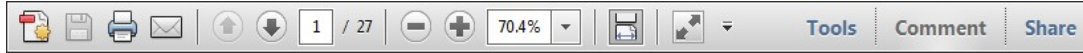
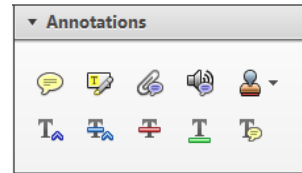


Once you have Acrobat Reader open on your computer, click on the [Comment](#) tab at the right of the toolbar:



This will open up a panel down the right side of the document. The majority of tools you will use for annotating your proof will be in the [Annotations](#) section, pictured opposite. We've picked out some of these tools below:



1. Replace (Ins) Tool – for replacing text.

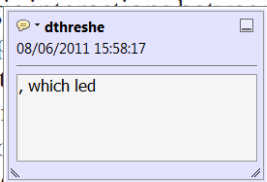


Strikes a line through text and opens up a text box where replacement text can be entered.

How to use it

- Highlight a word or sentence.
- Click on the [Replace \(Ins\)](#) icon in the Annotations section.
- Type the replacement text into the blue box that appears.

standard framework for the analysis of microeconomic activity. Nevertheless, it also led to the development of a number of strategic approaches to the analysis of the number of competitors in an industry. It is that the strategic components of the main components of the industry level, are exogenous to the industry. An important work on this by Shirasaka (henceforth) we open the 'black b



2. Strikethrough (Del) Tool – for deleting text.



Strikes a red line through text that is to be deleted.

How to use it

- Highlight a word or sentence.
- Click on the [Strikethrough \(Del\)](#) icon in the Annotations section.

there is no room for extra profits as mark-ups are zero and the number of firms (net) values are not determined by market structure. Blanchard and ~~Kiyotaki~~ (1987), perfect competition in general equilibrium. The effects of aggregate demand and supply shocks in a classical framework assuming monopolistic competition and an exogenous number of firms

3. Add note to text Tool – for highlighting a section to be changed to bold or italic.



Highlights text in yellow and opens up a text box where comments can be entered.

How to use it

- Highlight the relevant section of text.
- Click on the [Add note to text](#) icon in the Annotations section.
- Type instruction on what should be changed regarding the text into the yellow box that appears.

dynamic responses of mark-ups consistent with the VAR evidence

sation by Markov processes. The VAR model is used to estimate the parameters of the VAR model. The VAR model is used to estimate the parameters of the VAR model. The VAR model is used to estimate the parameters of the VAR model.



4. Add sticky note Tool – for making notes at specific points in the text.

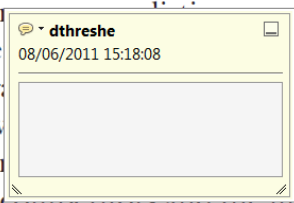


Marks a point in the proof where a comment needs to be highlighted.

How to use it

- Click on the [Add sticky note](#) icon in the Annotations section.
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the yellow box that appears.

and supply shocks. Most of the literature on the effects of aggregate demand and supply shocks in a classical framework assuming monopolistic competition and an exogenous number of firms. The effects of aggregate demand and supply shocks in a classical framework assuming monopolistic competition and an exogenous number of firms.



5. Attach File Tool – for inserting large amounts of text or replacement figures.

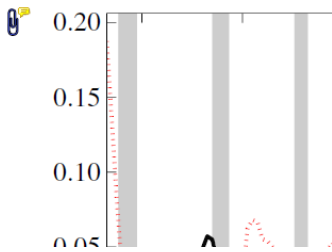


Inserts an icon linking to the attached file in the appropriate place in the text.

How to use it

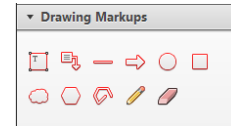
- Click on the **Attach File** icon in the Annotations section.
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.

END



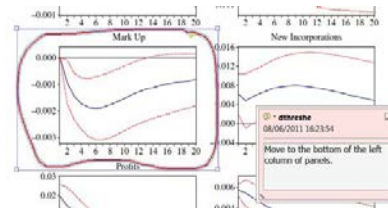
6. Drawing Markups Tools – for drawing shapes, lines and freeform annotations on proofs and commenting on these marks.

Allows shapes, lines and freeform annotations to be drawn on proofs and for comment to be made on these marks.



How to use it

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, move the cursor over the shape until an arrowhead appears.
- Double click on the shape and type any text in the red box that appears.



Co-benefits of biodiversity and carbon sequestration from regenerating secondary forests in the Philippine uplands: implications for forest landscape restoration

1 Sharif A. Mukul^{1,2,4}, John Herbohn^{1,2}, and Jennifer Firm³

1 Tropical Forestry Group, School of Agriculture and Food Sciences, The University of Queensland, Brisbane, Qld 4072, Australia

2 Tropical Forests and People Research Centre, University of the Sunshine Coast, Maroochydore, Qld 4558, Australia

3 School of Earth, Environmental and Biological Sciences, Faculty of Science and Engineering, Queensland University of Technology, Brisbane, Qld 4001, Australia

ABSTRACT

Shifting cultivation is a widespread practice in tropical forested areas that policy makers often regard as the major cause of forest degradation. Secondary fallow forests regrowing after shifting cultivation are generally not viewed as suitable for biodiversity conservation and carbon retention. Drawing upon our research in the Philippines and other relevant case studies, we compared the biodiversity and carbon sequestration in recovering secondary forests after shifting cultivation to other land uses that commonly follow shifting cultivation. Regenerating secondary forests had higher biodiversity than fast growing timber plantations and other restoration options available in the area. Some old plantations, however, provided carbon benefits comparable the old growth forest, although their biodiversity was less than that of the regenerating forests. Our study demonstrates that secondary forests regrowing after shifting cultivation have a high potential for biodiversity and carbon sequestration, representing an effective strategy for forest management and restoration in countries where they are common and where the forest is an integral part of rural people's livelihoods. We discuss the issues and potential mechanisms through which such dynamic land use can be incorporated into development projects that are currently financing the sustainable management, conservation, and restoration of tropical forests.

Key words: community forestry; forest degradation; reforestation; shifting cultivation; trade-off.

DEFORESTATION AND FOREST DEGRADATION ARE AMONG THE MAJOR THREATS TO FORESTS AND BIODIVERSITY IN SOUTHEAST ASIA (Achard *et al.* 2002, Sodhi *et al.* 2010). Shifting cultivation, also known as swidden agriculture or slash-and-burn, has long been seen as the primary agent of deforestation and forest degradation in this region (Angelsen 1995, Ziegler *et al.* 2011). Shifting cultivation involves growing subsistence crops in areas formed by clearing and burning of the primary vegetation within tropical forests. These areas are typically cultivated for a few years and abandoned when the agricultural yields decrease, with farmers then moving to another area and repeating the process. In areas that have been abandoned, secondary vegetation regrows (see Fox *et al.* 2000 for further details). In Southeast Asia, shifting cultivation has been practised for centuries and supports an estimated 14–34 million people (Mertz *et al.* 2009, Dressler *et al.* 2015). However, in the last few decades, political and economic pressure has discouraged this practice (Ziegler *et al.* 2012). Thus, secondary forests regrowing after shifting cultivation are rapidly becoming a prominent forest type in Southeast Asia, constituting approximately 63 percent of the total forest cover (de Jong *et al.* 2001, Koh 2007, Kettle 2010).

The Philippines are a biodiversity hotspot (Myers *et al.* 2000, Posa *et al.* 2008) and a high priority for biodiversity conservation (Conservation International 2013). This country has experienced one of the highest rates of deforestation in Southeast Asia and was one of the first countries to introduce massive reforestation and forest restoration programs to address its rapid forest loss (Chokkalingam *et al.* 2006, Pulhin *et al.* 2007). The National Greening Program (NGP), the country's most recent reforestation initiative, aims to reforest 1.5 million hectares of degraded upland areas by 2016. The success of such efforts are still uncertain, as they are influenced by many factors, and past reforestation programs in the Philippines have had only limited success (see Le *et al.* 2014, 2015).

Shifting cultivation, locally known as *kaingin*, contributes to the livelihoods of many marginal upland farmers in remote rural areas in the Philippines (Kummer 1992, Lawrence 1997). In these areas, three to five million people depend on *kaingin* for their subsistence (Mertz *et al.* 2009). Major forestry policies, however, have aimed to restrict it, assuming detrimental environmental impacts (Suarez & Sajise 2010). The Philippines is one of the pioneers in large-scale restoration and reforestation activities, yet the participation in such efforts by smallholder and subsistence farmers remains very limited (Harrison *et al.* 2004, Pulhin *et al.* 2007). Thus, until local communities are granted greater access to state-regulated reforestation programs, *kaingin* are likely to continue in the country's remote areas (Pulhin *et al.* 2007).

Received 2 December 2015; revision accepted 27 May 2016.

⁴Corresponding author; e-mails: s.mukul@uq.edu.au, sharif_a_mukul@yahoo.com

| | |
|---|-------------------|
| Dispatch: 27.9.16 | CE: Shanthi M |
| No. of pages: 8 | PE: Krishnaveni A |
| WILEY | |
| 12389 | Manuscript No. |
| B T P | Journal Code |
|  | |

Due to the dynamic nature of shifting cultivation, it is difficult to predict environmental outcomes during and after the practice (Mukul & Herbohn 2016). We present evidence that following shifting cultivation with fallow secondary forest can provide biodiversity and carbon co-benefits, thus constituting a cost-effective forest management and reforestation measure. We also draw upon results from other relevant studies to perform a biodiversity and carbon trade-off analysis focusing on alternative land uses, namely plantations of fast growing timber species (*e.g.*, *Acacia* sp., *Swietenia macrophylla*, *Gmelina arborea*), oil palm (*Elaeis guineensis*), coconut (*Cocos nucifera*), grassland (*Imperata* sp. and *Saccharum* sp., rice, sugarcane), and Abaca (*Musa textilis*, a species of banana native to the country and used for fiber). We discuss how these benefits could be integrated into ongoing forest conservation measures such as Payment for Environmental Services (PES), Reducing Emissions from Deforestation and Forest Degradation (REDD+), and Clean Development Mechanism (CDM) projects. We also emphasize measures essential for the success of such efforts, with a focus on forest landscape restoration and local development in the Philippines and in other Southeast Asian countries with similar biophysical and socio-political contexts.

METHODS

STUDY AREA DESCRIPTION.—The Philippine archipelago comprises 7107 islands, with a total land area of approximately 30 million ha (Chokkalingam *et al.* 2006). The country is divided into 17 regions covering 81 provinces, 118 cities, 1520 municipalities, and 41,995 Barangay (the smallest administrative entity, similar to a village). The climate is tropical humid (Kummer 1992). Based on the national land classification system, 53 percent of lands are forest (all areas with a slope above 18%, irrespective of forest cover), and 47 percent are alienable and disposable lands (*i.e.*, lands not classified as forest and with slopes <18%) (Jahn & Asio 2001, Fig. 1).

Upland areas in the Philippines are important for three main reasons. First, most of the remaining forests are there; second, they have been subject to intensified human use since the Second World War; and third, land degradation in the uplands is severe and widespread (Cramb 1998). At the same time, a great deal of uncertainty exists regarding the recovery of biodiversity and carbon stocks in degraded upland secondary forests after varying levels of disturbance and human use (Herbohn *et al.* 2014).

We conducted the empirical part of our study on Leyte Island, the eighth largest island in the country. Leyte has a forest cover of approximately 10 percent; the once extensive dipterocarp rainforests are now mainly patches of disturbed old growth forest. The island is approximately 800,000 ha in area and lies between 124°17' and 125°18' East longitude and 9°55' and 11°48' North latitude. According to Corona's Classification of Climate, Leyte has a 'type IV' climate (Navarrete *et al.* 2013). The island enjoys relatively even distribution of rainfall throughout the year, with annual rainfall totaling about 4,000 mm (Jahn & Asio

2001). Mean annual temperature is 28°C, which remains constant throughout the year (Navarrete *et al.* 2013).

STUDY SITE SELECTION.—Our study sites were in Barangay Gaas on Leyte Island. We selected the area based on its comparatively high altitudinal range (450–650 m asl) and relatively high amount of undisturbed forests with low population density. Both of these factors favor natural regeneration in the *kaingin* fallow forests (Chokkalingam *et al.* 2006). Smallholder farmers living in the area usually grow Abaca or coconut in their *kaingin* fallow area following final abandonment (after several cycles of cropping when the land is no longer suitable for agricultural use) to receive some further financial benefits. We confined our study to the areas where farmers cultivated only Abaca post-abandonment, since coconut plantations generally involve more intensified land management during the fallow periods and do not favor secondary forest development.

DATA COLLECTION.—We undertook a series of extensive field surveys in Barangay Gaas between May and October 2013. We divided our sites into four age categories: new fallows (<5 yr old), young fallows (6–10 yr old), middle-aged fallows (11–20 yr old), and oldest fallows (21–30 yr old). We sampled five sites from each category; all sites were at least 1 ha in size. Within each site, we established four transects of 50 m × 5 m and identified and measured the dbh (diameter at breast height) and height of trees that were at least 5 cm dbh. We placed transects at least 5 m from the edge of the site boundary to minimize any possible edge effect. We also quantified the biomass of dead wood and other non-woody vegetation. More information about the survey design and data collection methods can be found at Mukul *et al.* (2016). Additionally, we sampled old growth forests for a control. Control sites were structurally and floristically similar to intact primary forests and had never been logged or used for *kaingin*. As with almost all forests in the Philippines, they may, however, have experienced limited anthropogenic disturbances (*e.g.*, collection of firewood and wild fruit).

INTERPRETATION AND ANALYSIS.—We used tree species density or the number of unique tree species per unit area in each land use/cover as a measure of biodiversity. We calculated above-ground biomass (Mg or Mega grams) on a per-hectare (ha) basis. We used the generic allometric model developed by Chave *et al.* (2014) for measuring biomass in standing live trees (≥5 cm dbh).

$$AGB = 0.0673 \times (\rho D^2 H)^{0.976}$$

where *AGB* is the aboveground biomass in kg, *D* is the dbh, *H* is the height of the tree, and ρ is the species-specific wood density (g/cm³). We assumed carbon content was 50 percent of the dry woody biomass (Brown 1997) and used our own estimates of wood density based on samples collected from the area. For species where samples for wood density were not available, we used

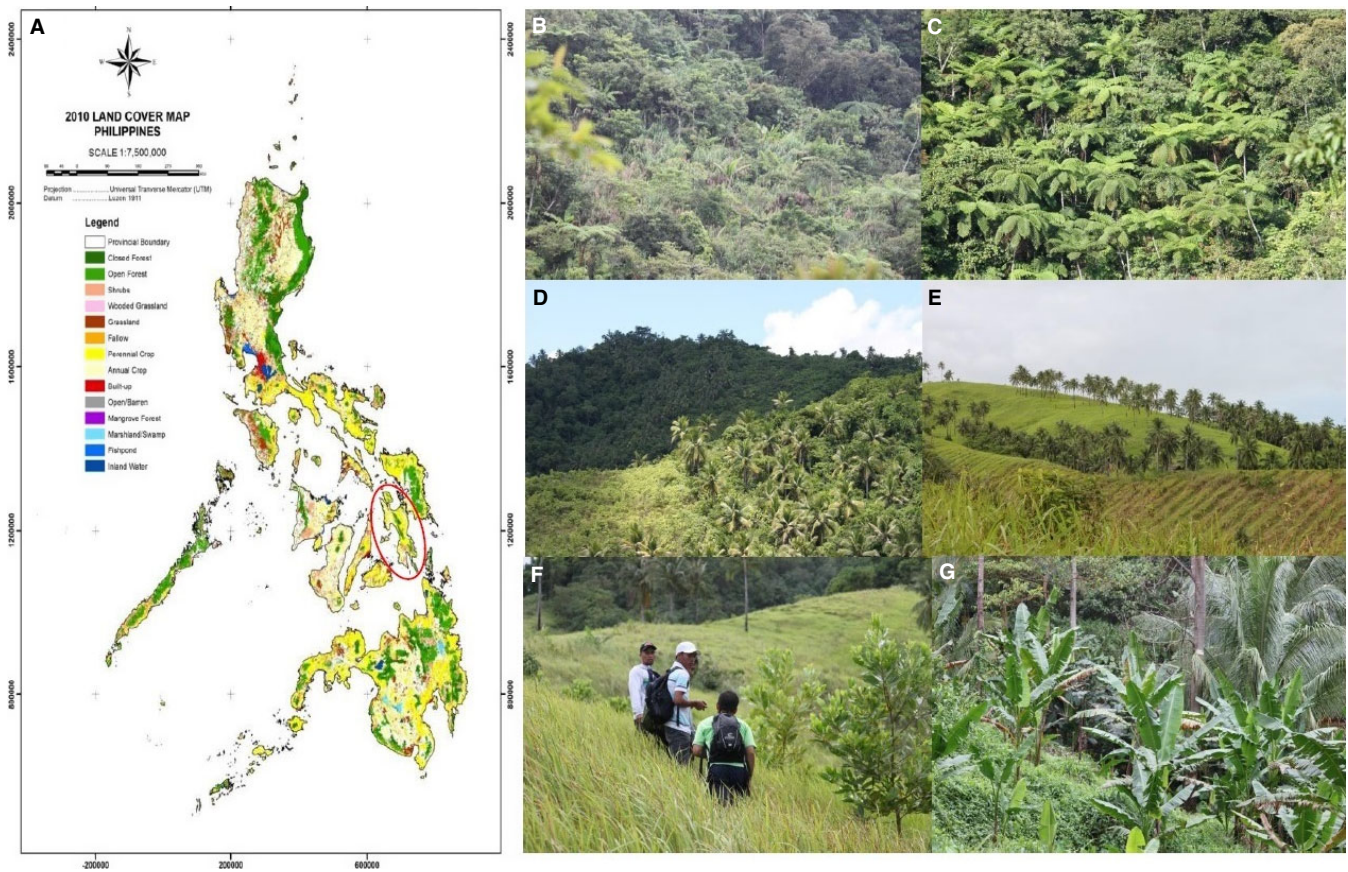


FIGURE 1. (A) Major land use/land cover in the Philippines (Source: Manuel 2014) with a map of Leyte Island, and some common land uses in the upland areas after shifting cultivation (from top-left): (B) regenerating forest dominated by seedlings and undergrowth, (C) secondary forest dominated by tree ferns, (D) old coconut plantation within secondary forest, (E) coconut plantation in grassland, (F) Acacia plantation in upland forest invaded by grassland, and (G) Abaca in the abandoned upland area after *kaingin* (Photo credits: S.A. Mukul).

the genus average wood density, and for species where this was not possible, we used transect average wood density. We also measured biomass in undergrowth, litter, deadwood, and non-woody plants using standard procedures (see Mukul *et al.* 2016 for further details).

We used descriptive statistics for data interpretation and analysis. For the trade-off analysis, we used median value for species density and biomass carbon for each fallow category and the control. We expressed biodiversity and carbon trade-offs as the Ecosystem services benefit (Δ), and calculated it as below (Maron *et al.* 2013):

$$\Delta \text{ Ecosystem services benefit} = \text{Biodiversity or Carbon in old growth forest} - \text{Biodiversity or Carbon in other land use/cover reported from the Philippines.}$$

where ecosystem services benefit (Δ) could be either positive (+) or negative (-), with positive value indicating biodiversity and/or carbon gain and a negative value indicating biodiversity and/or carbon loss.

RESULTS

BIODIVERSITY AND CARBON CO-BENEFITS FROM REGENERATING SECONDARY FORESTS.—Biodiversity in terms of density of tree species was significantly higher ($P < 0.01$) in the oldest fallow sites, followed by old growth forest, middle-aged sites, and young fallow secondary forest. Other indicators of biodiversity, such as the number of locally endemic species (*i.e.*, not found outside of the Philippines), were higher in the relatively old fallow sites (Fig. 2). Aboveground biomass carbon was significantly higher ($P < 0.01$) in the old growth forests compared to all age classes of secondary forest (Fig. 3). Biomass in the other categories mostly comprised deadwood, which was significantly higher ($P < 0.01$) in the new fallow sites and lower in the older sites. Thus, although this area had low population density, we found carbon and biodiversity benefits from more intensified land use and/or secondary forests having shorter fallow periods (see Table 1).

BIODIVERSITY AND CARBON TRADE-OFFS IN UPLAND LAND USE.—The ecosystem services benefits and potential trade-offs

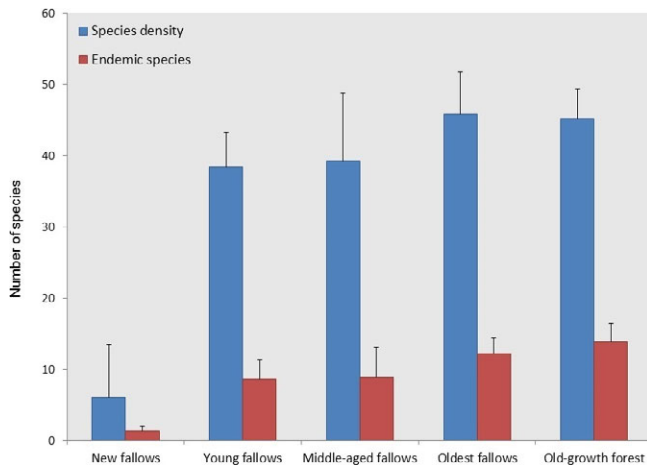


FIGURE 2. Tree diversity in regenerating forest after shifting cultivation in the Philippines uplands.

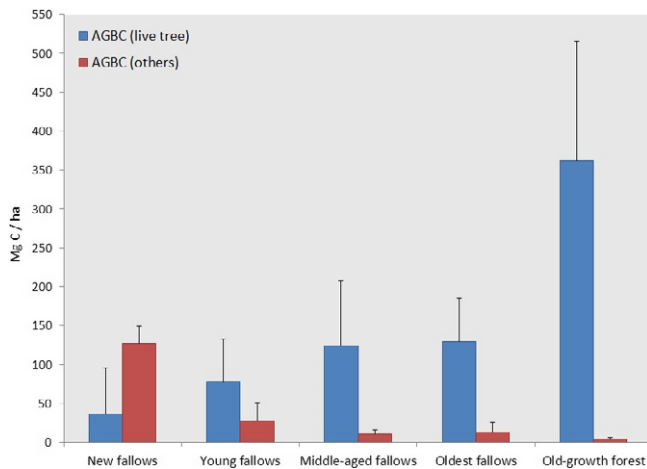


FIGURE 3. Aboveground biomass carbon in regenerating forest following shifting cultivation in the upland Philippines.

associated with regenerating secondary forests after shifting cultivation and other land uses are presented in Table 1. Here, we only consider the biodiversity and carbon benefits for the common uses of land that may replace the secondary forests in the uplands after shifting cultivation has been abandoned. These include land conversion for permanent and/or more intensive sedentary agriculture, plantation and/or reforestation using single species or mixed species, Abaca cultivation, invasion by grassland, and so on. The old growth forest always provided the highest carbon benefits (380.49 Mg C/ha) in aboveground biomass. The 80-yr-old *Swietenia macrophylla* plantation had the nearest carbon stock (264.0 Mg C/ha) to the old growth forest sites, followed by an 80-yr-old mixed plantation of *Parashorea malaanonan* and *Anisoptera thurifera* and *kaingin* fallow sites of various ages (see Table 1). The high level of aboveground carbon biomass in new fallow sites was, however, mainly due to high levels of coarse, dead wood remaining after clearing; this disappears with

increasing fallow age. Due to the limited data available on belowground biomass/carbon, we did not include it in our comparisons. A recent study, however, suggested that carbon estimates without belowground biomass in tropical fallow secondary forests can underestimate the total carbon content in forests by up to 30 percent (McNicol *et al.* 2015).

The biodiversity and conservation importance of the plantations were very low compared to *kaingin* fallow secondary forests (see Table 1). Only fallow secondary forests had the potential to provide relatively similar biodiversity and carbon co-benefits compared to old growth forests. As expected, agricultural use (rice paddy and sugarcane) and plantations of commercially important species such as oil palm, coconut, and fast growing *Gmelina arborea*, exotic *Albizia falcataria*, and *Acacia* species also had lower conservation values and less importance for carbon sequestration than fallow secondary forests regrowing after shifting cultivation or the dipterocarp forest (Table 1). The two mixed plantations provided relatively high carbon benefits in aboveground biomass compared to monocultures of fast growing timber species. The young fallow secondary forest sites had the highest carbon accumulation rate (8.4 Mg C/ha/yr) in aboveground biomass, followed by the middle-aged secondary forest sites (7.9 Mg C/ha/yr). Among the plantations, *Acacia* sp. and *Gmelina arborea* had relatively high biomass carbon accumulation rates compared to other species. The biomass carbon accumulation rate was lower in older stands.

DISCUSSION AND IMPLICATIONS

Forest conservation in the Philippines clearly benefits local livelihoods and mitigates climate change (Sheeran 2006, Lasco *et al.* 2011, 2013). Our results demonstrate that secondary forest regrowing after shifting cultivation can support substantial biodiversity and carbon benefits compared with old growth forests, fast growing timber species, and other commercially important species that may grow on the land after shifting cultivation. While some plantations may also provide more carbon storage and sequestration in tropical countries (see Erskine *et al.* 2006), their conservation value is not always comparable to that of old growth forests or regenerating secondary forests. In addition, successful establishment and maintenance of plantations require large inputs of labor and money, which are not always available (Gregorio *et al.* 2015). As such, regrowing secondary forests after shifting cultivation offers a cost-effective restoration measure when considering the costs of plantation establishment and management (Chazdon & Guariguata 2016). Our findings are consistent with those of Evans *et al.* (2015) and Gilroy *et al.* (2014) showing the high potential of post-agricultural forest regeneration for biodiversity and carbon co-benefits in tropical countries.

The extensive deforestation and degradation of tropical forests is a significant contributor to the loss of biodiversity and to carbon emissions that cause global warming (Budiharta *et al.* 2014, Chazdon 2014). In tropical regions, uncertainties in biomass carbon and forest distribution and recovery are one of the main constraints for including secondary forests degraded by

TABLE 1. Biodiversity and aboveground carbon stocks in biomass in common upland land use/land cover in the Philippines uplands.

| Land use | Species density ¹ | Carbon ² (Mg C/ha) | Ecosystem services benefit ³ | | Stand age (yr) | C sequestration (Mg C/ha/yr) | Source |
|--|------------------------------|----------------------------------|---|-----------------|----------------|---------------------------------|--|
| | | | Δ Biodiversity | Δ Carbon | | | |
| Old growth forest | 45 | 380.49 | – | – | – | | Mukul <i>et al.</i> (2016), Mukul (2015) |
| Post- <i>kaingin</i> secondary forests | | | | | | | |
| New fallow | 5 | 155.1 | –40 | –225.39 | 5 | – | Mukul <i>et al.</i> (2016) |
| Young fallow | 39 | 87.99 | –6 | –292.5 | 10 | 8.43 | Mukul (2016) |
| Middle-aged | 42 | 135.73 | –3 | –244.76 | 20 | 7.87 | As above |
| Oldest fallow | 47 | 155.71 | +2 | –224.78 | 30 | 4.34 | As above |
| Dipterocarp forest | NA | 221.0 | – | –159.49 | NA | – | Lasco and Pulhin (2009) |
| Grasslands | | | | | | | |
| <i>Imperata</i> sp. | 0 | 8.5 | –45 | –371.99 | 1 | 0 ⁴ | Lasco and Pulhin (2009) |
| <i>Saccharum</i> sp. | 0 | 13.1 | –45 | –367.39 | 1 | 0 ⁴ | Lasco and Pulhin (2009) |
| Plantations | | | | | | | |
| <i>Swietenia macrophylla</i> | 1 | 264.0 | –44 | –116.49 | 80 | 3.57 | Racelis <i>et al.</i> (2008) |
| <i>Acacia</i> sp. | 1 | 81.0 | –44 | –299.49 | NA | 6.40 | Lasco and Pulhin (2009) |
| <i>Albizia falcataria</i> | 1 | 48.69 | –44 | –331.8 | 9 | 5.41 | Lasco (2002) |
| <i>Gmelina arborea</i> | 1 | 54.32 | –44 | –326.17 | 9 | 6.1 | Lasco (2002) |
| <i>Parashorea malaanonan</i> <i>Anisoptera thurifera</i> | 2 | 241.25 | –43 | –139.24 | 80 | 3.02 | Lasco and Pulhin (2009) |
| <i>Parashorea malaanonan</i> | 2 | 125.61 | –43 | –254.88 | 80 | 1.57 | Lasco and Pulhin (2009) |
| <i>Dipterocarpus grandiflorus</i> | | | | | | | |
| Oil palm | 1 | 55.0 | –44 | –325.49 | 9 | 6.1 | Pulhin <i>et al.</i> (2014) |
| Coconut | 1 | 86.0 | –44 | –294.49 | 30 | 4.78 | Lasco (2002) |
| Agriculture | | | | | | | |
| Rice paddy | 0 | 3.1 | –45 | –377.39 | 1 | 0 ⁴ | Lasco and Pulhin (2009) |
| Sugarcane | 0 | 12.5 | –45 | –367.99 | 1 | 0 ⁴ | Lasco and Pulhin (2009) |
| Abaca | 0 | 5.7 | –45 | –374.79 | 1 | 0 ⁴ | Lasco (2002) |

NA, not available.

¹Here, we only consider the main and/or characteristics plant diversity of a particular land use.

²Aboveground carbon in forest biomass.

³The difference, either positive or negative between control old growth forest and respective land use/land cover.

⁴No sequestration due to regular harvest.

shifting cultivation in the global voluntary carbon market (Gibbs *et al.* 2007, Mertz 2009, Ziegler *et al.* 2012). Because of the dynamic nature of secondary forests regenerating after shifting cultivation, the instability of biodiversity and biomass carbon in such landscapes can be an issue (Mukul & Herbohn 2016). In such circumstances, biodiversity and carbon co-benefits can be achieved by either avoiding further landscape degradation from intensification or by enhancing natural regeneration. Intensification can be avoided through allowing longer fallow cycles or using multipurpose species that are also common in the forest. Enhancement of natural regeneration, on the other hand, can be achieved through preventing further use of the area for shifting cultivation and by assisted natural regeneration.

Globally, policy makers have recently committed to the Bonn Challenge, an initiative to restore 150 million hectares of degraded forests by 2020 and 350 million hectares by 2030 (Locatelli *et al.* 2015). Furthermore, global forest carbon credits are valued at over US\$100 billion/year and are an emerging,

growing sector (Petrokofsky *et al.* 2011). In 2012, the price of sequestered carbon in the internationally recognized market averaged US\$9.20 per tonne, although in recent years, this has declined (US\$3.8 per tonne in 2014), mainly due to the failure to ratify the next phase of the Kyoto Protocol (Peters-Stanley & Yin 2013, Hamrick 2015). The prospect of including regenerating secondary forests in emerging global carbon markets, however, largely depends on obtaining reliable estimates of carbon together with the biodiversity benefits of a particular land use (Maron *et al.* 2013, Evans *et al.* 2015, Law *et al.* 2015).

Our trade-off analysis found that, in all cases, regenerating secondary forests outperform other land uses and available reforestation options with regard to biodiversity and carbon co-benefits in the upland Philippines. However, we did not consider livelihoods and other social capital that may also be associated with a change in land use or cover in tropical countries, which may respond differently to a changing context (Adams *et al.* 2016). For example, van Vliet *et al.* (2012) found that a decline in

area of shifting cultivation may correlate with a higher income but with lower biodiversity and carbon benefits due to more intensified land use in areas previously used for shifting cultivation. Population density and growth, which are also major drivers of intensification of the shifting cultivation system (van Vliet *et al.* 2012), reduce carbon benefits due to shorter fallow periods and frequent cycles (Lawrence *et al.* 2010).

Due to diverse stakeholder needs, managing tropical forest is always complex and challenging (Yasmi *et al.* 2012). In tropical forest regions, particularly in South and Southeast Asia, there are potential benefits in involving local communities in forest conservation (Balooni & Inoue 2007, Bowler *et al.* 2012, Robinson *et al.* 2014). Programs on PES are increasingly gaining wider recognition for protecting tropical forests and improving the standard of living of smallholders by giving them access to forest management, monitoring, and benefits from carbon trading. The current REDD+ schemes, however, are still limited to a few tropical countries, and the number of CDM projects with afforestation/reforestation objectives remains very limited (Thomas *et al.* 2010). Due to the large areas involved and their importance to smallholders, regrowing tropical secondary forests after shifting cultivation could provide important benefits to both the environment and the local community if properly incorporated in REDD+ and CDM schemes. Our study also reveals that allowing forests to regenerate after shifting cultivation can be an effective restoration approach in the Philippines, with a high potential for integration into REDD+ and CDM. It is, however, critical to involve local community members in such activities, with clearly defined rights and responsibilities (Mukul *et al.* 2014). Improving environmental governance through legal and regulatory reform, better land tenure, land allocation and management, law enforcement, and monitoring are also crucial for the successful implementation and involvement of local people in forest management under REDD+ and CDM schemes (see Grabowski & Chazdon 2012, Le *et al.* 2012, Chazdon 2013, Baynes *et al.* 2015, 2016).

ACKNOWLEDGMENTS

We are grateful to Professor Robin Chazdon for the valuable edits and comments on an earlier draft of this manuscript and to Professors Maria Uriarte, Steve Harrison, and David Lamb for their valuable suggestions. We also thank the dedicated VSU-ACIAR project staffs in the Philippines for their assistance in the field. This research was funded by the Australian Centre for International Agricultural Research (ACIAR) under ASEM/2010/050 - Improving the outcomes of watershed rehabilitation in the Philippines using a systems approach. The work was also supported by a scholarship to Sharif A. Mukul from the Australian Government (International Postgraduate Research Scholarship).

LITERATURE CITED

ACHARD, F., H. D. EVA, H. J. STIBIG, P. MAYAUX, J. GALLEGO, T. RICHARDS, AND J. P. MALINGREAU. 2002. Determination of deforestation rates of the world's humid tropical forests. *Science* 297: 999–1002.

- ADAMS, C., S. RODRIGUES, M. CALMON, AND C. KUMAR. 2016. Impacts of large-scale forest restoration on socioeconomic status and local livelihoods: what we know and do not know. *Biotropica* 48: ?????–?????.
- ANGELSEN, A. 1995. Shifting cultivation and “deforestation”: a study from Indonesia. *World Dev.* 23: 1713–1729.
- BALOOONI, K., AND M. INOUE. 2007. Decentralized forest management in South and Southeast Asia. *J. Forest.* 105: 414–420.
- BAYNES, J., J. HERBOHN, AND W. DRESSLER. 2016. Power relationships: their effect on the governance of community forestry in the Philippines. *Land Use Policy* 54: 169–176.
- BAYNES, J., J. HERBOHN, C. SMITH, R. FISHER, AND D. BRAY. 2015. Key factors which influence the success of community forestry in developing countries. *Glob. Environ. Change* 35: 226–238.
- BOWLER, D. E., L. M. BUYUNG-ALI, J. R. HEALEY, J. P. G. JONES, T. M. KNIGHT, AND A. S. PULLIN. 2012. Does community forest management provide global environmental benefits and improve local welfare? *Front. Ecol. Environ.* 10: 29–36.
- BROWN, S. 1997. Estimating biomass and biomass change of tropical forests: a primer. FAO Forestry Paper 134. FAO, Rome, Italy.
- BUDIHARTA, S., E. MEIJAARD, P. D. ERSKINE, C. RONDININI, M. PACIFICI, AND K. A. WILSON. 2014. Restoring degraded tropical forests for carbon and biodiversity. *Environ. Res. Lett.* 9: 114020.
- CHAVE, J., *et al.* 2014. Improved allometric models to estimate the above-ground biomass of tropical trees. *Glob. Change Biol.* 20: 3177–3190.
- CHAZDON, R. L. 2013. Making tropical succession and landscape reforestation successful. *J. Sustain. For.* 32: 649–658.
- CHAZDON, R. L. 2014. Second growth: the promise of tropical forest regeneration in an age of deforestation. University of Chicago Press, Chicago, IL.
- CHAZDON, R. L., AND M. R. GUARIGUATA. 2016. Natural regeneration as a tool for large-scale forest restoration in the tropics: prospects and challenges. *Biotropica* 48: ?????–????.
- CHOKKALINGAM, U., A. P. CARANDANG, J. M. PULHIN, R. D. LASCO, R. J. J. PERAS, AND T. TOMA (eds). 2006. One century of forest rehabilitation in the Philippines: approaches, outcomes and lessons. Centre for International Forestry Research (CIFOR), Bogor, Indonesia.
- Conservation International. 2013. Biological diversity in the Philippines. Retrieved from <http://www.eoearth.org/view/article/150648>.
- CRAMB, R. 1998. Environment and development in the Philippine uplands: the problem of agricultural land degradation. *Asian Stud. Rev.* 22: 289–308.
- DRESSLER, W., D. WILSON, J. CLENDENNING, R. CRAMB, S. MAHANTY, R. LASCO, R. KEENAN, P. TO, AND D. GEVANA. 2015. Examining how long fallow swidden systems impact upon livelihood and ecosystem services outcomes compared with alternative land-uses in the uplands of Southeast Asia. *J. Dev. Effect.* 7: 210–229.
- ERSKINE, P. D., D. LAMB, AND M. BRISTOW. 2006. Tree species diversity and ecosystem function: can tropical multi-species plantations generate greater productivity? *For. Ecol. Manage.* 233: 205–210.
- EVANS, M. C., J. CARWARDINE, R. J. FENSHAM, D. W. BUTLER, K. A. WILSON, H. P. POSSINGHAM, AND T. G. MARTIN. 2015. Carbon farming via assisted natural regeneration as a cost-effective mechanism for restoring biodiversity in agricultural landscapes. *Environ. Sci. Policy* 50: 114–129.
- FOX, J., D. M. TRUONG, A. T. RAMBO, N. P. TUYEN, L. T. CUC, AND S. LEISZ. 2000. Shifting cultivation: a new old paradigm for managing tropical forests. *Bioscience* 50: 521–528.
- GIBBS, H. K., S. BROWN, J. O. NILES, AND J. A. FOLEY. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environ. Res. Lett.* 2: 045023.
- GILROY, J. J., P. WOODCOCK, F. A. EDWARDS, C. WHEELER, B. L. G. BAPTISTE, C. A. M. URIBE, T. HAUGAASEN, AND D. P. EDWARDS. 2014. Cheap carbon and biodiversity co-benefits from forest regeneration in a hotspot of endemism. *Nat. Clim. Chang.* 4: 503–507.

- GRABOWSKI, Z. J., AND R. L. CHAZDON. 2012. Beyond carbon: redefining forests and people in the global ecosystem services market. *SAPIENS – Surv. Perspect. Integr. Environ. Soc.* 5: 1–14.
- GREGORIO, N., J. HERBOHN, S. HARRISON, AND C. SMITH. 2015. A systems approach to improving the quality of tree seedlings for agroforestry, tree farming and reforestation in the Philippines. *Land Use Policy* 47: 29–41.
- HAMRICK, K. 2015. Ahead of the curve: state of the voluntary carbon markets 2015. *Forest Trends*, Washington, DC and Ecosystem Market Place Initiative, New York.
- HARRISON, S., N. F. EMTAGE, AND E. E. NASAYAO. 2004. Past and present forestry support programs in the Philippines, and lessons for the future. *Small-scale For. Econ. Manag. Policy* 3: 303–317.
- HERBOHN, J. L., J. K. VANCLAY, H. NGYUEN, H. D. LE, S. R. HARRISON, E. CEDAMON, C. SMITH, J. FIRN, N. O. GREGORIO, E. MANGAOANG, AND E. LAMARRE. 2014. Inventory procedures for smallholder and community woodlots in the Philippines: methods initial findings and insights. *Small-scale For.* 13: 79–100.
- JAHN, R., AND V. B. ASIO. 2001. Climate, geology, geomorphology and soils of the tropics with special reference to Leyte islands (Philippines). *In Proceedings of the 8th International Seminar and Workshop on Tropical Ecology*. Visayas State College of Agriculture, Baybay, Leyte, pp. 25–43.
- de JONG, W., U. CHOKKALINGAM, AND G. A. D. PERERA. 2001. The evolution of swidden fallow secondary forests in Asia. *J. Trop. Forest Sci.* 13: 800–815.
- KETTLE, C. J. 2010. Ecological considerations for using dipterocarps for restoration of lowland rainforest in Southeast Asia. *Biodivers. Conserv.* 19: 1137–1151.
- KOH, L. P. 2007. Impending disaster or sliver of hope for Southeast Asian forests? The devil may lie in the details. *Biodivers. Conserv.* 16: 3935–3938.
- KUMMER, D. M. 1992. Upland agriculture, the land frontier and forest decline in the Philippines. *Agrofor. Syst.* 18: 31–46.
- LASCO, R. D. 2002. Forest carbon budgets in Southeast Asia following harvesting and land cover change. *Sci. China* 45: 55–64.
- LASCO, R. D., AND F. B. PULHIN. 2009. Carbon budgets of forest ecosystems in the Philippines. *J. Environ. Sci. Manage.* 12: 1–13.
- LASCO, R., F. PULHIN, L. BUGAYONG, AND M. MENDOZA. 2011. An assessment of potential benefits to smallholders of REDD+ components in the Philippines. *Ann. Trop. Res.* 33: 31–48.
- LASCO, R. D., R. K. A. VERIDIANO, M. HABITO, AND F. B. PULHIN. 2013. Reducing emissions from deforestation and forest degradation plus (REDD+) in the Philippines: will it make a difference in financing forest development? *Mitig. Adapt. Strat. Glob. Change* 18: 1109–1124.
- LASCO, R. D., R. G. VISCO, AND J. M. PULHIN. 2001. Secondary forests in the Philippines: formation and transformation in the 20th century. *J. Trop. Forest Sci.* 13: 652–670.
- LAW, E. A., B. A. BRYAN, N. TORABI, S. A. BEKESY, C. A. McALPINE, AND K. A. WILSON. 2015. Measurement matters in managing landscape carbon. *Ecosyst. Serv.* 13: 6–15.
- LAWRENCE, A. 1997. Kaingin in the Philippines: is it the end of the forest? *Rural Development Forestry Network Paper 21*, London, UK.
- LAWRENCE, D., C. RADEL, K. TULLEY, B. SCHMOOK, AND L. SCHNEIDER. 2010. Untangling a decline in tropical forest resilience: constraints on the sustainability of shifting cultivation across the globe. *Biotropica* 42: 21–30.
- LE, H. D., C. SMITH, AND J. L. HERBOHN. 2014. What drives the success of reforestation projects in tropical developing countries? The case of the Philippines. *Glob. Environ. Change* 24: 334–348.
- LE, H. D., C. SMITH, AND J. HERBOHN. 2015. Identifying interactions among reforestation success drivers: a case study from the Philippines. *Ecol. Model.* 316: 62–77.
- LE, H. D., C. SMITH, J. HERBOHN, AND S. HARRISON. 2012. More than just trees: assessing reforestation success in tropical developing countries. *J. Rural Stud.* 28: 5–19.
- LOCATELLI, B., C. P. CATTERALL, P. IMBACH, C. KUMAR, R. LASCO, E. MARÍN-SPIOTTA, B. MERCER, J. S. POWERS, N. SCHWARTZ, AND M. URIARTE. 2015. Tropical reforestation and climate change: beyond carbon. *Restor. Ecol.* 23: 337–343.
- MANUEL, W. V. 2014. Land cover data in the Philippines. Presentation at the 5th UN-REDD Regional Lessons Learned Workshop on Monitoring Systems and Reference Levels for REDD+, October 20–22, 2014, Hanoi, Viet Nam.
- MARON, M., J. R. RHODES, AND P. GIBBONS. 2013. Calculating the benefit of conservation actions. *Conserv. Lett.* 6: 359–367.
- McNICOL, I. M., N. J. BERRY, T. B. BRUUN, K. HERGOUALCH, O. MERTZ, A. de NEERGAARD, AND C. M. RYAN. 2015. Development of allometric models for above and belowground biomass in swidden cultivation fallows of Northern Laos. *For. Ecol. Manage.* 357: 104–116.
- MERTZ, O. 2009. Trends of shifting cultivation and the REDD mechanism. *Curr. Opin. Environ. Sustain.* 1: 156–160.
- MERTZ, O., O. LEISZ, A. HEINMANN, K. RERKASEM, THIIHA, W. DRESSLER, V. C. PHAM, K. C. VU, D. SCHIMDT-VOGT, C. J. P. COLFER, M. EPPECHT, C. PADOCH, AND L. POTTER. 2009. Who counts? Demography of Swidden cultivators in Southeast Asia. *Hum. Ecol.* 37: 281–289.
- MUKUL, S. A. 2016. Shifting cultivation in the upland secondary forests of the Philippines: Biodiversity and carbon stock assessment, and ecosystem services trade-offs in land-use decisions. PhD Thesis, The University of Queensland, Australia.
- MUKUL, S. A., AND J. HERBOHN. 2016. The impacts of shifting cultivation on secondary forests dynamics in tropics: a synthesis of the key findings and spatio temporal distribution of research. *Environ. Sci. Policy* 55: 167–177.
- MUKUL, S. A., J. HERBOHN, AND J. FIRN. 2016. Tropical secondary forests regenerating after shifting cultivation in the Philippines uplands are important carbon sinks. *Sci. Rep.* 6: 22483.
- MUKUL, S. A., J. HERBOHN, A. Z. M. M. RASHID, AND M. B. UDDIN. 2014. Comparing the effectiveness of forest law enforcement and economic incentive to prevent illegal logging in Bangladesh. *Int. Forest Rev.* 16: 363–375.
- MYERS, N., R. A. MITTERMEIER, C. G. MITTERMEIER, G. A. B. da FONSECA, AND J. KENT. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.
- NAVARRETE, I. A., K. TSUTSUKI, AND V. B. ASIO. 2013. Characteristics and fertility constraints of degraded soils in Leyte, Philippines. *Arch. Agron. Soil Sci.* 59: 625–639.
- PETERS-STANLEY, M., AND D. YIN. 2013. Maneuvering the Mosaic: state of the voluntary carbon markets 2013. *Forest Trends*, Washington, DC and Bloomberg New Energy Finance, New York.
- PETROKOFKY, G., P. HOLMGREN, AND N. D. BROWN. 2011. Reliable forest carbon monitoring – systematic reviews as a tool for validating the knowledge base. *Int. Forest Rev.* 13: 56–66.
- POSA, M. R., A. C. DIESMOS, N. S. SODHI, AND T. M. BROOKS. 2008. Hope for threatened tropical biodiversity: lessons from the Philippines. *Bio-science* 58: 231–240.
- PULHIN, J. M., M. INOUE, AND T. ENTERS. 2007. Three decades of community-based forest management in the Philippines: emerging lessons for sustainable and equitable forest management. *Int. Forest Rev.* 9: 865–883.
- PULHIN, F. B., R. D. LASCO, AND J. P. URQUIOLA. 2014. Carbon sequestration potential of Oil palm in Bohol, Philippines. *Ecosyst. Dev. J.* 4: 14–19.
- RACELIS, E. L., W. M. CARANDANG, R. D. LASCO, D. A. RACELIS, A. S. A. CASTILLO, AND J. M. PULHIN. 2008. Assessing the carbon budgets of large leaf mahogany (*Swietenia macrophylla* King) and Dipterocarp plantations in the Mt. Makiling Forest Reserve, Philippines. *J. Environ. Sci. Manage.* 11: 40–55.

- 1 ROBINSON, B. E., M. B. HOLLAND, AND L. NAUGHTON-TREVES. 2014. Does
2 secure land tenure save forests? A meta-analysis of the relationship
3 between land tenure and tropical deforestation. *Glob. Environ.*
4 *Change* 29: 281–293.
- 5 SHEERAN, K. A. 2006. Forest conservation in the Philippines: a cost effective
6 approach to mitigating climate change? *Ecol. Econ.* 58: 338–349.
- 7 SODHI, N. S., L. P. KOH, R. CLEMENTS, T. C. WANGER, J. K. HILL, K. C.
8 HAMER, Y. CLOUGH, T. TSCHARNTKE, M. R. C. POSA, AND T. M. LEE.
9 2010. Conserving Southeast Asian forest biodiversity in human-modi-
10 fied landscapes. *Biol. Conserv.* 143: 2375–2384.
- 11 SUAREZ, R. K., AND P. E. SAJISE. 2010. Deforestation, swidden agriculture and
12 Philippine biodiversity. *Philippine Sci. Lett.* 3: 91–99.
- 13 THOMAS, S., P. DARGUSCH, S. HARRISON, AND J. HERBOHN. 2010. Why are there
14 so few afforestation and reforestation Clean Development Mechanism
15 projects? *Land Use Policy* 27: 880–887.
- 16 van VLIET, N., O. MERTZ, A. HEINIMANN, T. LANGANKE, U. PASCUAL, B.
17 SCHMOOK, C. ADAMS, D. SCHMIDT-VOGT, P. MESSERLI, S. LEISZ, J.-C.
18 CASTELLA, L. JØRGENSEN, T. BIRCHTHOMSEN, C. HETT, T. BECH-BRUUN,
19 A. ICKOWITZ, K. C. VU, K. YASUYUKI, J. FOX, C. PADOCH, W. DRESSLER,
20 AND A. D. ZIEGLER. 2012. Trends, drivers and impacts of changes in
21 swidden cultivation in tropical forest-agriculture frontiers: a global
22 assessment. *Glob. Environ. Change*, 22: 418–429.
- 23 YASMI, Y., L. KELLEY, D. MURDIYARSO, AND T. PATEL. 2012. The struggle over
24 Asia's forests: an overview of forest conflict and potential implications
25 for REDD+. *Int. Forest Rev.* 14: 99–109.
- 26 ZIEGLER, A. D., J. M. FOX, E. L. WEBB, C. PADOCH, S. J. LEISZ, R. A. CRAMB,
27 O. MERTZ, T. B. BRUNN, AND T. D. VIEN. 2011. Recognizing contem-
28 porary roles of swidden agriculture in transforming landscapes of
29 Southeast Asia. *Conserv. Biol.* 25: 846–848.
- 30 ZIEGLER, A. D., J. PHELPS, J. Q. YUEN, E. L. WEBB, D. LAWRENCE, J. M. FOX,
31 T. B. BRUNN, S. J. LEISZ, C. M. RYAN, C. PADOCH, AND L. P. KOH.
32 2012. Carbon outcomes of major land-cover transitions in SE Asia:
33 great uncertainties and REDD+ policy implications. *Glob. Change*
34 *Biol.* 18: 3087–3099.
- 35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55

Author Query Form

Journal: BTP

Article: 12389

Dear Author,

During the copy-editing of your paper, the following queries arose. Please respond to these by marking up your proofs with the necessary changes/additions. Please write your answers on the query sheet if there is insufficient space on the page proofs. Please write clearly and follow the conventions shown on the attached corrections sheet. If returning the proof by fax do not write too close to the paper's edge. Please remember that illegible mark-ups may delay publication.

Many thanks for your assistance.

| Query reference | Query | Remarks |
|-----------------|---|---------|
| 1 | AUTHOR: Please confirm that given names (red) and surnames/family names (green) have been identified correctly. | |
| 2 | AUTHOR: Please check that authors and their affiliations are correct. | |
| 3 | AUTHOR: Kettle <i>et al.</i> 2010 has been changed to Kettle 2010 so that this citation matches the Reference List. Please confirm that this is correct. | |
| 4 | AUTHOR: Mukul (2015) has not been included in the Reference List, please supply full publication details. | |
| 5 | AUTHOR: Please provide the page range for reference Adams et al. (2016). | |
| 6 | AUTHOR: Journal style is to include all author names for each reference in the reference list. Please replace all appearances of 'et al.' in your reference list with the complete author lists. | |
| 7 | AUTHOR: Please provide the page range for reference Chazdon and Guariguata (2016). | |
| 8 | AUTHOR: Lasco et al. (2001) has not been cited in the text. Please indicate where it should be cited; or delete from the Reference List. | |
| 9 | AUTHOR: Please provide the givenNames/initials for the author Thiha for reference Mertz et al. (2009). | |
| 10 | AUTHOR: Figure 1 has been saved at a low resolution of 181 dpi. Please resupply at 600 dpi. Check required artwork specifications at http://authorservices.wiley.com/bauthor/illustration.asp | |
| 11 | AUTHOR: Figure 2 has been saved at a low resolution of 259 dpi. Please resupply at 600 dpi. Check required artwork specifications at http://authorservices.wiley.com/bauthor/illustration.asp | |
| 12 | AUTHOR: Figure 3 has been saved at a low resolution of 254 dpi. Please resupply at 600 dpi. Check required artwork specifications at http://authorservices.wiley.com/bauthor/illustration.asp | |