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ORIGINAL ARTICLE

Status of forest development and opportunity cost of avoiding forest conversion in Ba Be National Park, Vietnam

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ABSTRACT This study aimed to discover the status of several types of forest and based on the opportunity costs of REDD+ to identify which greenhouse gas (GHG) emission mitigation options can be implemented in different forest types in Ba Be National Park, Vietnam. From 1990 to 2000, forest in the study area faced a high rate of forest cover loss and degradation. During the next decade from 2000 to 2010, total forest cover increased gradually. However, the natural forest area still decreased. In our household survey (n = 103), respondents reported that main drivers of deforestation and forest degradation in those areas were timber extraction for commercial or subsistence purposes, shifting cultivation, inadequate forest management, bribes to forest rangers, felling trees for firewood and bamboo shoots, and conversion to Mo (*Manglietia conifera*) and other perennial plants. There are some differences in those drivers between the three villages surveyed. From 2000 to 2010, several land use changes such as the conversion of poor timber forest into recovered timber forest, medium timber forest into poor timber forest and planted forest into bare land with scattered trees caused more than 8,000 tCO_2e emissions per year. In regard to opportunity costs, most of the avoidance options have negative opportunity costs, which mean potential benefits. Within the current carbon market price, the avoidance can be applied to reduce approximately 7,900 tCO_2e emissions (about 98% reduction) per year in the three communes surveyed.

Key words: REDD+, land use changes, forest carbon stock, deforestation, Bac Kan Province

INTRODUCTION

Reducing Emissions from Deforestation and Forest Degradation, including the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) is a group of mitigation actions to respond to climate change in the forest sector (The REDD Desk 2014). Since the IPCC Fourth Assessment Report estimated GHG emissions from the forestry sector accounted for 17.4% of the total GHG emissions in 2004 (IPCC 2007), the REDD+ mechanism has gained momentum and various projects have been implemented.

Vietnam experienced severe deforestation in the past with a loss in forest cover of about 15.2% from 1943 to 1990 (Maurand 1943, Vo 1997, Pham 2006). Since the 1990 s, due to policy renovations related to land allocation, afforestation, forest management and protection, the forest cover of the country increased significantly from 27.8% in 1990 to 39.7% in 2011 (Vo 1997, MARD 2012). However, natural forests especially those with high carbon stock, which are estimated to have five to ten times the potential for capturing and storing carbon than the same area of planted forest (Hoang et al. 2010), are still being degraded. Therefore, Vietnam is eligible to participate in REDD+ under the approach of increasing carbon stock and conserving carbon storage through protecting natural forests and reducing forest degradation.

Basically, REDD+ employs economic incentives to encourage developing nations to implement REDD+ related activities through payment by industrialized countries for the reduced emissions from business as usual activities in the forest sector of those developing countries (White and Minang 2011, Hirata et al. 2012, The REDD Desk 2014). Since REDD+ will only work when the costs of REDD+ related activities can be covered by the emission trading market, estimation of the costs plays a very important role in the REDD+ related policies and project design (Wulan 2012). Above all, opportunity costs of REDD+, which refer to foregone benefits of alternative land uses when conserving and enhancing forest, have been recognized as the highest share in REDD+ costs and play an essential role in REDD+ design and implementation (White and Minang 2011).

Opportunity costs of REDD+, also called opportunity costs of alternative land use, have been considered in many countries and regions. ADB (2009) reviewed previous studies related to opportunity costs to summarize GHG emission reduction potentials of some tropical countries and Southeast Asia. They highlighted that the potential of GHG emission reduction in those countries starts from US \$5.4 tCO_2^{-1} and begins to have financial attraction from US \$27 tCO_2^{-1} (ibid.). In Indonesia, opportunity costs of land-use changes, in both national and local levels, varied between US \$0.4 tCO_2^{-1} and US \$33 tCO_2^{-1} depending on location and type of land uses (Butler et al. 2009, Olsen and Bishop 2009, Venter et al. 2009, Wulan 2012). Generally, oil palm plantation and commercial logging had high costs and a voluntary carbon price of US \$5 tCO_2e^{-1} could not cover their costs. The cost of paddy field was lower and could be compensated in some places (ibid.).

Several studies related to the implementation of REDD+ in Vietnam have been conducted during the last few years. World Agroforestry Centre (ICRAF), for example, in their study in Dak Nong Province suggests that Vietnam needs to develop more superior land-use planning system, which uses "multiple land-use planning parameters" including the consideration of co-benefits, to ensure the transparency of REDD+. They also note the enhancement of carbon stock in forest production areas as the appropriate option to implement REDD+ in Dak Nong Province, and the distribution of benefits and the deliberation of potential benefits for each forest user group (Hoang et al. 2010). Other study from ICRAF, applying history-based and opportunity-cost analyses of land-use changes in Bac Kan Province points out three options for REDD+ implementation: 1) increasing carbon stock in forests with low-carbon storage capacity; 2) compensation for retaining standing forest; and 3) paying for carbon stock enhancement via strengthened forest protection and management (Hoang and Do 2011). Findings from a study by the International Institute for Environment and Development reveal that the opportunity cost of conversion from low profitable crops to high quality forests might be less than US \$1. Meanwhile, conversion from more profitable crops to lower quality forests has an opportunity cost of more than US \$10. Thus, REDD+ should focus on the conversion of crops having low economic benefits (Holland and McNally 2010).

Other issues to consider when designing national REDD+ policies are the integration of REDD+ in land use planning at both national and local levels, improvement of monitoring system with the participation of local communities and a third party, better law enforcement and transparency, and pro-poor approach (Pham et al. 2012). Although those studies introduce some alternative solutions for preparing the implementation of REDD+ in Vietnam, they rarely focus on the differences in forest management types in Vietnam, namely special-use forest mainly used for nature and biodiversity conservation related purposes, protection forest, and production forest (Law on Forest Protection and Development 2004).

Therefore, our study aimed to discover both the status of several forest types and the status of different forest management types. Accordingly, forest problems in each type of forest were identified. Moreover, by comparing the opportunity costs of REDD+, we determined which GHG emission mitigation options can be implemented in different forest types. Bac Kan Province is recognized as a high-potential area for REDD+ implementation in Vietnam due to the compensable opportunity costs and potential of carbon stock enhancement (Hoang and Do 2011). Since Ba Be National Park (BBNP) and its surrounding area are located in Bac Kan Province and reflect all three types of forest management in Vietnam, we selected BBNP as the study site.

MATERIALS AND METHODS

Study site

BBNP, established in 1992, is located in a mountainous province in the northeast of Vietnam (Fig. 1). The total area of BBNP is 44,750 ha, in which the area of core zone is 10,048 ha and buffer zone is 34,702 ha (Fig. 2). BBNP has a complex of rivers, springs, freshwater natural lake (Ba Be Lake), limestone mountains and a mix of limestone and lowland evergreen forest with an elevation of approximately 150 m to 1,098 m above sea level. Ba Be Lake is listed in the top hundred largest freshwater lakes of the world and BBNP was recognized as an ASEAN heritage park in 2004.

BBNP has a high rate of biodiversity encompassing 417 species of flora and 299 species of fauna, including terrestrial, aquatic and flying animals, of which numerous species are listed in Vietnam's Red Data Book, the authorized record of Vietnamese rare and endangered native species of fauna and flora. Of 417 species of flora, plants recognized in the Book such as *Markhamia pierrei*, *Burretiodendon hsienmu*, *Chukrasia tabulatis*, *Amomum longiligulare*, *Garcinia fagraioides*, and *Aesculus chinensis* (National Institute of Agricultural Planning and Projection 2008). Among 299 species of fauna, there are 22, 6, 12, 2, and 49 species in the mammals, birds, reptile, amphibians, and fish classes respectively in the Book (ibid.).

The core zone and buffer zone of BBNP are categorized to special-use forest and protection forest respectively, and forests outside BBNP are mostly production forests. BBNP is under the management of the BBNP Management Board, which is supervised by Bac Kan Provincial People's Committee.

The livelihoods of local people in the mountainous area are still deprived and Ba Be is identified as one of the three districts with the highest poverty rate of more than 50% in Vietnam (Hoang and Do 2011). Though forest degradation as a result of illegal logging and shifting cultivation still remains high, local people especially those who depend on natural forest resources are not involved much in forest management (People's Committee of Bac Kan Province 2012). We selected P village of Nam Mau commune as the case of special-use forest in the core zone, N village of Quang Khe commune as the case of protection forest in the buffer zone, and T village of Dia Linh commune as the case of production forest outside BBNP.

Data collection

In this study, the term afforestation means "the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources"; the term deforestation means "the direct human-induced conversion of forested land to non-forested land" (UNFCCC 2002); and the term forest degradation means "changes within the forest attributed directly to human activity that leads to a long-term reduction in forest carbon stocks" (Angelsen et al. 2009).

As secondary data, national forest policies, local government reports and land use maps and carbon stock data from projects conducted in the study site were collected. Primary data were obtained through a cross-sectional household survey conducted in August 2012. Semi-structured questionnaire and in-depth interviews with key informants were used. 103 households in three different villages were randomly selected as sample households (see Table 1 for more information about the number of sample households and sampling rates). This study used the annual household economic classification utilized by the government, which divides the household groups into poor, average wealth and wealthy groups. The criteria used by the government of Vietnam include the value and quality of household dwellings and property, and their income in the previous year.

Based on current economic activities in the study area, income sources were divided into four primary categories:

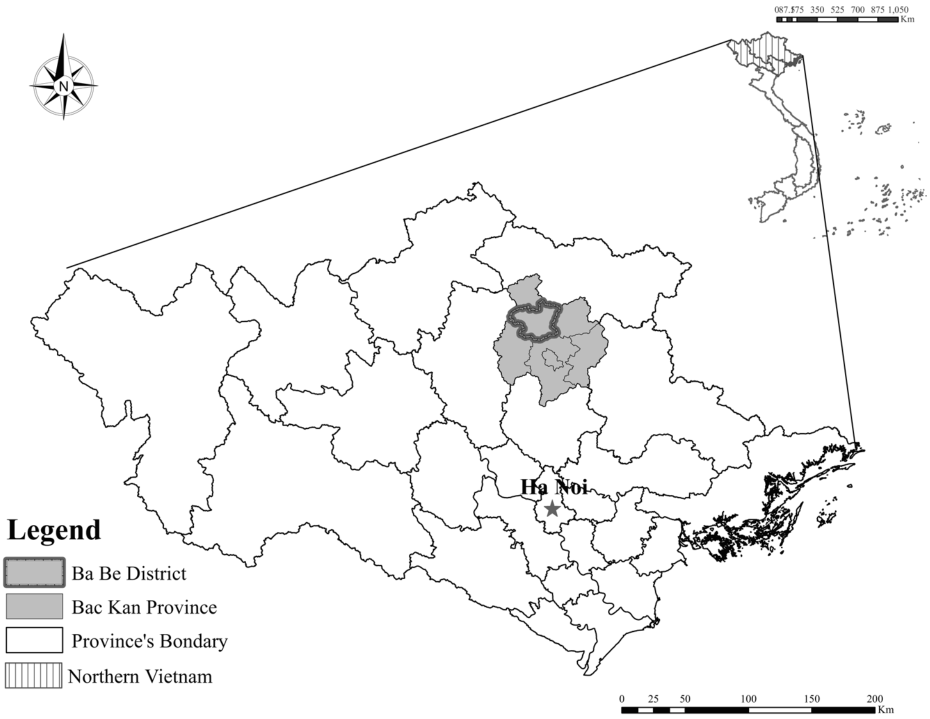

Fig. 1. Location of Ba Be District - the study area in northern Vietnam.

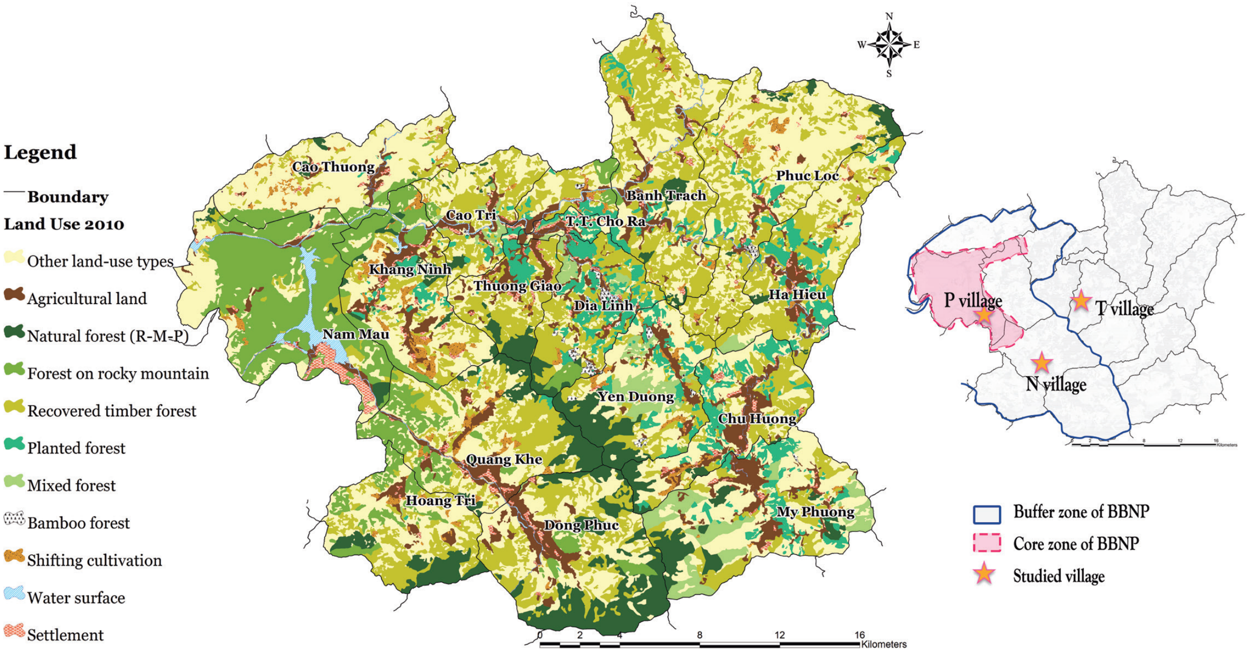

Fig. 2. Land use map of Ba Be District, 2010, zones in BBNP and location of the sample villages in the study.
Note: This map was made by the authors using land use map data provided by ICRAF Vietnam in 2012 and ArcGIS. Natural forest (R-M-P) means Rich-Medium-Poor timber forest.

Table 1. Number of sample households and sampling rates

			Poor		Average wealth		Wealthy		
Village	Location	Total No. Hhs	No. Hhs	% of total Hhs	No. Hhs	% of total Hhs	No. Hhs	% of total Hhs	Total interviewed Hhs
P	Core zone	86	5	15	0	0	29	85	34
N	Buffer zone	86	18	53	11	32	5	15	34
T	Outside BBNP	51	16	46	8	23	11	31	35

Note: Household wealth groups: the criteria used by the government of Vietnam to classify household wealth groups include the value and the quality of the household dwelling and property and their income in the previous year. Norms were set as follows: (1) A rural poor household is a household where each member earns an average income of up to VND 400,000 (US $19.72) per month; (2) A rural average wealth household is a household where each member earns an average income of between VND 401,000 (US $19.77) and VND 520,000 (US $25.64) per month; (3) A rural wealthy household is a household where each member earns an average income higher than VND 520,000 (US $25.64) per month.

agricultural, fishing, forest and off-farm income. Agricultural income involved income from cultivation, husbandry farming and agricultural services. Income from forest was the combination of non-timber forest products (NTFPs) collection, and timber exploitation from both natural forest and planted forest. Off-farm income referred to non-agricultural income sources such as wage employment, self-employment, interest from savings, salary, pension and money received. However, arbitrary income from the sale of a house or savings withdrawal was not considered household income. Agricultural income such as cultivation, husbandry farming and NTFPs collection consisted of both consumption-in-kind or own farm output and cash income from output sales (Ellis 1998).

Income for each household was obtained by summing net incomes of all livelihood activities of the household in 2011. Net income from annually-benefited activity, such as annual crop cultivation, agricultural services, fishing, NTFPs collection and wage employment, was estimated by total cost minus gross income (Avila 1992). Regarding annual crop income, for instance, gross crop income was the combination of value selling cultivation outputs and value of consumed output. Total cost for cultivation consisted of seed costs, fertilizer, pesticide, and hiring labor, paying loan interest, tools, energy, irrigation and other investment in 2011 for cultivation. Deducting the total cost from the gross income determined the net income for the crop. Net livestock income was calculated similar to net annual crop income. However, we adapted the computation of its costs. Let's consider A equals the total cost of livestock divided by the number of livestock the household possessed multiplied by current herd numbers. In order to get the real value of husbandry farming, the real cost of the income they get from livestock had to equal total cost minus A.

Net income from perennial crop and forest plantation was calculated by

$$Income = \sum_{t=0}^{n} (TGI_t - TC_t)/[(1+r)^t] \text{ (US \$)} \quad (1)$$

where TGI_t is total gross income in year t (US \$), TC_t is total costs in year t (US \$), r is discount rate (-), and n is time horizon (Avila 1992).

Livelihood activities for households in this area are mostly for subsistence which means they consume most of the output from agriculture. For these reasons, we used farm-gate prices provided by respondents in the household survey to calculate the net income. We also ignored the labor cost of NTFPs collection because in poor rural areas, it is not necessary to consider own-labor value in net income as both labor markets and alternative opportunities are limited. Moreover, the collection of NTFPs does not require a high skill level and the investment capital is low. The opportunity cost of unskilled labor is also very low (Babulo et al. 2008). On the other hand, due to the specific characteristics of livelihood activities in the study area, forestry was not considered the main income of households compared with agricultural production and other off-farm activities. It was recognized that alternative opportunities in labor for forestry were higher than other sectors. Thus, labor cost was included in the calculation of forest income.

To determine the opinions of local people about drivers for deforestation and forest degradation in their surrounding area, an integrated multi-choice and open-end questionnaire was used. Respondents could choose as many answers as they thought appropriate and even add more comments to the list. Then, one point was given to each respondent and a point for each of their choices was equivalent to one divided by total choices they made. Total points for each answer were calculated for each village. To enable the comparison among villages, the final result of respondents' choices in each village was converted to a percentage.

Estimation of opportunity costs

REDD Abacus software (ICRAF 2011) was utilized to estimate the opportunity cost of land use changes in the study area over 20 years from 1990 to 2010. REDD Abacus is a support tool to estimate the opportunity cost of land use changes in an area over a period of time with the generation of abatement cost curve (Harja et al. 2011). The required data input includes net present value (NPV) of each type of land use, time-averaged carbon stock of each type of land use and a land use transition matrix. Fig. 3 shows sources of data that this study used in the software.

We used the land-use classification of Vietnam's Ministry of Agriculture and Rural Development which divides land uses into five groups, including forest, mosaic, non-forest vegetation, agriculture and non-vegetated followed by 19 land-use types (for more information refer to Appendix 1) . Land use map data were available for the year 1990, 1995, 2000, 2005 and 2010 and carbon stock of land uses were provided by ICRAF Vietnam Office in 2012. The land use change matrix was derived from land use map data by utilizing the Spatial Analysis tool in ArcGIS.

The NPV of each type of land use can be calculated by

$$NPV = \sum_{t=0}^{n} (B_t - C_t)/[(1+r)^t] \text{ (US \$ ha}^{-1}) \quad (2)$$

where B_t is benefit in year t (US \$/ha), C_t is cost in year t (US \$ ha^{-1}), r is discount rate (-), and n is time horizon (-) (Hoang et al. 2010, White and Minang 2011).

Annual cropland and planted forestland were the land use types affecting the livelihood of local people the most and varied following local conditions. Therefore, we focused on calculating the NPVs of annual cropland and planted forestland. The NPV of other land uses were acquired from other study in Bac Kan Province from ICRAF (Hoang and Do 2011). In this area, most of the forest regulations were followed in different types of forests and the three villages are located in different types of forest. Therefore, forest benefits in each village could represent benefits of the same type from forest in other villages. Thus, the average NPV of plantation forest in T village, where the highest number of households engaged in plantation forest related activities, was applied for all three villages. Regarding agricultural fields, due to the difference in attitude and soil conditions, NPVs of agricultural fields in the three villages were different. Consequently, we considered a separate NPV for each village/ village area.

Opportunity costs of land use changes can be calculated by

$$OPCOST = (NPV_{before} - NPV_{after})/[(44/12)\ (Cstock_{after} - Cstock_{before})] \text{ (US \$ tCO}_2\text{e}^{-1}) \quad (3)$$

where 44/12 is the conversion factor from C to CO_2 based on their molecular weights, $NPV_{before/after}$ is NPV of the land-use type before/after conversion (US \$ ha^{-1}) and $Cstock_{before/after}$ is time-averaged above ground carbon stock before/after conversion (tC ha^{-1}) (Hoang et al. 2010, White and Minang 2011).

This study applied the average REDD offset price in 2013 at US \$4.2 tCO_2e^{-1} (Peters-Stanley and Gonzalez 2014).

RESULTS

Main characteristics of households

According to current local policies on forest management, there were different legal activities related to forest in the three communes. As a matter of course, forest use in P village in the core zone was the most strongly regulated (Table 2).

With respect to the planting contract in T village, three years after entering the contract if the number of standing trees was equal or more than 80% of received seedlings, villagers could receive 100% of the contract money (including rice and cash). Local people could enjoy 100% benefit from the products in their planted forest. They could exploit planted forest after ten years and from 5 to 10% of the total amount of trees each year under the terms of the contract. Those people received much financial support from the local government for planting forests. However, they also claimed that the allocated forests were almost depleted and the soil quality was not good. Furthermore, these forests were far from their residence and difficult to access. Therefore, local people met many difficulties in both planting and exploiting their planted forests.

Fig. 4 shows the contribution of household income sources in total income of interviewed households in 2011. Three main income sources of the study area were cultivation, animal husbandry and off-farm activities. All sample households collected NTFPs for use in their daily life: 100% of households collected firewood, 11% households exploited bamboo, and 6% households collected other

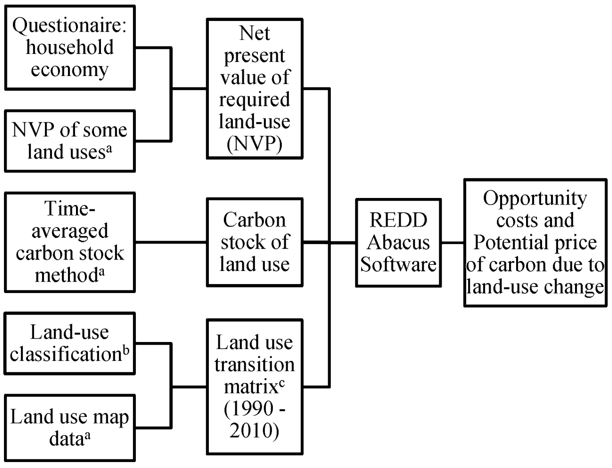

Fig. 3. Input data of REDD Abacus software.

[a] Data provided by ICRAF Vietnam, 2012

[b] The classification of the Ministry of Agriculture and Rural Development, Vietnam

[c] Derived from land use map data using Spatial Analysis tool in ArcGIS. Data is available for years 1990, 1995, 2000, 2005, and 2010.

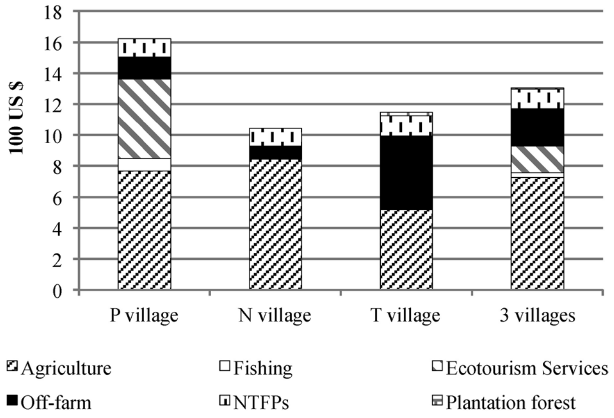

Fig. 4. Annual average household income in the three villages, 2011.

Table 2. Different legal activities by forest management type in the three communes

P village	N village	T village
Special-use forest: Local people have rights to collect dead and fallen trees for firewood purposes and NTFPs. Moreover, they can enter a contract to protect and tend forest, then receive VND 200,000/ha/year (US \$9.6/ha/year)	**Protection forest:** Local people have rights to exploit dead or diseased trees for firewood purposes, NTFPs, trees standing in the area having a higher density than required, bamboo shoots and assorted bamboo. Moreover, they can receive VND 100,000/ha/year (US \$4.8/ha/year) for forest care (Hoang and Do 2011)	**Production forest:** Local people have rights to collect firewood and other NTFPs and obtain benefits from their planted trees. According to local people, those who contracted to plant production forest could receive approximately VND 5,000,000/ha/3 years (US \$240/ha/3 years) in both cash and kind such as seedlings and rice (mostly they planted Mo (*Manglietia conifera*)).

NTFPs such as mushrooms, bamboo shoots and honey. In general, in all three villages, cultivation and husbandry farming played an important role in the income of households but their tendency varied among villages. Particularly the sample households of P village in the core zone comprising Ba Be Lake gained cash income from fishing and ecotourism services. Off-farm income from planted forest almost only existed in T village located outside BBNP, where more than 60% of sample households received a forestland allocation.

There were six main energy sources in this area, including firewood and gas for cooking, diesel for operating machines, petrol for transport and electricity and oil mostly used for lighting and other purposes (Fig. 5). For all energy sources, 100% of households in the three groups used firewood for cooking purposes; electricity and petrol were used more in average and wealthy households. Moreover, only wealthy households used gas for cooking. However, the number of wealthy households that used gas accounted for approximately 10% of all wealthy households. Oil was still utilized by poor households (nearly 10% of the interviewed poor households) and average wealth households (approximately 5% of the interviewed households in the average wealth group). Overall, firewood was the main source for cooking in this area.

Local people's viewpoints on the drivers of deforestation and forest degradation in the study area

Respondents reported that some main drivers of deforestation and forest degradation in those areas were extracting timber for commercial and house constructing purposes, shifting cultivation, inadequate forest management, bribes to forest rangers, felling trees for firewood and bamboo shoots, converting natural forests to plantation forests, and poverty. There were several differences in these drivers between the three villages (Fig. 6). The differences between P village and other two villages were the two largest drivers, including timber extraction for commercial and house constructing purposes and the existence of poor forest management and bribery. From P village to N village and T village (from core zone to buffer zone and outside of the BBNP) there was a decrease in the contribution of timber extraction for commercial and house constructing purposes and an increase in shifting cultivation and the conversion of natural forests to plantation forests. These differences clearly described the change in the forest and could be explained by the differences in forest management in the three village locations. P village was located in the special-use forest - core zone of BBNP with the highest forest protection policies and had many rare and valuable timber trees. Therefore, threats to this area might be illegal selective logging mostly caused by local people for house construction and outsiders for commercial purposes. Those threats were supported by the connivance of forest rangers due to bribery. Meanwhile, in T village located in production forest area, due to lax forest management policies the forest could be exploited. Therefore, the more serious threats to the forest might be caused by shifting cultivation and the existence of clear-felling forest. Forest status could be identified by degradation in P village and deforestation in T village. We will give more detail and precise evidence about the forest cover

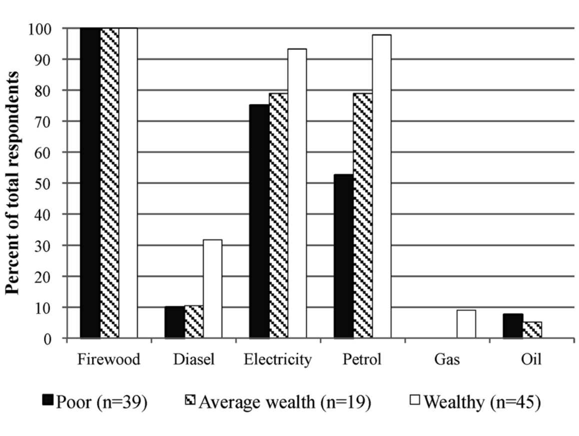

Fig. 5. Domestic energy sources by income level in the three villages, 2011.

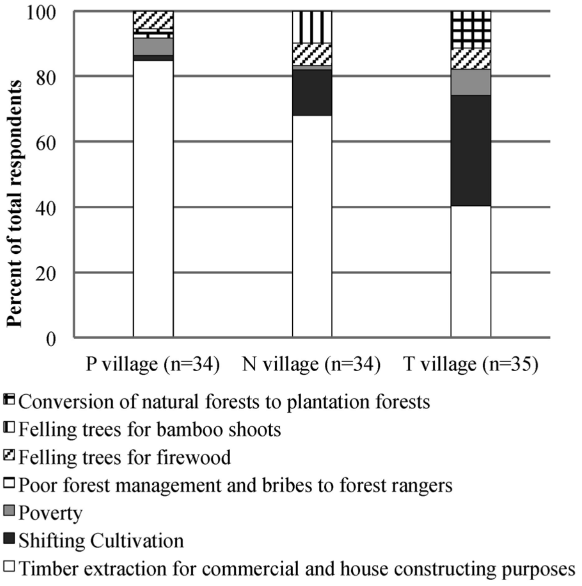

Fig. 6. Local people's viewpoints on the drivers for deforestation and forest degradation in the study area.

change in the study area in the following section.

Moreover, the top ten solutions for better forest management that local people suggested were forest land allocation, strengthening forest patrol and protection, giving more subsidies for local people to enhance their living conditions, job creation and orientation, strengthening awareness of local people, more strict management of illegal logging, house construction support and enhance participation and cooperation between local government and local people.

Land use changes in the study area from 1990 to 2010

In Nam Mau commune, special-use forest was 100% natural forest. Forest area slightly decreased from 1990 to 1995, remained stable from 1995 to 2000, and gradually increased from 2000 to 2010 (Fig. 7). Quang Khe commune comprised protection forest and a small area of special-use forest: natural forest cover that declined considerably from 1990 to 2000, and since 2000 had almost remained the same. Planted forest was begun in 2000; however planted forest area rose slowly by approximately 32 ha within a ten-year period. Thus the total forest cover of the commune followed the same trend of natural forest with a significant decreased from 1990 to 2000 and had remained stable since then. In Dia Linh commune - production forest, natural forest dramatically fell from 1990 to 2000 (steeper slope from 1995 to 2000) and since then had remained stable. As the afforestation policies began in 1995, planted forest cover increased significantly from 1995 to 2010. Accordingly, the total forest cover of the commune gradually decreased from 1990 to 2000 and had increased considerably since then. Therefore, in general, the year 2000 could be considered as a switch point for the implementation and effects of forest policies to be manifested in the study areas. Thus, the following sections of this study only focus on estimating the emissions and opportunity costs of land use changes for the ten-year period from 2000 to 2010.

Economics of land uses

NPV per hectare of annual cultivation land was calculated for rice and other mix crops for each household using the equation 1 with $t = 0$. The mean value of NPV was used for each village. Due to natural disasters in 2011,

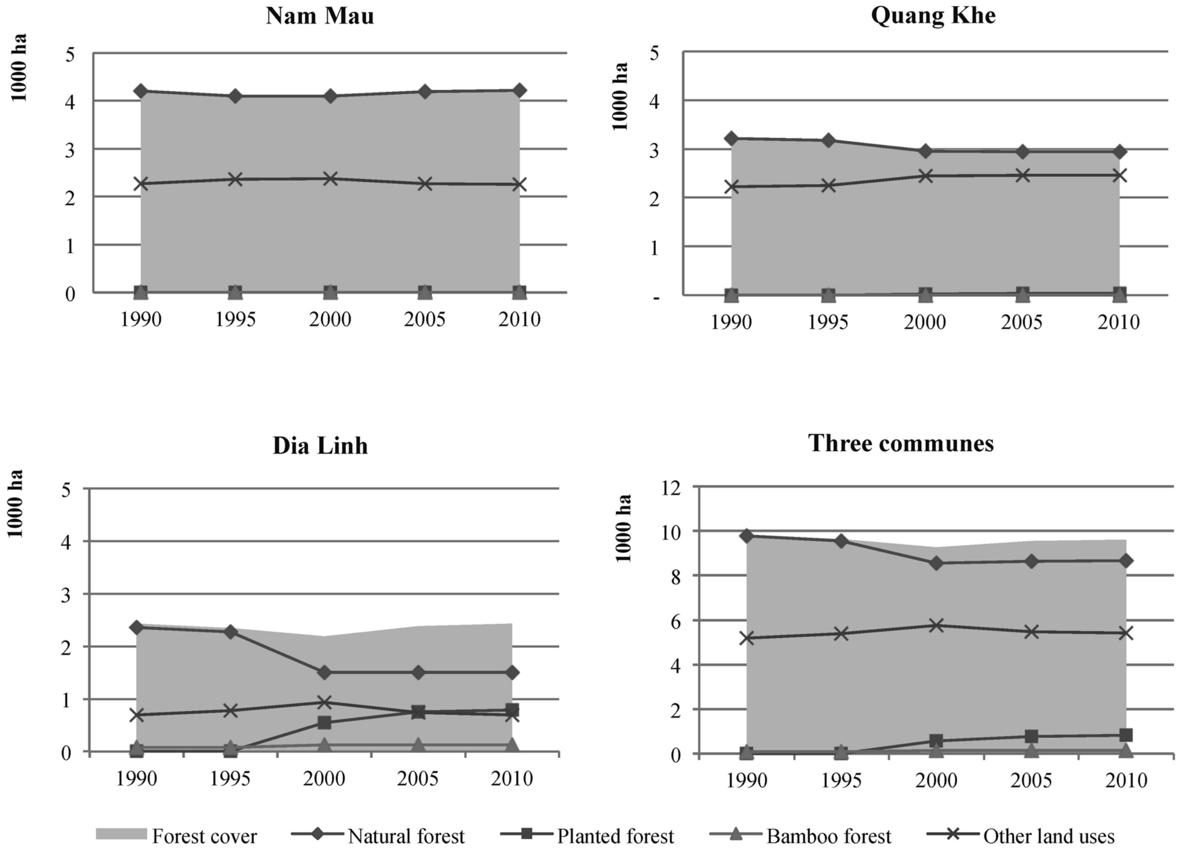

Fig. 7. Land use changes in the three communes, 1990–2010.

the rice productivity of some households was lost or reduced. Thus, when processing the data, all the households who experienced loss were skipped to get a more accurate NPV for each village. Accordingly, NPV of rice cultivation land in P village, in N village and in T village were US \$850.42 ha^{-1}, \$1,070.79 ha^{-1} and \$1,099.25 ha^{-1} respectively. In addition, the NPV of other annual mixed crops cultivation land was US \$865.12 ha^{-1} in P village, \$1,118.69 ha^{-1} in N village, and \$542.18 ha^{-1}.in T village. Overall, in the three villages, the NPVs of annual rice cultivation and mixed crop land were approximately US \$1,009.36 ha^{-1} and \$833.95 ha^{-1} respectively.

According to our survey and the information provided by local government, planted trees in this area comprised mainly Mo, Keo (*Acacia mangium)*, and Caribbean pine (*Pinus caribaea*). Based on planting and growth rate, the time horizon until felling for Mo, Keo and pine trees were 10 years, five years and 15 years respectively. Thirty two out of 33 interviewed households participating in afforestation planted Mo. Local people preferred to sell the standing trees to the buyer at a price of VND 12,500 (US \$0.6) per tree (authors' household survey, 2012). In order to fell planted trees, they had to get permission from local government. Customarily, local people were not familiar with these administrative procedures. Therefore, they sold the standing trees, which could be logged, in their allocated forest at a cheaper price than the real market-based cost. The costs of planted forest included labour and seedling costs. Labour cost was estimated based on the requisite technique for planting Mo, working days provided by local people, and household income per day. Seedling cost was calculated by multiplying the number of planted seedlings with the price of seedlings provided by the Department of Agriculture and Rural Department of Bac Kan Province in 2010, which cost VND 690 (US \$0.03) per seedling. Discount rate (r) was the mean of interest rates of the State Bank of Vietnam from 2001 to 2010, which was approximately 8.5%. The NPV of one ha of planted forest was estimated at US \$306.36.

The findings showed that when forest was converted to agricultural land, aboveground carbon stocks reduced considerably meanwhile the NPV of land uses significantly increased. Other changes of land use decreasing the carbon stocks were from rich timber forest to medium timber forest, from medium timber forest to poor timber forest, from poor timber forest, forest on rocky mountain, recovered timber forest and mixed forest to planted forest, and from forest to bare land without forest or bare land with scattered trees or rocky mountain without forest. However, the relationship between time-averaged carbon stock and NPV was not only a downward trend. It also indicated some win-win and lose-lose outcomes for the connection between carbon stocks and the NPV of land use. The change from poor timber forest to medium timber forest, for example, increased both carbon stock and NPV (refer to Appendix 2 for detailed information about carbon stocks and NPV for each land type).

Generation of opportunity cost curve from 2000 to 2010

We categorized the changes of land use in the study areas into five groups, including forest enhancement, afforestation, deforestation, forest degradation and other land-use changes. Forest enhancement and afforestation groups comprised land use changes that increase the quality or area of forest and vice versa deforestation and forest degradation groups consist of land use changes causing a decrease in

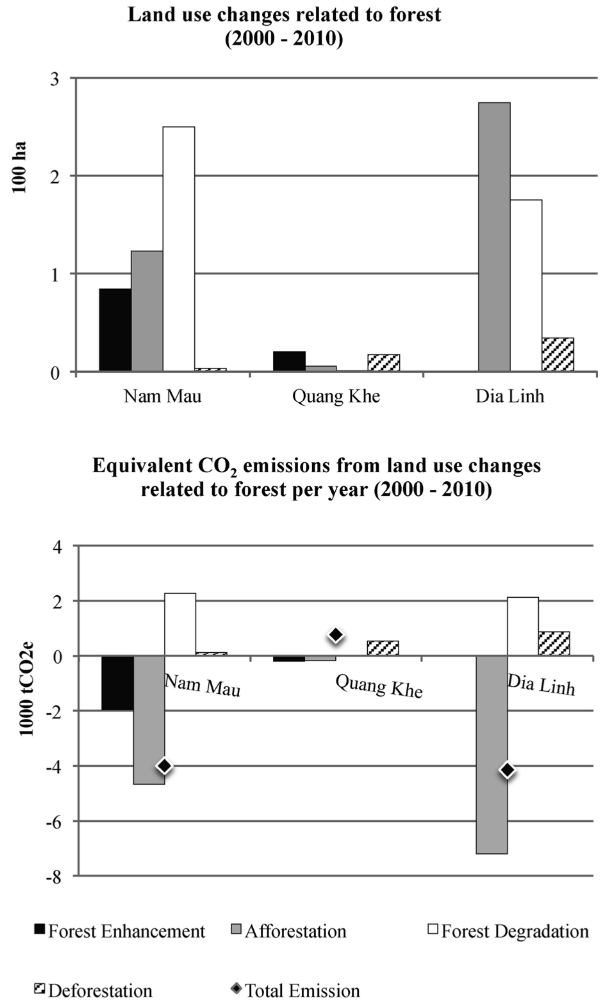

Fig. 8. Land use changes related to forest and equivalent CO_2 emissions from those land use changes per year in the three communes, 2000–2010.

forest area and quality. From 2000 to 2010, due to the change and success of some forest policies, the forest development trend of the three communes showed a marked shift. As shown in Fig. 8, although forest degradation still occurred consistently in Nam Mau and Dia Linh communes, deforestation reduced significantly. In Nam Mau commune, the area of deforested land was less than 15 ha per year and 20 ha per year in Dia Linh and Quang Khe communes respectively. Forest enhancement and afforestation activities were implemented in Nam Mau commune. Dia Linh commune paid more attention to afforestation. Nevertheless, the noticeable growth in forested area brought a great reduction in emission for Dia Linh commune leading to the highest level of emission reduction in total. Emission still occurred in Quang Khe due to the lack of forest development activities in this area. Overall, in the three communes, the net emission per year was about -7,374 tCO_2e. In other words, in three communes, carbon sequestration increased 7,374 tCO_2e per year. In which, the contribution of Nam Mau, Quang Khe and Dia Linh was approximately 4,000 tCO_2e, -775 tCO_2e, and 4,149 tCO_2e per year respectively.

Using NPV and carbon stock data for each type of land use, and its changes over the period 2000−2010, an opportunity cost curve was constructed for each commune using REDD Abacus software. The main results are shown below.

Land use changes which had considerable effect on reducing emission in Nam Mau commune were recovered timber forest to medium timber forest, rocky mountain without forest to forest on rocky mountain, and shifting cultivation to bare land with grass and shrub; in Quang Khe commune were bare land with grass and shrub to planted forest and recover timber forest to poor timber forest; and in Dia Linh commune were bare land with scattered trees to planted forest and bare land with grass and shrub to planted forest. Fig. 9 shows the main conversion of lands that caused GHG emission in the three communes in the 10-year period from 2000 to 2010. The opportunity costs for avoiding the conversion of these land uses ranged from US \$-1.22 tCO_2e^{-1} to US \$231.78 tCO_2e^{-1}.

Some avoidance options had negative opportunity costs, which mean potential benefits. In Nam Mau commune, these potential benefits which came from the avoidance of poor timber forest to recover timber forest (US \$-0.16 tCO_2e^{-1}) and forest on rocky mountain to rocky mountain without forest (US \$-0.03 tCO_2e^{-1}) could reduce about 2,388 tCO_2e emission per year. In Quang Khe, the avoidance of changes from recovered timber forest to bare land with scattered trees (US \$-0.08 tCO_2e^{-1}) and from recovered timber forest to bare land with grass and shrub (US \$-0.07 tCO_2e^{-1}) could reduce about 430 tCO_2e emission per year. In Dia Linh, the avoidance of changes from planted forest to bare land with scattered trees (US

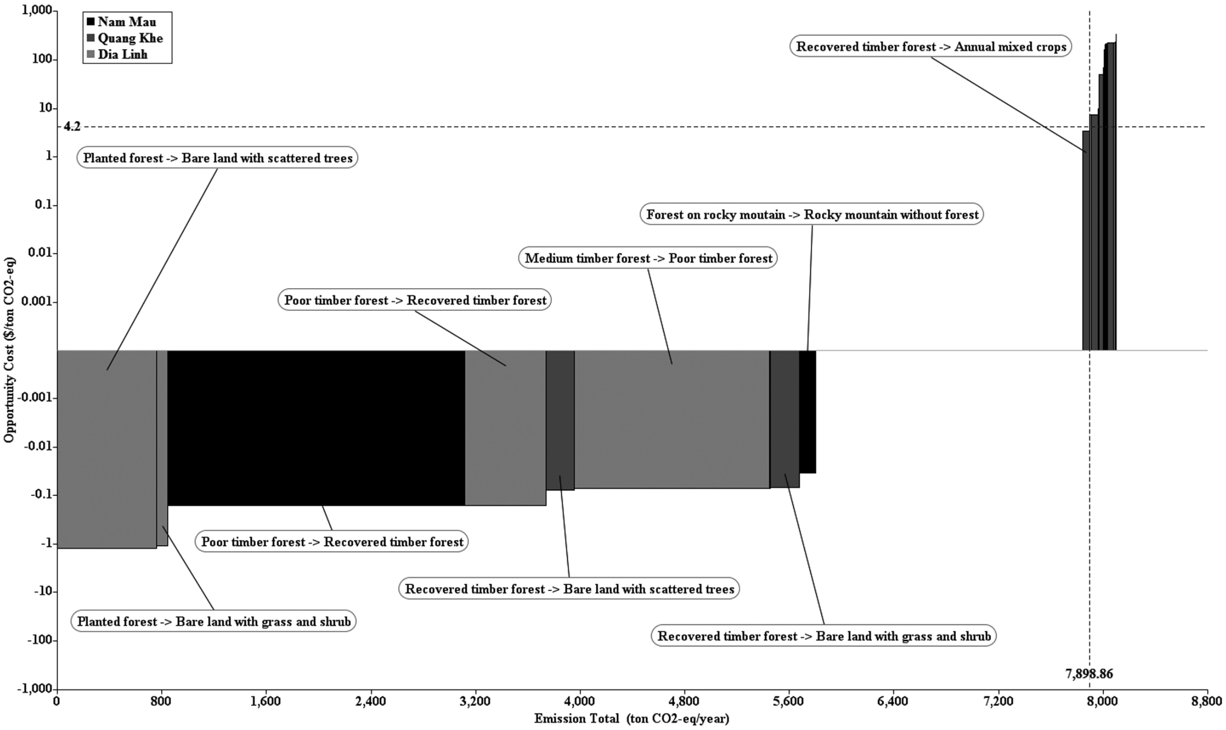

Fig. 9. Land use changes causing GHG emissions and their opportunity costs, 2000−2010.

$-1.22 tCO_2e^{-1}), from planted forest to bare land with grass and shrub (US $-1.06 tCO_2e^{-1}), from poor timber forest to recovered timber forest (US $-0.16 tCO_2e^{-1}), and from medium timber forest to poor timber forest (US $-0.07 tCO_2e^{-1}) could reduce nearly 3,000 tCO_2e emission per year.

For positive opportunity costs, the lowest opportunity cost was the avoidance of the shift from recovered timber forest to annual mixed crop (US $3.39 tCO_2e^{-1}) in Quang Khe Commune. Other remaining options were the avoidance of the changes from recovered timber forest to shifting cultivation, from bare land with scattered trees to shifting cultivation, and from bare land with grass and shrub to shifting cultivation in Quang Khe commune; from recovered timber forest to shifting cultivation, recovered forest to planted forest, bare land with grass and shrub to annual crop-rice and bare land with grass and shrub to annual crop-rice in Dia Linh commune. The opportunity costs of those options varied between US $7.34 tCO_2e^{-1} and US $333 tCO_2e^{-1}. Assessing the average REDD offset price in 2013 at about US $4.2 tCO_2e^{-1}, these costs were far higher and might not be compensated by the current market carbon price.

DISCUSSION AND CONCLUSION

Profitability assessment shows that industrial perennial crops have the highest profit among all land use types in the study areas (US $8,830 ha^{-1}). In general, benefits from agricultural land are considerably higher than forestland (including planted forestland) where the lowest benefit from agricultural land (US $542.18 ha^{-1} - annual mixed crops) is nearly twofold higher than that from forestland (US $306.36 ha^{-1} - planted forest). Moreover, within types of forest land, planted forests (US $306.36 ha^{-1}) shows approximately six times as much profit as natural forest (US $46 ha^{-1} - medium timber forest). These findings are consistent with a previous study conducted in Bac Kan Province, Vietnam (Hoang and Do 2011), which also presented a lower NPV for forestland and natural forest compared to agricultural land and plantation forest, respectively. Other study on the opportunity costs of land use changes conducted in Dak Lak, Lam Dong Province, Vietnam indicated a small difference where NPV of plantation forest is higher than that of agricultural land. NPV of natural forest, nevertheless, is still considerably lower than that of plantation forest (Hoang et al. 2010). Due to the considerably lower benefits, current monetary incentives for forest protection and plantation, especially the protection of natural forest, are not sufficient enough to facilitate the participation of local people. This exposes the high potential for forest degradation and deforestation in those areas.

Related to the status of forest types and forest management types, the findings of this study reveal that, rich-medium-poor timber forest and forest on rocky mountain area (natural forest) has remained almost stable in Quang Khe and Dia Linh communes. Moreover, the medium timber forest and forest on rocky mountain has gradually increased. The deforestation in the study area has been prevented successfully. However, forest degradation still occurred even in the core zone of BBNP. The main drivers are illegal logging in the core zone and buffer zone (special-use forest and protection forest), shifting cultivation and forest exploitation in production forest. Moreover, due to the low benefit and the current land allocation policies, local people are not very interested in forest related activities, especially forest protection. In order to derive applicable REDD+ implementation policies, it is necessary to consider a variety of land use planning strategies for enhancing both environmental protection and local economic development.

From 2000 to 2010, several land use changes such as the conversion of poor timber forest into recovered timber forest, medium timber forest into poor timber forest and planted forest into bare land with scattered trees caused more than 8,000 tCO_2e emissions per year. Regarding opportunity costs, most of the avoidance options have potential benefits. Within the current market carbon price, the avoidance can be applied to reduce approximately 7,900 tCO_2e emissions (about 98% reduction) per year in the three communes. This confirms our statement in the beginning of this paper that even being a forest-gained country, Vietnam could still participate in REDD+ by increasing carbon stock and conserving carbon storage through protecting natural forests and reducing forest degradation.

Furthermore, to identify and recognize forest problems in each type of forest, we observe an adequate combination of technical and local community approaches in problem identification. With regard to forest threats, the experience and observation of local people and the land use change analysis indicates the close relationship and the support between the two. The analysis of land use change maps gives precise information about forest cover changes and status. Forest dwelling people, for instance, live nearest to forests and have long-time empirical knowledge on their forests, thus they can thoroughly understand the surrounding forests. Thus, accessing the knowledge and views of local people provides general information about the real situation for both the drivers of change in the forestry sector and change itself. A synthesis of this information is a sophisticated reference for policymakers. This conclusion is supported by previous studies. Numerous studies point out that consideration of local people's needs and opinions in policy design to enhance their active participation is a pillar for the success of community-based management mechanism (Agrawal and Ostrom 2001, FAO 2010, Chen et al. 2012, Niraula et al. 2013, Tavares et al. 2014). In particular, the United Nations Framework Convention on Climate Change (UNFCCC) recognizes the essentials of 'the full and effective participation' of local communities in safeguarding the implementation of Reducing Emissions from Deforestation and forest Degradation (REDD +) (UNFCCC 2010).

Responding to the results, some suggestions for forest policies are as follows: strengthening the practice of preventing illegal logging by supporting local people who participate in forest protection and management and improving the cooperation among local people, forest rangers and the government; subsidizing or providing materials for local people to construct and maintain their houses; creating job and training for local people to ensure a stable income; enhancing the shift from using firewood for cooking and heating to other energy sources such as electricity, gas and diesel; and promoting forestland allocation. Additionally, forest policies also need to consider several different solutions for each zone. In the core zone, forest policies should focus on increasing the salary of rangers, and strict handling of bribes, and strengthening forest patrols and protection with the participation and observation of local people. In the buffer zone, forest policies should focus more on the prevention of shifting cultivation and felling tree for bamboo shoot collection. Surrounding BBNP, forest policies should reconsider the conversion of natural forest to production/plantation forest and the prevention of shifting cultivation.

Furthermore, under the REDD + mechanism, Vietnam as a forest gain country can aim for the improvement of carbon stock in the forest sector. Emission mitigation options can be implemented in different forest types, for instance, forest policies should focus on reforestation to turn rocky mountain without forest to forest on rocky mountain; the avoidance of the change from recovered forests and planted forests to bare land; and the avoidance of forest degradation such as from poor timber forests to recovered timber forests and medium timber forests to poor timber forests. Particularly, in the core zone, avoidance can be applied to the conversion from poor timber forest to recovered timber forest and from forest on rocky mountain to rocky mountain without forest. In the buffer zone, avoidance could be applied to the conversion from recovered timber forest to bare land with scattered trees and grass and shrub and from recovered timber forest to annual mixed crops. In areas surrounding BBNP, avoidance could be applied to conversion from planted forest to bare land with scattered trees and grass and shrub, from poor timber forest to recovered timber forest and from medium timber forest to poor timber forest.

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Appendix 1. Land-use classification in Vietnam since 2009 adapted from MARD (2009) and Hoang and Do (2011).

Land-use group	Land-use type	Definition of forests
Forest	Rich timber forest	Forests have a timber reserve of 200 m^3 ha^{-1}–300 m^3 ha^{-1}
	Medium timber forest	Forests have a timber reserve of 101 m^3 ha^{-1}–200 m^3 ha^{-1}
	Poor timber forest	Forests have a timber reserve of 10 m^3 ha^{-1}–100 m^3 ha^{-1}
	Recovered timber forest	Forests formed through natural regeneration on land already deforested due to milpa cultivation, forest fires or exhaustive exploitation
	Bamboo forest	Forests consisting of species from the bamboo family
	Mixed forest	Forests encompass both broadleaf trees and needle leaf trees in which each kind of these trees accounts for between 25% and 75% of the total number of trees
	Forest on rocky mountain	Forests grow on rocky mountain or rocky areas with or without a sparse soil surface
	Planted forest	Forests formed through plantation.
Mosaic	Shifting cultivation	—
Non-forest vegetation	Rocky mountain without forest	—
	Bare land with grass and shrub	—
	Bare land with scattered trees	—
Agriculture	Industrial perennial crop	—
	Mixed fruit garden	—
	Annual crop rice	—
	Annual mixed crops	—
Non-vegetated	Settlement	—
	Specially used land	—
	Water surface	—

Appendix 2. Carbon stocks and NPV for each type of land adapted from Hoang and Do (2011)

Land-use classification	Carbon stock** (tCO_2e)	NPV (US $ ha^{-1})***				Rotation (Year)
		Nam Mau	Quang Khe	Dia Linh	Mean	
Rich timber forest	202.60	21.50	21.50	21.50	21.50	Not defined, calculated for last 7 years
Medium timber forest	156.50	46.00	46.00	46.00	46.00	as above
Poor timber forest	117.90	36.00	36.00	36.00	36.00	as above
Recovered timber forest	93.20	21.50	21.50	21.50	21.50	as above
Bamboo forest	13.00	27.50	27.50	27.50	27.50	as above
Mixed forest	85.20	27.50	27.50	27.50	27.50	as above
Forest on rocky mountain	116.80	13.00	13.00	13.00	13.00	as above
Planted forest*	85.20	306.36	306.36	306.36	306.36	10 (Mo)
Rocky mountain without forest	13.19	0.00	0.00	0.00	0.00	NA
Bare land with grass and shrub	6.41	0.00	0.00	0.00	0.00	NA
Bare land with scattered trees	16.85	0.00	0.00	0.00	0.00	NA
Industrial perennial crop	11.37	8830.00	8830.00	8830.00	8830.00	20 (tea)
Mixed fruit garden	9.70	4275.00	4275.00	4275.00	4275.00	30
Annual crop-rice*	5.00	850.42	1070.79	1099.25	1009.36	1
Annual mixed crops*	5.00	865.12	1118.69	542.18	833.95	1
Shifting cultivation	3.45	2436.00	2436.00	2436.00	2436.00	1
Settlement	0.00	0.00	0.00	0.00	0.00	NA
Specially used land	0.00	0.00	0.00	0.00	0.00	NA
Water surface	0.00	1576.70	1576.70	1576.70	1576.70	2 (aquaculture)

Note: *NPV of this land use type was calculated by the authors based on a field survey in 2012.

**Data prepared by Forest Resources and Environment Center (FREC) - Forest Inventory and Planning Institute (FIPI), National Institute and National Institute for Agricultural Planning, and ICRAF Vietnam using remote sensing and plot-level data collection, Rapid Carbon Stock Appraisal (RaCSA) (for more information about the RaCSA methodology please refer to Hairiah et al. (2010)).

***Data prepared by FREC-FIPI, Forest Science Institute of Vietnam and ICRAF through field survey, data synthesis and calculation of NPV.