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Spatiotemporal changes in aboveground biomass in relation to local uses of forest resources in the central mixed deciduous forest area in Myanmar

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မြန်မာနိုင်ငံအလယ်ပိုင်းဒေသ ရွက်ပြတ်ရောနှောတောများတွင် သစ်တောသယံဇာတများ အသုံးချမှုနှင့် ဆက်စပ်၍ အချိန်ကာလအလိုက် ဇီဝဒြပ်ထု၏ ပါဝင်မှုပုံစံ ပြောင်းလဲလာမှုများကို လေ့လာခြင်း

Toshinori OKUDA[1], Mizuki KOBAYASHI[1], Tsukasa HORIKANE[1], Toshihiro YAMADA[1], Ei Swe HLAING[2], Kyi Kyi KHAING[2], Masahiro AMANO[3]

စာတမ်းအကျဉ်း

သစ်တောသယံဇာတများအားဒေသတွင်းအသုံးပြုလာမှု များပြားလာမှုကြောင့် သစ်တောအတန်း အစားကျဆင်းမှုနှင့် ကာဗွန်ထုတ်လွှတ်မှုကို လျှော့ချနိုင်ရန် မြန်မာနိုင်ငံ အလယ်ပိုင်းဒေသ ရွက်ပြတ်ရောနှော တောများတွင် မြေအသုံးချမှုနှင့် ဇီဝဒြပ်ထုပြောင်းလဲလာမှု၊ ထင်းသုံးစွဲမှု၊ မိုးစွေဒေသခံတို့၏ ကြိုက်နှစ်သက်သော မြေအသုံးချမှုပုံစံတို့ကို လေ့လာခဲ့ပါသည်။ ၁၉၉၅၊ ၂၀၀၅ နှင့် ၂၀၁၅ LANDSAT ကောင်းကင်ဂြိုလ်ထု ဓာတ်ပုံများကို အသုံးပြု၍ ၂၀၀ စတုရန်းကီလိုမီတာအတွင်း သစ်တောသယံဇာတလေ့လာဆန်းစစ် ခြင်းမှ ၁၉၉၅ ခုနှစ်မှ ၂၀၁၅ ခုနှစ်အတွင်း သဘာဝမျိုးဆက်တောများနှင့် သက်ကြီးသစ်တောများသည် ၂၅%နှင့် ၂၇% အသီးသီး လျှော့ကျခဲ့ပြီး သစ်တောပြုန်တီးမှု ဖြစ်ပွားပြီးနောက် ချုံတောများသည် ၃၄% အထိ ရှိလာခဲ့ပါသည်။ လေ့လာတွေ့ရှိချက်များမှ ဇီဝဒြပ်ထု ၂၂% လျှော့ကျခဲ့ပြီး ၂၀၀၅ ခုနှစ်မှ ၂၀၁၅ ခုနှစ်အထိမြေအသုံးချမှု ပြောင်းလဲခြင်းနှင့် သစ်တောအတန်းအစားကျဆင်းခြင်းတို့ အများဆုံးဖြစ်ပွားခဲ့ပါ သည်။ ထိုကာလများအတွင်း ဇီဝဒြပ်ထု တိုးလာသည်ဟု ယူဆနိုင်သော်လည်း ဒေသတွင်း ထင်း သုံးစွဲမှုသည် အသားတင် ဇီဝဒြပ်ထု ၂၈%နှင့် မီးသွေးသုံးစွဲမှုသည် အသား တင် ဇီဝဒြပ်ထု ၆၈% ဆုံးရှုံးစေခဲ့ပါသည်။ သက်ကြီးတောကျန်များတွင် တရားမဝင် သစ်ခိုးထုတ်မှုများ ဆက်လျက် ဖြစ်ပွားနေပြီး ဇီဝဒြပ်ထု မြန်မြန်ဆန်ဆန် ကျဆင်းမှုများကို ဖြစ်ပေါ်စေပါသည်။ ထို့ကြောင့် ဇီဝဒြပ်ထုအား ထိန်းသိမ်းကာကွယ်နိုင်ရန် သစ်တောများအတွင်း ကင်းလှည့်ခြင်း များ ဆောင်ရွက် ရန်လိုအပ်လာပါသည်။ လေ့လာတွေ့ရှိချက်များမှ သက်ကြီးတောကျန်များတွင် ဇီဝဒြပ်ထု (ကာဗွန်သိုလှောင်မှု)ကို ထိန်းသိမ်းနိုင်ရန် မြေအသုံးချမှုအလိုက် ဇုန်များ အမြန်ဆုံး သတ်မှတ်ပေး နိုင်ရန်နှင့် ဒေသခံများ၏ ထင်းလိုအပ်ချက်များကို ဖြည့်ဆည်း ပေးနိုင် ရန် ရွာအနီးဝန်းကျင်တွင် သဘာဝတော မျိုးဆက်ခြင်းများကို တွန်းအားပေး ဆောင်ရွက်ရန် လိုအပ်လှပါသည်။

Spatiotemporal changes in aboveground biomass in relation to local uses of forest resources in the central mixed deciduous forest area in Myanmar

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Abstract

To assess the feasibility of a program to reduce carbon emission and degradation of forestland under intensive local uses of forest resources, we studied the land-use and biomass changes, fuel consumption, and land-use preferences of locals in the Moe Swe Tract in central dry deciduous forest area in Myanmar. Based on satellite images (LANDSAT) acquired in 1995, 2005, and 2015 of the target region of 200 km^2 (20 × 10 km), we found that the areas of young regenerating forest and mature forest were reduced by 25% and 27%, respectively, from 1995 to 2015, whereas the area of shrubland that developed after deforestation increased by 34%. Total biomass reduction was estimated as 22% during the study period. Most of the land-use changes and forest degradation occurred from 2005 to 2015. During that period, local use of fuel wood for charcoal accounted for 68% of net biomass losses, although the proportion of fuel wood consumption was 28% when biomass growth was considered. Illegal logging has continued in remnant mature forest areas and was responsible for the rapid biomass reduction, so guarding the forest by patrolling was evidently not effective to prevent biomass loss. Our findings indicate that an action plan of land-use zoning is urgently needed to maintain the biomass (carbon stocks) in remaining mature forest patches and to encourage forest regeneration to meet the local demand for fuel wood in the vicinity of villages.

Key words: carbon stocks, deforestation, forest degradation, local benefit, REDD+, tropical forest

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1. Introduction

Myanmar has suffered from very rapid and intensive deforestation and forest degradation. Approximately 7.44 M ha of forest was lost between 1990 and 2010 (FAO 2010), resulting in a 19% loss of forest land and an annual deforestation rate of 1%, which is higher than any other country in Southeast Asia (FAO 2015). Deforestation has been particularly intense and rapid in areas where the driving forces of land-use conversion are active, such as those in Shan State in northern Myanmar, whereas forest degradation has prevailed in the countryside, particularly in areas adjacent to cropland or new settlements. This land and forest degradation is mostly attributed to the intensive use and dependence on forest resources in Myanmar (FAO 2009, Htun et al. 2013, Rao et al. 2002).

From the viewpoint of global warming and climate change, the protection of forest land in the tropics is an urgent issue. Proper plans of action with economic incentives must be undertaken to conserve forest land and mediate deforestation and tropical ecosystem degradation, which contribute to increased CO_2 emissions at the global scale (Fanin and Van der Werf 2015, Fearnside et al. 2009, Gibbs et al. 2007, Van der Werf and Peterson 2009). Efforts to reduce CO_2 emission from deforestation and forest degradation (REDD+) have been expected to provide such long-term incentives in developing countries, and many experimental trials have been undertaken for the protection of carbon pools in the tropics (Busch et al. 2011, Minang and van Noordwijk 2013, Pasgaard 2013, Sangermano et al. 2012). Nevertheless, tropical forests provide extensive and diverse ecosystem services (e.g., Costanza et al. 1997, Edwards et al. 2014, Myers 1996, Okuda et al. 2003), providing indispensable resources for local communities and people. If it ignores considers on the tangible and intangible benefits of forest, and only highlights carbon pools, the REDD+ scheme will not be successful. Therefore, a strategic plan should be established to find better management options that will secure local benefits under the REDD+ scheme.

However, no quantitative indicators have been proposed to overcome the conflicts between preserving forest carbon pools and providing local benefits. Although the "safeguard" concept has been raised and legitimized, it remains vague and unpractical. Along this line, we urgently need to identify the indicators that facilitate supplying the needs of local communities while maintaining carbon pools. The target area of this study has experienced a reduction in biomass and closed-forest coverage, primarily due the intensive local use of forest resources.

The objectives of the present study are (i) to analyze spatiotemporal land-use and biomass changes in the northern part of the central plain area of Myanmar; (ii) to examine the extent to which local uses (e.g., fuel wood consumption) are contributing to total biomass losses in the target area; and (iii) to suggest some land-use management options that can facilitate the provision of local benefits and reduction of total carbon losses in the study area.

2. Study area and methods

We chose a study area of 10 × 20 km in Moe Swe village and its vicinity (hereafter "Moe Swe Tract"; 19°55'N, 57°54'E), Oke Ta Ra Thiri County of Oke Ta Ra Prefecture, 65 km northeast of Nay Pyi Taw (Fig. 1). Within this area, we surveyed the spatiotemporal changes in land-use and forest biomass (aboveground biomass of forest). The study area is located in the dry zone of Myanmar, and overall the vegetation is characterized as mixed deciduous forest (Chan et al. 2013).

The study area has been designated as a “forest reserve” since the early 20th century (Thein and Naing 2011). In addition to forest land, it includes cropland (mostly paddy fields and mowing and grazing land for cows and water buffalo), secondary forest that regenerated after the harvest of timber trees (mostly teak trees and other canopy-forming trees) in the 1980s, and a teak (*Tectona grandis*) plantation that has been developed and operated by the Forest Department and Forest Research Institute, Myanmar. The Moe Swe Tract includes seven villages (Moe Swe, Leong, Guencho, Banting, Menten Ya, Myo Luwintaya, and Nyan Biye Vine), with a total of 1396 households (personal communication with Mr. Myint, a Moe Swe village head).

The elevation of the study area ranges from 150 to 400 m, with gently and undulate rolling hills and swampy areas where paddy cultivation is practiced. The overall landscape can be described as a flat plateau without any distinct peaks. The average monthly temperature ranges from 24.5 to 32 °C, with a distinct dry season from January to early April and a rainy season from late June to early October. The average temperature and annual precipitation were 24.5 °C and 1421.1 mm, respectively, from 2014 to 2016 (Moe Swe Forest Research Station).

2.1 Land-use changes in relation to local accessibility of the forest resources

We developed land-use maps of the 200-km^2 area for 1995, 2005, and 2015 based on satellite images (LANDSAT TM/ETM+, hereafter LANDSAT) and ground surveys (Fig. 1), and classified six land-use types in the area: (1) tall tree forest (naturally developed mature forest, but traces of commercial logging operations in the 1970s, canopy height > 15 m), (2) young regenerating forest (naturally regenerating forest after the logging operation, but canopy height has been suppressed to <10 m due to fuel wood collection by locals), (3) shrub land (very early stage of succession after clear cutting), (4) paddy fields, (5) cropland, and (6) residential areas (Fig. 1). The maps were subdivided into the grid cells (pixels, 10 × 10 m), which were represented by the most dominant land-use type within each grid cell. The total number of grid cells represents the total area for each land use type.

The land-use classification accuracy was examined by ground-truthing the vegetation map made from the 2015 LANDSAT image. The ground-truthing was conducted in August 2016, so it occurred a year after the 2015 images were captured, but we intended to choose ground-truth points where no extensive land-use operations (e.g., logging or cropland extension) had ever been conducted or not within ___ years prior. We were not able to verify the accuracy of the vegetation maps for 1995 and 2005, but we could examine whether a proved land-use type shown in the 2015 map could be extrapolated to a similar land-use type shown in the 1995 or 2005 map.

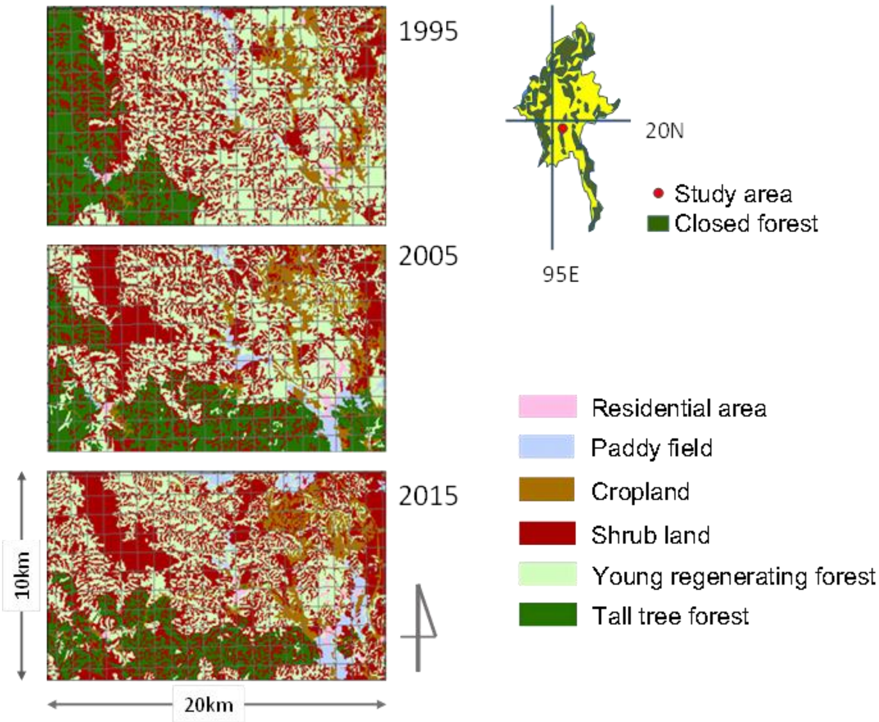

Fig 1. Spatiotemporal changes of land-use types, including paddy fields, cropland (upland farming area), and residential areas in the study area (20 × 10 km). Shrub land, young regenerating forest, and tall tree forest were distinguished by forest physiognomy (closed or open) and canopy height (< 5 m, 5–10 m, and >15 m, respectively) and correspond to the forest community types NGF, GF, and FRA, respectively.

2.2 Aboveground biomass of forest communities based on a plot survey

We placed 46 circular plots (10-m radius) in three types of vegetation classified with regard to the history of the stands: nonguarded forest (NGF, mostly freely accessible forest for the villages, loggers, and other NTFS collectors), guarded forest (GF, young regenerating forests still in the developing stage, under the periodic patrol of district foresters and officers and researchers from the Forest Research Institute), and forests in remote areas (FRA, forests that usually are remote from villages and have poor accessibility for locals).

Within each plot, all trees (≥ 5 cm in DBH) were measured for diameter and height. Aboveground biomass was then calculated for each individual tree based upon its allometric relationship with height and DBH (Chave et al. 2015), and total aboveground biomass (TAGB) was obtained by summing the aboveground biomass of all measured trees in each plot.

2.3 TAGB for each forest community type

By using the number of pixels obtained for the three forest land-use types and mean TAGB of the three forest types (GF, NGF, and FRA), we analyzed the spatiotemporal changes of forest TAGB across the entire study area. Farming (cropland, paddy field) and residential areas were excluded from this analysis, and the three forest types distinguished from LANDSAT images and plot surveys were regarded to correspond with each other; that is, tall tree forest, young regenerating forest, and shrub land identified on the land-use maps corresponded to FRA, GF, and NGF, respectively. The mean values of TAGB calculated based on plot surveys were then employed for estimating the TAGB for each forest type identified on the vegetation map.

2.4 Local uses of forest resources and villagers' preferred land-use types

We conducted interviews with Moe Swe villagers regarding their charcoal consumption for fuel energy uses. No fossil fuels (e.g., propane gas, kerosene, coal) are available in the village, so all heating materials for cooking come from forest resources. We also interviewed several restaurant owners in the village about their charcoal consumption.

In the present research, we attempted to analyze how local benefit can be secured while sustaining the carbon stocks in the forest. We conducted interviews with members of 31 households, inquiring about their preferred land-use (forest) types in relation to the distance from their residential area. Their preferred land-use types were categorized as either near the village area (< 2 km from the residential area) or remote (> 10 km). These categories are intuitive and reflect whether the fuel and other forest resources are within a walking distance so that villagers can collect timber or fuel wood materials manually without mechanical power (e.g., trailer).

3. Results and Discussions

3.1 Land-use changes in relation to local accessibility of forest resources

The results showed that deforestation was more apparent and serious during the decade from 2005 to 2015 than in that from 1995 to 2005 (Fig. 2). During the 20-year study period, the shrub land increased by 34%, whereas young regenerating forest and tall tree forest decreased by 25% and 27%, respectively. The area of tall tree forest had actually increased by 21% from 1995 to 2005, but it sharply declined by 38% from 2005 to 2015. This variation is probably due to progressive forest maturity that occurred in the southeastern part of the study area, where the proportion of young regenerating forest decreased because the trees matured into tall tree forest from 1995 to 2005. Thus far, we have no evidence that can clearly explain why such progressive succession occurred in this area, but it may be attributable to the temporary fallow period of shifting cultivation or the cessation of human-induced forest fires. Forest degradation with reductions in canopy height and biomass volume has been more frequently observed on the upper part of the hillslopes and on ridge tops than in the lower part of hills or valley floors, where vegetation recovery may be faster. After 2005, both tall tree and young regenerating forests decreased from the original forest edges adjacent to farming areas, as paddy field area increased by 196% and cropland (upland farming area) increased by 17% from 1995 to 2015. The residential area did not show any distinct increase, although the population in the Moe Swe village increased by 60% from 1993 to 2015 (personal communication with the village head).

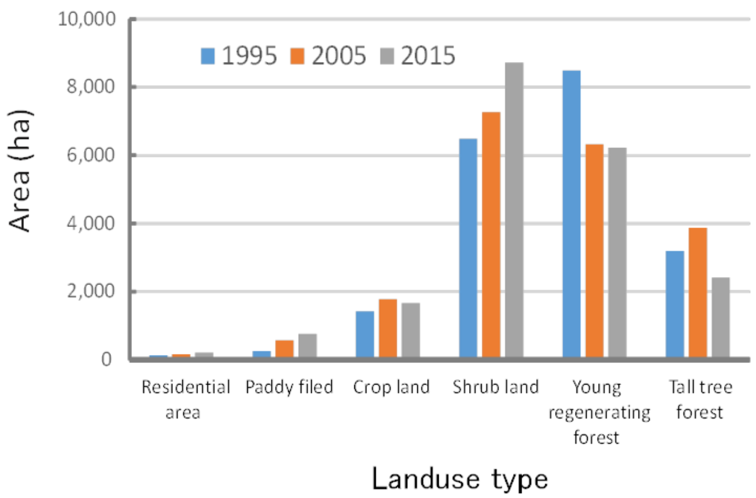

Fig. 2. Temporal changes in the six land-use types (cropland represents upland farming areas), in the 200-km2 study area.

Spatial variation in TAGB

The average TAGB of FRA showed the highest value (1792 ± 32.3 t/ha), followed by GF (116.2 ± 28.5 t/ha) and NGF (6.3 ± 6.8 t/ha; Fig. 3). The difference in TAGB was significant between FRA and NGF (P<0.01, Turkey multiple comparison), but not between NGF and GF, indicating that guarding forest by patrolling does not function in maintaining the TAGB (carbon stock). It should be noted that both GF and NGF are located within a few kilometers of the central part of the village.

Poor accessibility of the forest appears to play a role in maintaining the biomass to some extent. However, considering the illegal logging that still occurs in FRA, the remaining volume may suffer rapid and extensive reduction in TAGB to the level of NGF. During our tree census over the past 1.5 years, our study plots were logged twice. The large merchantable sized trees left by loggers in our first visit were all extracted 1 year later.

The tree census plots in GF and NGF consisted of many small trees (<10 cm DBH), whereas the plots in FRA still included many larger trees (> 30 cm DBH), but as noted above, these areas have suffered from illegal logging during the study period. In contrast, the trees in the GF and NGF were logged mainly for fuel consumption by the villagers, who mostly extract fuel wood from the coppices, because many sprouts were found surrounding main stems of trees in these forest types. The trees are therefore maintained at a small size. As long as trees can sustain regenerating potential to maintain the present standing crop by coppice regeneration, the biomass of GF and NGF can be sustained at present levels, provided the villagers use these forest resources only for the extraction of fuel wood.

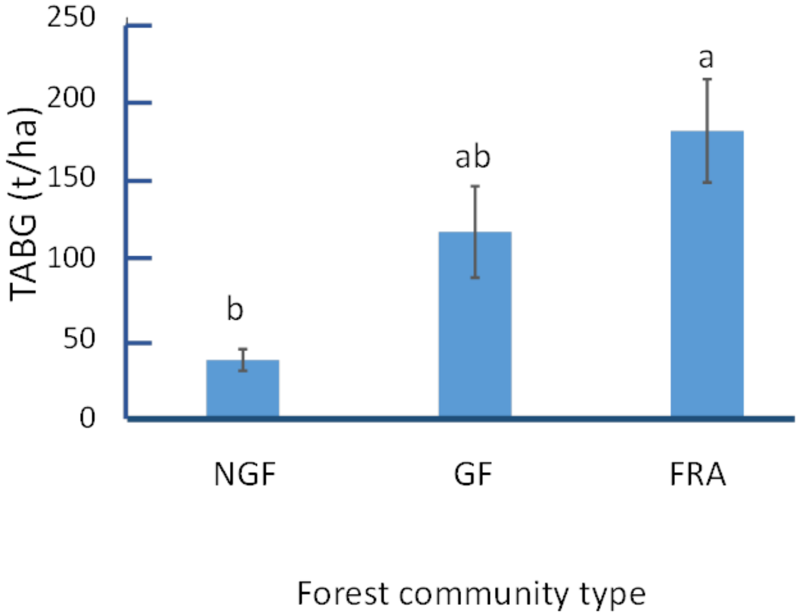

Fig. 3. Average total aboveground biomass (TAGB) in the three types of forest: NGF, nonguarded forest; GF, and guarded forest; FRA, forest in remote area, which correspond to shrub land, young regenerating forest, and tall tree forest, respectively. Vertical bars represent the ±1 SD and different letters indicate a statistical difference between the two forest types ($P < 0.05$).

3.2 Temporal changes in TAGB in relation to local use

The TAGB of the entire study area did not show distinct changes from 1995 to 2005, but it was reduced by 22% between 2005 and 2015 (Fig. 4). This is mainly because forest succession in the southeastern part of the study area offset the reduction of TAGB in the other part, whereas elsewhere TAGB declined from 2005 to 2015 regardless of the distance from forest patches to villages or the main road.

Interviews revealed that fuel consumption by local villagers was about 5 t/year (100 packages × 50 kg) per household. There are about 10 restaurants that each consume fuel charcoal of 18 t/year during regular operation, for a total of 180 t/year. Multiplying the household average by the 1396 households in the village and including restaurant consumption gives total fuel wood consumption of 7160 t/year (carbon basis) or 143,000 t/year (TAGB basis for 10 years) in the study area. The fuel wood is collected within the village area and has not been imported from elsewhere. Thus, we estimate that the consumption of charcoal was responsible for 68% of the net loss of TAGB from 2005 to 2015.

However, this proportion should also be examined while accounting for net primary production. In this respect, given that biomass growth of the dry deciduous forest community in this region is 2–5 t/ha/year during the regenerating stage, the proportion would be reduced to only 13–25% of the net loss of TAGB. If this is the case, then fuel consumption can likely be sustained by the regeneration potential of the forest, provided that proper forest management is introduced, such as AR activities encouraging the natural regeneration or enrichment planting.

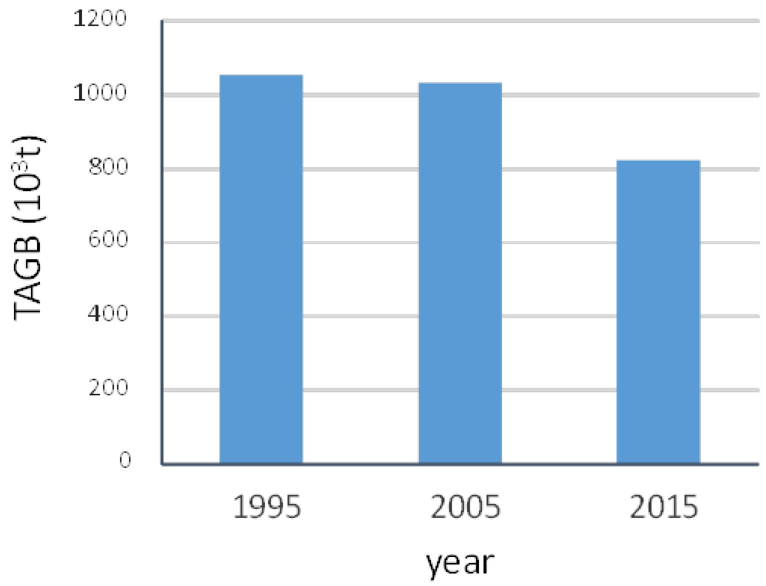

Fig. 4. Temporal changes in total aboveground biomass (TAGB) from 1995 to 2015 in the study area.

3.3 Optional land-use preference and affinity to natural resources by locals

Our interviews revealed that local people tend to prefer forests with high carbon stocks (biomass stocks) and biodiversity (including wildlife), provided they exist in areas remote from their villages. This indicates that local people recognize and accept the tangible and intangible importance of ecosystem services such as those of biodiversity, carbon stock, and CO_2 sequestration, which will be helpful when attempting to implement feasible and practical land-use zoning plans.

4. Conclusions

With regard to the actual differences in GF, NGF, and FRA, we note that guarding operations (by range mangers or forest officer's patrol) are not noticeably effective for protecting the biomass, mostly from local fuel wood consumption. It is also evident that poor accessibility to the forest resources results in greater biomass in forests remote from villages. Thus, the regeneration potential of secondary forest patches in the vicinity of the village will be a key to whether or not local benefit can be sustained in the short- and mid-term periods (<10 years).

In contrast, it appears that the TAGB in FRA will be reduced and no longer serve as a carbon pool, because intensive illegal logging operations are rapidly removing trees from these forests. The main stems of logged trees were processed as planks by loggers using chainsaws and soon extracted from the forest. The remnant parts (twigs and foliage) were then converted to charcoal using temporary on-site char-grills. Thus, the high demand for charcoal is contributing to the biomass losses in FRA. Nevertheless, free access to the timber resources in these areas should be stopped for the implementation of REDD+. It should be noted the one-time logging of large trees results in extensive loss of forest biomass (Fig. 5).

It appears that the distance from the village to the core area of FRA is beyond the villagers' capability of transporting the extracted timbers manually by themselves. Thus, a ban on illegal logging may influence the secondary use of logged trees for charcoal. It should be noted that illegal logging is still common over almost all of the study area. The direct actors contributing to the forest degradation are illegal logging operations, not local fuel users. In fact, the proportion of local fuel use from among total forest production is not extensive (<25%). If forest regeneration is encouraged, forest degradation might be alleviated. Nevertheless, the illegal extraction of large trees will result in the extensive loss of carbon stock from the forest. Unless these issues are solved, the REDD+ scheme will not be achieved.

We suggest that logging operations for timber production should be demarcated (separated) from the livelihood zone and should be under a proper management scheme with stringent control of timber extraction, possibly by the introduction of a chain of custody program. Our interviews with local villagers indicate that they would likely cooperate with a land-use zoning plan. The best mixture of controlled land uses will secure the long-term reduction of CO_2 emission from the projected REDD+ area.

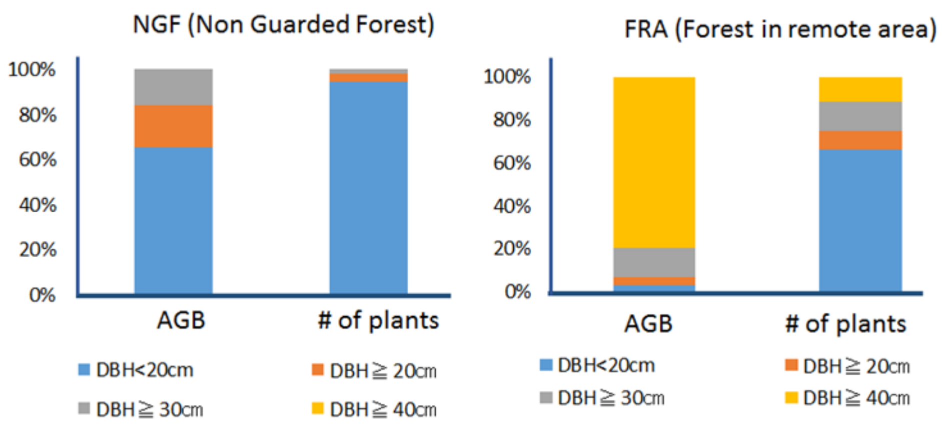

Fig. 5. Comparisons of aboveground biomass (AGB) for each size class and number of individuals between nonguarded forest (NGF) and forest in remote areas (FRA). NGF is located close to the villages. FRA consists of very few large trees that make a large contribution to the TAGB of the forest, whereas NGF consists of a large number of small trees.

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References

Busch J, Godoy F, Turner WR, Harvey CA. 2011. Biodiversity co-benefits of reducing emissions from deforestation under alternative reference levels and levels of finance. *Conservation Letters* 4: 101–115

Chan N., Takeda S., Suzuki R., Yamamoto S. (2013) Establishment of allometric models and estimation of biomass recovery of swidden cultivation fallows in mixed deciduous forests of the Bago Mountains, Myanmar. Forest Ecol and Manage 304: 427–436

Chave J, Rejou-Mechain M, Burquez A, Chaidumayo E, Colgan MS, Delitti WBC, Duque A, Eid T, Fearnside PM, Goodman RC, Henry M, Martinez-Yrizar A, Mugasha WA, Muller-Landau HC, Mencuccini M, Nelson BW, Ngomanda A, Nogueira EM, Ortiz-Malavassi E, Pelissier R, Ploton P, Ryan CM, Saldarriaga JG, Vieilledent G. 2015. Improved allometric models to estimate the aboveground biomass of tropical trees. Global Change Biology 20: 3177–3190

Costanza, R., d'Rage, R., de Grout, R., Farber, S., Grass, M., Hannon, B., Limburger, K., Name, S., O'Neill, R.V., Paulo, J., Ruskin, R.G., Sutton, P., van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253–260

Edwards, D.P., Gilroy, J.J., Woodcock, P., Edwards, F.A., Larsen, T.H., Andrews, D.J.R. et al. 2014. Land-sharing versus land-sparing logging: reconciling timber extraction with biodiversity conservation. Global Change Biology 20: 183–191

Fanin T., Van der Werf G. R. 2015. Relationships between burned area, forest cover loss, and land cover change in the Brazilian Amazon based on satellite data. Biogeosciences 12: 6033–6043

[FAO] Food and Agriculture Organization of the United Nations. (2009) Asia-Pacific Forestry Sector Outlook Study Ⅱ Working Paper Series Working No. Apfesos Ⅱ /WP/2009/07 Myanmar Forestry Outlook Study 2009

[FAO] Food and Agriculture Organization of the United Nations. (2010). Global Forest Resources Assessment 2010 Main report.

[FAO] Food and Agriculture Organization of the United Nations. 2015. Global Forest Resources Assessment.

Fearnside, P. M., Righi, C. A., Graça, P. M. L. d. A., Keizer, E. W. H., Cerri, C. C., Nogueira, E. M., and Barbosa, R. I. 2009. Biomass and greenhouse-gas emissions from land-use change in Brazil's Amazonian "arc of deforestation": The states of Mato Grosso and Rondônia, Forest Ecol. Manag. 258: 1968–1978

Htun NZ, Mizoue N, Yoshida S (2013) Changes in determinants of deforestation and forest deforestation and forest degradation in Popa Mountain Park, Central Myanmar. Environmental Management, 51:423–434

Minang, P.A. and van Noordwijk, M. 2013. Design challenges for achieving reduced emissions from deforestation and forest degradation through conservation: Leveraging multiple paradigms at the tropical forest margins. Land Use Policy 31: 61–70

Myers, N. (1996) The world's forest: problems and potentials. Environmental Conservation 23: 156–168

Okuda T., Suzuki M., Numata, S., Yoshida, K., Nishimura, S., Niiyama, K., Adachi N, Manokaran, N. Hashim, M. 2004. Estimation of tree above-ground biomass in a lowland dipterocarp rainforest, by 3-D photogrammetric analysis. Forest Ecol and Management 203: 63–75

Pasgaard, M. 2013. The challenge of assessing social dimensions of avoided deforestation: Examples from Cambodia. Env Impact Assess Review 38: 64–72

Rao M, Rabinowitz A, Khaing ST (2002) Status review of the protected-area system in Myanmar, with recommendations for conservation planning. Conservation Biology16: 360–368

Sangermano, F., Toledano, J. Eastman J. R. 2012. Land cover change in the Bolivian Amazon and its implications for REDD+ and endemic biodiversity. Landscape Ecol. 27: 571–584

Thein DLL, Naing UT (2011) Ministry of Forestry The Union of Myanmar: 21

Van der Werf, E., Peterson, S. 2009. Modeling linkages between climate policy and land use: an overview. Agricultural Economics 40: 507–51