+ for carbon stock conservation and poverty alleviation. In Luang Prabang Province, REDD+ could provide compensation for the loss of revenue from agriculture caused by prolonging the crop-fallow cycles, a step that is needed to accumulate more carbon in the landscape. However, pro-poor REDD+ actions should not be limited to the upland areas in the northern part of the country; areas in the Annamite range along the border of Vietnam should receive equal attention. Against the general REDD+ euphoria in Lao PDR, an important fact was revealed: most people living below the poverty line in Lao PDR do not live in a carbon-rich environment. For them, REDD+ is not the instrument to lift them out of poverty.

From a methodological point of view, this study showed that, despite the complexity of REDD+ and a general lack of data, research can assist policy-making at the national level. The challenge here was to find a solution for combining spatial data from different sources in a meaningful way. This was achieved by the introduction of village carbon values so that village geometries could serve as a common base geometry for both the socioeconomic and environmental data sets.

Researchers are often tempted to narrow their focus to provide detailed answers on a tiny aspect of REDD+ in a small case study area. Despite the merit of these initiatives, the mismatch between the scale of knowledge production and currently relevant decision-making processes is reinforced (Cash et al 2006). Normally, generalized insights are derived from such case studies and applied to the national level. Local case studies, however, have limited validity for large territories. This study introduced promising avenues for obtaining a better understanding of the bigger REDD+ picture in Laos by exploring the possibility of developing and applying detailed but comprehensive and consistent data at the national level.

ACKNOWLEDGMENTS

We acknowledge support from the Swiss National Centre of Competence in Research North–South, cofunded by the Swiss National Science Foundation, the Swiss Agency for Development and Cooperation, and the participating institutions. This research is part of a project titled Impacts of Reducing Emissions from Deforestation and Forest Degradation and Enhancing Carbon Stocks, which is funded by the European Community's Seventh Framework Research Programme. More information can be found on the project's website: http://www.i-redd.eu. We thank the 2 anonymous reviewers for their very useful comments.

REFERENCES

Angelsen A, Brockhaus M, Kanninen M, Sills E, Sunderlin WD, Wertz-Kanounnikoff S. 2009. *Realising REDD+: National Strategy and Policy Options*. Bogor, Indonesia: Center for International Forestry Research.

Baker DJ, Richards G, Grainger A, Gonzalez P, Brown S, DeFries R, Held A, Kellndorfer J, Ndunda P, Ojima D, Skrovseth P-E, Souza C Jr, Stolle F. 2010. Achieving forest carbon information with higher certainty: A five-part plan. *Environmental Science & Policy* 13(3):249–260.

Björnsen Gurung A, Wymann von Dach S, Price MF, Aspinall R, Balsiger J, Baron JS, Sharma E, Greenwood G, Kohler T. 2012. Global change and the world's mountains—Research needs and emerging themes for sustainable development. *Mountain Research and Development* 32(S1):47–54.

Bourgoin J, Castella J-C. 2011. "PLUP fiction": landscape simulation for participatory land use planning in northern Lao PDR. *Mountain Research and Development* 31(2):78–88.

Brown D, Seymour F, Peskett L. 2007. How do we achieve REDD co-benefits and avoid doing harm? *In:* Angelsen A, editor. *Moving Ahead with REDD: Issues, Options and Implications*. Bogor, Indonesia: Center for International Forestry Research, pp 107–119.

Campbell BM. 2009. Beyond Copenhagen: REDD+, agriculture, adaptation strategies and poverty. *Global Environmental Change* 19(4): 397–399.

Cash DW, Adger W, Berkes F, Garden L, Lebel L, Olsson P, Pritchard L, Young O. 2006. Scale and cross-scale dynamics: Governance and information in a multilevel world. *Ecology and Society* 11(2):8 [online].

Epprecht M, Minot N, Dewina R, Messerli P, Heinimann A. 2008. *The Geography of Poverty and Inequality in the Lao PDR*. Bern: Swiss National Center of Competence in Research North–South, University of Bern, International Food Policy Research Institute, and Geographica Bernensia.

Foppes J, Ketphanh S. 2004. NTFPs for poverty reduction and shifting cultivation stabilization in uplands of Lao PDR. *In: NAFRI Workshop on Poverty Reduction and Shifting Cultivation Stabilization in the Uplands of Lao PDR: Technologies, Approaches and Methods for Improving Upland Livelihoods*. Vientiane, Lao PDR: National Agriculture and Forestry Research Institute.

GoL [Government of Lao PDR]. 2008. *Lao Readiness Plan Idea Note (R-PIN) for the Forest Carbon Partnership Facility (FCPF).* Lao PDR: GoL.
Heinimann A, Hett C, Hurni K, Messerli P, Epprecht M, Joergensen L, Breu T. 2012. Socio-economic perspectives on shifting cultivation landscapes in Northern Laos. *Human Ecology* 40(6) (in press). http://dx.doi.org/10.1007/s10745-012-9551-y.
Hett C, Castella J-C, Heinimann A, Messerli P, Pfund JL. 2012. A landscape mosaics approach for characterizing swidden systems from a REDD+ perspective. *Journal of Applied Geography* 32(2):608–618.
Hett C, Heinimann A, Messerli P. 2011. Spatial assessment of carbon stocks of living vegetation at the national level in Lao PDR. *Geografisk Tidsskrift-Danish Journal of Geography* 111(1):11–26.
Hurni K, Hett C, Heinimann A, Messerli P, Wiesmann U. 2012. Dynamics of shifting cultivation landscapes in northern Lao PDR between 2000 and 2009 based on an analysis of MODIS time series and Landsat images. *Human Ecology* 40(6) (in press).
Luyssaert S, Schulze E, Börner A, Knohl A, Hessenmöller D, Law BE, Ciais P, Grace J. 2008. Old-growth forests as global carbon sinks. *Nature* 455(7210):213–215.
Mertz O. 2009. Trends in shifting cultivation and the REDD mechanism. *Current Opinion in Environmental Sustainability* 1(2):156–160.
Messerli P, Heinimann A, Epprecht M. 2009. Finding homogeneity in heterogeneity—A new approach to quantifying landscape mosaics developed for Lao PDR. *Human Ecology* 37(3):291–304.
Messerli P, ***Heinimann A***, ***Epprecht M***, ***Phonesaly S***, ***Minot N, editors.*** 2008. *Socio-economic Atlas of the Lao PDR: An Analysis Based on the 2005 Population and Housing Census*. Swiss National Center of Competence in Research North–South, University of Bern ed. Bern, Switzerland, and Vientiane, Laos: Geographica Bernensia.
Parker C, Mitchell A, Trivedi M, Mardas N. 2008. *The Little REDD Book*. Oxford, United Kingdom: Global Canopy Programme.
Peskett L, Huberman D, Bowen-Jones E, Edwards G, Brown J. 2008. *Making REDD Work for the Poor*. London, United Kingdom: Poverty Environment Partnership.
Price MF, Gratzer G, Alemayehu Duguma L, Kohler T, Maselli D, Romero R. 2011. *Mountain forests in a changing world—Realizing values, addressing challenges*. Rome, Italy: Food and Agriculture Organization of the United Nations and Swiss Agency for Development and Cooperation.
Roder W. 2001. *Slash-and-Burn Rice Systems in the Hills of Northern Lao PDR: Description. Challenges, and Opportunities*. Los Baños, Philippines: International Rice Research Institute.
Stephens BB, Gurney KR, Tans PP, Sweeney C, Peters W, Bruhwiler L, Ciais P, Ramonet M, Bousquet P, Nakazawa T, Aoki S, Machida T, Inoue G, Vinnichenko N, Lloyd J, et al. 2007. Weak northern and strong tropical land carbon uptake from vertical profiles of atmospheric CO_2. *Science* 316(5832):1732–1735.
Sunderlin WD, Angelsen A, Wunder S. 2003. Forests and poverty alleviation. *In:* Food and Agriculture Organization (FAO), editor. *State of the World's Forests 2003*. Rome, Italy: FAO, pp 61–73.
Sunderlin WD, Dewi S, Puntodewo A, Müller D, Angelsen A, Epprecht M. 2008. Why forests are important for global poverty alleviation: A spatial explanation. *Ecology and Society* 13(2):24 [online].
Thomas I, Chorn Nak C, Braeutigam D, Thongmanivong S, Boulidam S, Phimminith T, Hurni K, Hett C. 2009. *Analysis of Land Use and Forest Changes and Related Driving Forces in the Lao PDR*. Vientiane, Lao PDR: Mekong Maps Co Ltd., Faculty of Forestry of the National University of Lao PDR and NCCR North–South, University of Bern, Switzerland.
Thongmanivong S, Fujita Y. 2006. Recent land use and livelihood transitions in northern Laos. *Mountain Research and Development* 26(3):237–244.
UN [United Nations]. 2012. Report of the United Nations Conference on Sustainable Development, Rio de Janeiro, Brazil, 20–22 June 2012. New York, NY: UN. http://www.uncsd2012.org/content/documents/814UNCSD%20REPORT%20final%20revs.pdf; accessed on 4 August 2012.
UNFCCC [United Nations Framework for Climate Change]. 2007. Report of the Conference of the Parties on its Thirteenth Session, Held in Bali from 3 to 15 December 2007. Addendum. Part Two: Action taken by the Conference of the Parties at its thirteenth session. Bonn, Germany: UNFCCC. http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf; accessed on 4 August 2012.
van der Werf GR, Morton DC, DeFries RS, Olivier JGJ, Kasibhatla PS, Jackson RB, Collatz GJ, Randerson JT. 2009. CO_2 emissions from forest loss. *Nature Geoscience* 2(11):737–738.
Vedeld P, Angelsen A, Bojö J, Sjaastad E, Kobugabe Berg G. 2007. Forest environmental incomes and the rural poor. *Forest Policy and Economics* 9(7):869–879.
World Bank. 2007. *Lao PDR Environment Monitor*. Washington, DC: World Bank.