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A methodological approach for assessing cross-site landscape change: Understanding socio-ecological systems

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ABSTRACT

The expansion of agriculture has resulted in large-scale habitat loss, the fragmentation of forests, significant losses in biological diversity and negative impacts on many ecosystem services. In this paper, we highlight the Agrarian Change Project, a multi-disciplinary research initiative, that applies detailed socio-ecological methodologies in multi-functional landscapes, and assess the subsequent implications for conservation, livelihoods and food security. Specifically, the research focuses on land use impacts in locations which exhibit various combinations of agricultural modification/change across a forest transition gradient in six tropical landscapes, in Zambia, Burkina Faso, Cameroon, Ethiopia, Indonesia and Bangladesh. These methods include integrated assessments of the perceptions of ecosystem service provision, tree cover loss and gain, relative poverty, diets and agricultural patterns of change. Although numerous surveys on rural livelihoods are undertaken each year, often at great cost, many are hampered by weaknesses in methods and thus may not reflect rural realities. We attempt to highlight how integrating broader socio-ecological methods can be used to fill in those gaps and ensure such realities are indeed captured. Early findings suggest that the transition from a forested landscape to a more agrarian dominated system does not necessarily result in better livelihood outcomes and there may be unintended consequences of forest and tree cover removal. These include the loss of access to grazing land, loss of dietary diversity and the loss of ecosystem services/forest products.

1. Introduction

Historically, the trade-off between increasing food security/production and the maintenance of natural systems has led to a perception that the two were mutually exclusive (Tscharntke et al., 2005; Brussaard et al., 2010). This perspective, however, has failed to account for the fact that certain levels of biodiversity exists within some agricultural landscapes which provide multiple contributions to food security and agricultural production (Perrings et al., 2006; Bharucha and Pretty, 2010; Sunderland, 2011). Managing, and negotiating, trade-offs between biodiversity and agriculture involves maximising food security benefits while minimising damage to the wider environment.

Globally, the total area of cultivated land increased by 466% from 1700 to 1980 (Meyer and Turner, 1992). Croplands and pastures have now become one of the largest terrestrial biomes on the planet, occupying ∼40% of the land surface (Ellis et al., 2010). Between

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1980 and 2000, more than half of new agricultural land across the tropics was established at the expense of intact forests, while a further 28% was opened up to the detriment of disturbed or secondary forests (Gibbs et al., 2010). This habitat loss is further compounded by land degradation and competition from other land uses such as urbanisation (Ellis et al., 2010). Although the overall rate of agricultural expansion has slowed considerably over the last three decades the global focus on food production has ensured a rapid rate of increase in yield per unit area (Gibbs et al., 2010). Technological and scientific advancements have provided access to cheaper chemical fertilisers and pesticides, high-yielding crop varieties, advanced irrigation technologies and more efficient mechanisation (Matson et al., 1997; Motes, 2010), which have all contributed to increased crop yields. Unsurprisingly, given the dependency of this model on fossil fuels, concerns have been raised over the long-term sustainability of increasingly intensified agriculture, particularly as food demands are projected to more than double by 2050 (Green et al., 2005; Fischer et al., 2008; Godfray et al., 2010).

While there has been significant progress towards meeting global commitments to reduce hunger, levels of food insecurity remain unacceptably high. Approximately 842 million people worldwide remain hungry and undernourished (UNICEF, 2011; Black et al., 2013; FAO et al., 2013) and this can be attributed as the cause of one third of child mortality figures in developing countries. This situation is further exacerbated by global population growth and changing dietary patterns with a predicted 50% increase in the demand of agricultural products by 2030 (Bruinsma, 2003). In this context, the provisioning of food is increasingly couched within multiple objectives sought from multifunctional mosaic landscapes namely, biodiversity conservation, maintenance of ecosystem services, food production, sustainable livelihood provision, and climate change mitigation (Sayer et al., 2013; Reed et al., 2015; Khatun et al., 2016). However, in many places, land scarcity results in trade-offs between many of these components, particularly between the need for agricultural commodities and conserving biodiversity (Law and Wilson, 2015).

To this end, two contrasting landscape management approaches; 'land sparing' and 'land sharing' have been identified as potential strategies to minimise the negative consequences of agriculture on biodiversity. These consider land use change in such a way that competing demands for food, commodities and forest services can be reconciled (e.g. Pirard and Treyer, 2010; Phalan et al., 2011a). 'Land sparing' aims at intensifying production and maximising agricultural yields by trading off its negative consequences on the environment by 'sparing' areas of natural capital (often in the form of protected areas) and therefore reducing the need for agricultural expansion into forest areas (Pirard and Treyer, 2010).[1] 'Land sharing', on the other hand - where agricultural production takes place within complex multi-functional landscapes - is based on a land use model that integrates production and conservation within the same land units. It proposes to minimise the use of external inputs and to retain patches of natural habitat within farmlands in a form of extensive agriculture. Under the latter management regime, landscapes consisting of low-intensity productive areas are combined with areas of natural biodiversity (Wright et al., 2012). Such strategies include agroforestry systems and traditional swidden farming practices (Ziegler et al., 2009; Clough et al., 2011).

Land sparing offers a convincing narrative for achieving desirable agrarian change, particularly in the developing world (e.g. Phalan et al., 2011a, 2011b), suggesting that efforts to emulate land sparing through the application of incentives, regulations, and land use planning could lead to optimal outcomes for food production, climate change mitigation and biodiversity conservation. Meanwhile 'land sharing', is supported by the fact that many species are dependent on farmland and other habitats maintained by humans (Wright et al., 2012; Deakin et al., 2016), and that farmlands that are often structurally similar to the original native vegetation can support biodiversity often as effectively as native vegetation (Clough et al., 2011).

The land sparing versus land sharing debate has become somewhat polarised in the scientific literature (Law and Wilson, 2015) and, it has been argued, has actually stagnated (Bennett, 2017). There is increasing opinion that a 'black and white' dichotomy over-simplifies issues that in practice are highly complex[2] (Adams, 2012; Fischer et al., 2014). Baudron and Giller (2014) suggest that both options are equally important and can be complementary strategies under different circumstances and some landscapes may exhibit elements of both. Smallholder farmers for example, who provide up to 40% of the world's food, mostly fall somewhere on the continuum between land sharing and land sparing (Tscharntke et al., 2012). The land sharing/sparing debate also suggests there is some level of "grand design" at the landscape scale which is simply not the case (Reed et al., 2017). Most landscapes are inherently dynamic and evolve through the influence and interactions of environment, society and economies (Sayer et al., 2016).

It has also been recognised that land use strategies aimed at balancing agriculture and biodiversity conservation must also consider socio-economic outcomes and trade-offs (Fischer et al., 2014; Loos et al., 2014; Khatun et al., 2015). Landscapes should be viewed as complex social-ecological systems that consist of mosaics of natural and/or human-modified ecosystems (Bennett et al., 2006; Reed et al., 2016). However, there is a distinct lack of information on the human impacts of agrarian change in forested areas, particularly with regards to socio-economic effects of agricultural intensification, long-tesrm dietary diversity and market integration processes (Byerlee et al., 2014). Previous research within the land-sharing vs. land sparing debate has focused heavily on the trade-offs between food security and biodiversity at a macro-level (Phalan et al., 2011a; Green et al., 2005; Clough et al., 2011), while local scale effects upon livelihoods, poverty, food security and nutrition have tended to be overlooked. Furthermore, it is also important to recognise that more food production does not automatically lead to better local food security and improved livelihoods for rural communities (Powell et al., 2015).

In this paper, we present the Agrarian Change Project, a multidisciplinary, research initiative led by the Center for International Forestry Research with direct funding from USAID's Biodiversity Bureau and the UK's Department for International Development (Deakin et al., 2016). The project applies detailed socio-ecological methodologies to examine the outcomes/impacts of land use and agrarian change processes in multi-functional landscapes, and the subsequent implications for conservation, livelihood, and food security. Specifically, the research focuses on land use impacts in locations which exhibit various combinations of agricultural modification/change across a forest transition gradient in six tropical landscapes in Zambia, Burkina Faso, Cameroon, Ethiopia, Indonesia and Bangladesh. The study attempts to highlight how integrating broader socio-ecological methods, within a novel experimental design can be used to fill in gaps in assessing local food security, dietary diversity and nutrition levels, tenure, local poverty, biodiversity/forest conservation and integration with global commodity markets. Thus the project seeks to explore these landscape components by answering the following research questions

1. How is land use changing over time and what are the underlying drivers behind these changes? Are there consistencies/differences between the case study landscapes/countries?
2. What are local people's perceptions of the outcomes of land use

[1] Agricultural intensification does not necessarily mean increases in inputs such as fertilizer and capital (e.g. through mechanisation), but it can also include changes to the use of labour and environmental services. See discussion in Pirard and Treyer, 2010, p.6. Most commonly, however, intensification is understood as additional inputs to increase productivity.

[2] See also: http://blog.cifor.org/8110/land-sharing-or-land-sparing-reconciling-agriculture-and-biodiversity-conservation?fnl=en

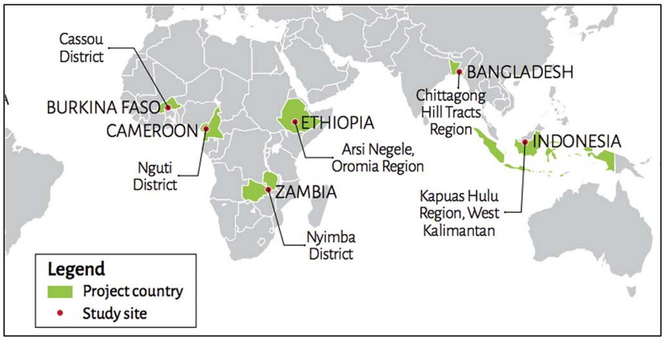

Fig. 1. Map showing the location of the six landscapes used as case studies for the Agrarian Change research project.

change in each landscape in terms of their livelihoods, access to natural resources, land tenure and food security?

3. What is the relationship between land use, local livelihoods, and food security under different land use scenarios along an agricultural modification gradient?

Here we present a methodological overview of the project and highlight some of the preliminary findings,

2. Research design at the landscape scale

2.1. Selection of landscapes, zones and villages

The selection of six landscapes in the Agrarian Change project was largely based on prior-knowledge of field teams in the focal countries; Ethiopia, Cameroon, Indonesia, Bangladesh, Zambia and Burkina Faso (Fig. 1) – (see: Deakin et al., 2016). Preliminary findings presented in this paper are derived from thorough reconnaissance or 'scoping' studies conducted in each landscape to ensure that these met project and experimental design criteria and also provided detailed background information regarding current and historical land management practices, for the regions selected.

Attempts were also made to co-locate landscapes where there were already research initiatives in place, such as the Sentinel Landscapes framework of the CGIAR's Forests Trees and Agroforestry research programme.[3] A continuum of changing land use practices was required to be present within each landscape, mimicking historical land use trajectories. Thus by looking at the transition through a gradient of change, the project offers a unique insight to potential impacts/benefits of a particular land use change, i.e. Zone 1 can potentially transform into Zone 3, should the same trajectory (or gradient) be followed. It works directly with communities within multi-functional landscapes to understand the social, economic and ecological consequences of land use and agrarian change processes in their vicinity. The study utilised a landscape-level approach through a three stage nested hierarchical experimental design. Village/s or settlement/s nested within or in close proximity to the dominant land use 'zones'- representing a gradient/ continuum of agricultural modification and decreasing tree cover—-which were nested within each representative landscape exhibiting various changing land use practices (Fig. 2).

Zones within the landscapes represented different levels of agroforestry pressure and were paired with household surveys exploring the diets and livelihoods of local people. By comparing households within different zones the impacts of forest loss and fragmentation within differing farming systems can be quantified. At the local scale, zones were selected based on a set of criteria including population density, crop types, infrastructure, etc. (Table 1). Zone 1 represents landscapes where people are carrying out subsistence farming and are heavily

[3] http://www1.cifor.org/sentinel-landscapes/home.html.

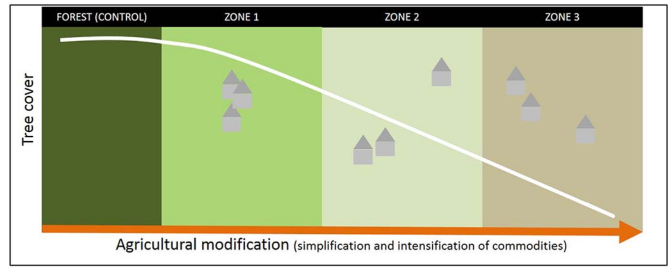

Fig. 2. Agrarian Change Project landscape level hierarchical research design. (Source Deakin et al., 2016).

dependent on forests. Zone 2 represents areas with an intermediate or mixed farming system with less access to forests. Zone 3 represents locations that have been converted to monoculture agricultural systems with very little access to forests. From a landscape perspective, final zones were selected based on the discretion of the Principal Investigators for each region. For Ethiopia and Indonesia, zones were digitised in ArcMap (ESRI, 2012). For all other study sites (Bangladesh, Burkina Faso, Cameroon, and Zambia) three-km buffers were created around each household and merged into one polygon for analysis using R statistical software (R Core Team, 2015).

For each landscape we ensured that there was limited variability among zones within a given landscape in rainfall/climatic and agro-ecological characteristics, elevation and biome type. The three zones were distinguished according to a set criteria for each focal landscape to help identify the different practices and relative differences of key characteristics of each zone (Table 1). This was modified for each landscape and helped to clarify whether the landscapes selected exhibited a gradient of agrarian change/agricultural modification. The type and number of criteria/variables differed between focal landscapes.

Within each landscape along a forest transition gradient, we then undertook research, to examine the effects of landscape configuration (including fragmentation and levels of patchiness), land sharing/ sparing scenarios, and synergies and trade-offs between different land uses (crops, livestock rearing, swidden agriculture, agroforestry) with forests and tree-based systems. A common set of qualitative and quantitative research methodologies were applied to enable a global comparative analysis, which included household surveys, focus groups, and semi-structured interviews with key informants (Fig. 3) to gauge information on variables such as relative poverty food security, dietary diversity and nutrition, agricultural production, land tenure, migration and biodiversity as well as stakeholder perceptions of ecosystem services, and their relative values. We aimed to capture as much variation along a modification gradient in each focal landscape regarding the following characteristics:

- Agricultural modification (from low inputs -diversified, extensive, subsistence orientated practices through to high input -market orientated, intensive, simplified practices), through extensive farm surveys
- Forest cover loss and gain (where detectable)
- Community dependency on forest resources
- Market access and infrastructure

The information gauged from the combined methodologies were complemented by alternative sources, such as researcher's own observation/measurement e.g., "distance to the nearest road usable during all seasons and GPS to measure distances and secondary data from village records e.g. population (time series), access to public services, land categories etc. Secondary data was also used to obtain information for some agricultural and forest products at the national or district level, e.g. Food and Agricultural Organization, International Tropical Timber Organization, World Resources Institute, and national

Table 1
Example criteria used to help distinguish characteristics of different 'zones' within a focal landscape.

	Criteria	Zone I	Zone 2	Zone 3
1	Population density	Sparse	Medium	Dense
2	Land tenure	State/customary	Customary	Customary/title deeds
3	Proximity to major towns	Distant	Far	Near
4	Level of dependence on forest resources	High	High-medium	Medium-low
5	Proximity to protected areas (forest reserves, Game Management Areas, National parks)	Near	Far	Distant
6	Level of in migration	High - medium	Medium-Low	Low
7	Level of agric. inputs (fertiliser)	None-Low	Medium	High
8	Market oriented crop production/presence of cash crops: Tobacco, maize, groundnuts and cotton	Rare	Occasional	Common
9	Presence of subsistence farming	High	Medium	Low
10	Levels of infrastructure development	Low	Moderate	High

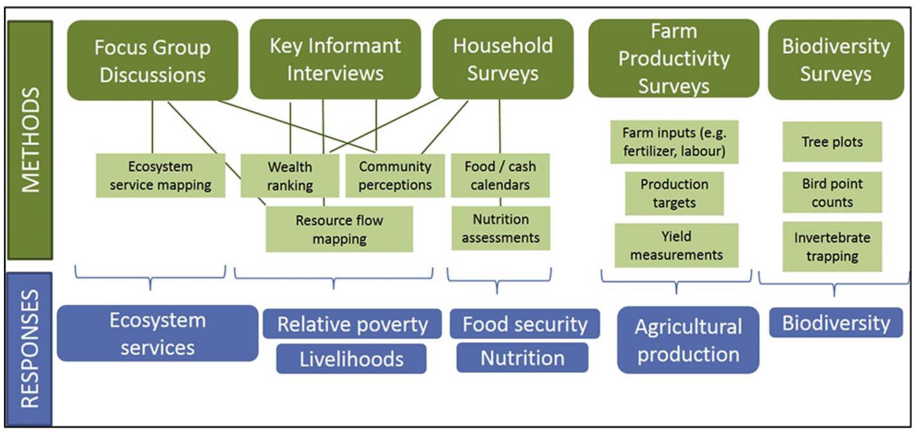

Fig. 3. Research design and data collection at the landscapes scale.
(Deakin et al., 2016).

Table 2
Assessing forest cover for the Agrarian Change project.

Region	Years	Data type/approach	Data source
Ethiopia	1988–2011, 2015	Sequence of Landsat imagery was used to classify the landscape into forest/non-forest cover using image differencing technique with a Normalized Burn Ratio (NBR) (Jin et al., 2013) supplemented with high spatial resolution imagery. Maximum likelihood supervised classification of orthorectified Rapideye 3A imagery (5 m) from January 2015 was used to further distinguish grasslands, agricultural fields and bare soils.	Scene selection used United States Geological Survey's (USGS) GLOVIS Earth Explorer for images containing < 10% cloud cover (http://glovis.usgs.gov/). Once selected, the scene list was uploaded to the USGS ESPA services online ordering system specifying the LEDAPS model (Masek et al., 2006) corrected products.
Cameroon	1987, 2000, 2002, 2014	Vegetation indices (e.g., NDVI Huete 1988) derived from Landsat imagery were used in an image differencing process to create an image times series. Radiometric normalization was conducted (Lu et al., 2004).	Surface reflectance Imagery from Landsat 5 and 7 were downloaded from the United States Geological Survey's (USGS) ESPA interface and was partially processed using the USGS ESPA service to deliver imagery provided as surface reflectance using the LEDPAS model (Masek et al., 2006). Landsat 8 imagery was downloaded directly using the USGS GLOVIS earth explorer tool.
Kapuas Hulu Regency-Indonesia	2000–2013	Moderate resolution global maps	Hansen/UMD/Google/USGS/NASA (2014) Hansen et al. (2013)
Bangladesh	1960–80 & 1990–2005	National spatial data obtained online	Bangladesh Forest Department (BFD, 2015)
Zambia	1990–2013	Land-use and land cover analysis, including land change detection	CIFOR's Nyimba Forest Project, (Gumbo, 2015)
Burkina Faso	1999–2013	High resolution satellite imagery, NDVI calculation/ classifications	High resolution imagery Google Earth & classifications from Wilson and Sader, 2002 & Kerr and Ostrovsky, 2003

inventories, that were consolidated by the interviews, focus groups and questionnaire pre-testing. Forest cover estimates were derived from a number of sources depending on data availability (Table 2). (See Table 3.)

Focus group discussions were carried out in all 54 communities across the project. These were primarily undertaken with the village head and elders on the historical and cultural background, land tenure and ownership, resource dependency and sale of forest products/ resources, and the regulations and taboos concerning land and forest use. We cross-checked for consistency, with more extensive semi-structured interviews conducted with key informants, specifically the settlement leaders and administration officers, identified by project staff in order to obtain general information about history, economic activities, agricultural seasons and presence of infrastructure in the regions. Selected key informants were interviewed per village to understand activities occurring in each village/settlement and provide field team leaders with sufficient background knowledge needed to properly conduct household and farm surveys.

Table 3
Spatial extent of zones in each country/landscape.

Country	Zone 1 area (km^2)	Zone 2 area (km^2)	Zone 3 area (km^2)	Total area (km^2)
Burkina Faso	97	103	105	305
Bangladesh	44	66	40	149
Cameroon	29	19	24	73
Ethiopia	20	23	19	63
Indonesia	84	37	89	210
Zambia	25	42	37	104

A representative sample of households was interviewed with both household and farm surveys in each zone. The household surveys were carried out either in one village with an approx. number of 100 households, or each zone, containing several villages, with an approx. number of 100 households combined (approx. 300 total per site). There were 9–10 farm surveys per zone, totaling approximately 30 per research site. The selection of households and farms within the chosen villages were undertaken by random sampling.

3. Preliminary results

The comparative study is still in in the early stages of data analysis. However, in this paper, we are able to present some preliminary assessments of agrarian drivers of change in the six diverse tropical landscapes described above. Some patterns and trends are clearly emerging, even at this nascent stage of the project. Figs. 4–6 show some initial comparative data. In addition, we present a brief insight of country level analyses, with some case study countries e.g. Cameroon and Zambia being less developed in terms of data exploration and analysis. The variables within each case study site differ slightly based on the expertise and current focus of the country level researchers involved in the Agrarian Change Project.

Figs. 4–6 show people's perception of the availability of forest cover, forest products, and agricultural expansion respectively. These were collated from the household and farm surveys. The perceptions are based on the time community members have resided in the area, which ranges from 8 to 38 years. Fig. 5 shows that in half the sites studied, there is a perception among households that there are fewer forest products available than in the past. Unsurprisingly, this is especially notable in the study zones further away from forest. Households in Ethiopia and Cameroon, stated that there are also fewer forest products available in Zone 2, while in Burkino Faso, households said that all zones have fewer forest products. These perceptions correlate well with the perception that there has been a decrease in forest cover across all the sites (Fig. 4).

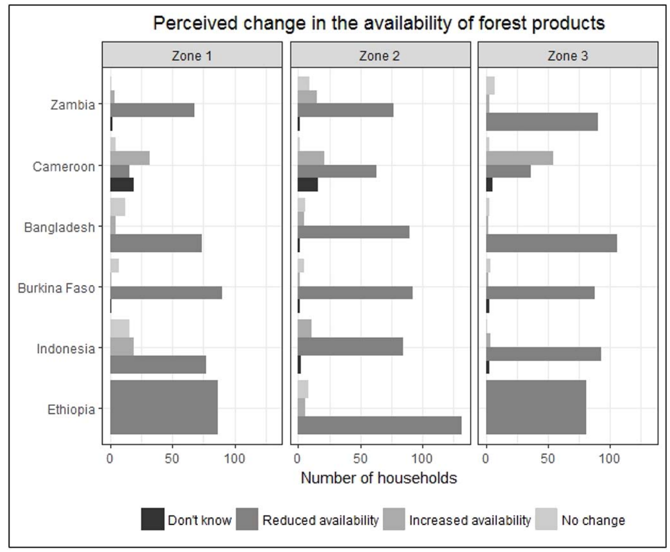

Fig. 5. Community perceptions of change in availability of forest products.

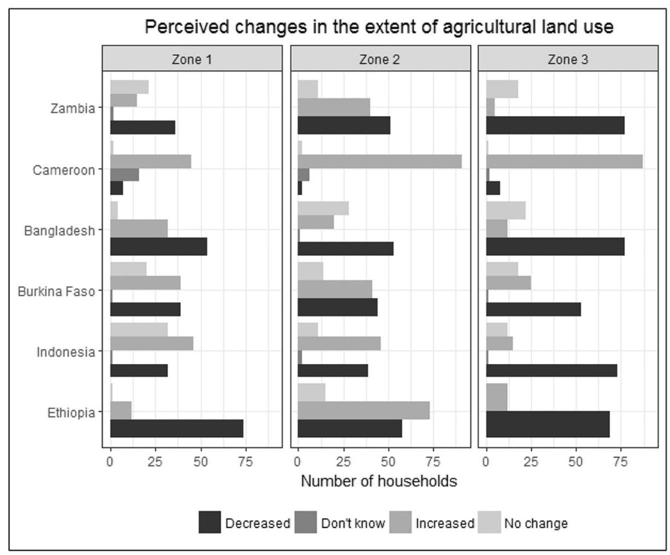

Fig. 6. Community perceptions of change in availability of agricultural land.

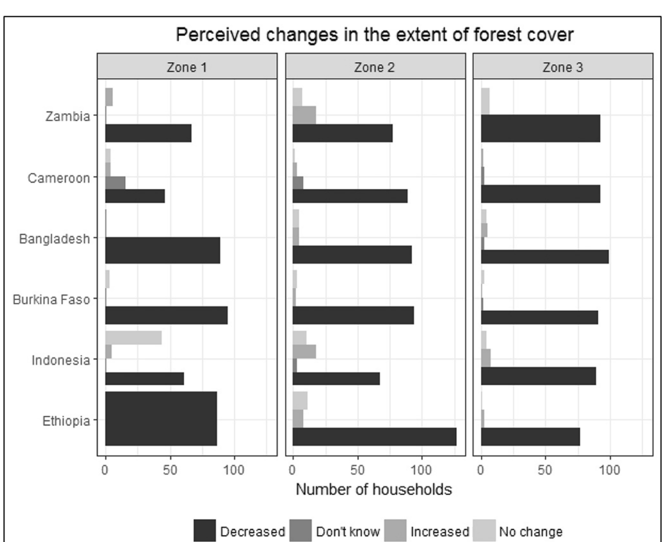

Fig. 4. Community perceptions of change in forest cover.

4. Ethiopia

The Ethiopian site is focused on the Munessa forest region, along corresponding agricultural intensification and forest cover gradients. The results of the focus group discussions conducted suggest that food security increased with agricultural expansion from the 1970s to date (Baudron et al., in press). Data along an intensification gradient show that rural households closest to the forest use significantly more fuelwood from the forest than households away from it (3257 ± 1461, 407 ± 978, and 353 ± 530 kg per household/year in Zones 1 to 3, respectively). The same pattern applies for biomass from the forest used as feed (2876 ± 2860, 1935 ± 859, and 306 ± 471 kg per household/year in Zones 1 to 3, respectively). As a consequence, farms closest to the forest contain more livestock (3.61 ± 3.10, 2.27 ± 2.03, and 1.85 ± 2.42 TLU per household in the near, intermediate and distant zones, respectively) and thus more manure, which they concentrate on home gardens producing a variety of nutrient-dense food items.

Only residents from villages adjacent to the forest are allowed to graze the forest (and harvest firewood) and this access is closely controlled. The proportion of farms having a home garden is 85.5%, 62.4%, and 38.5% in the near, intermediate and distant zones, respectively) and the dietary diversity score is significantly higher for rural household closest to the forest (weekly HDDS of 6.58 ± 1.21, 5.38 ± 1.02, and 4.41 ± 0.77 in the near, intermediate and distant zones, respectively, (Baudron et al., in press). In areas where agricultural intensification is at its greatest (Zone 3), there has been a significant decrease in the contribution of forest resources (notably fuelwood). Ownership of cattle, has also reduced, given the removal of appropriate grazing land. The long-term implications of this transition are yet to be fully understood. The role of the State has also made significant impacts on this landscape with uncertain property rights and land annexation playing significant role in driving rapid deforestation, that needs to be further explored in the subsequent phases of the project.

5. Cameroon

The livelihoods of the majority of households in South West Cameroon depend primarily on agricultural activities (Asaha, 2015). These include both shifting cultivation and cash crop production (coffee, cocoa and oil palm) and this is exhibited strongly across the three zones with Zone 1 being characterised by high forest cover and shifting cultivation systems and Zone 3 representing a more defined mosaic of sedentary farming and cash crops. Despite the relative importance of agriculture, there remains a strong reliance on forest products for rural income and consumption. This is reflected in the strong market values of NTFP's across the zones. As such, their cultural importance underpins their widespread availability.

Within the last two and a half decades, local communities have experienced different land-use changes around them, especially from the conservation sector. Annexation of land by conservation actors has led to a considerable proportion of South West Cameroon being gazetted as protected areas. However, the lack of enforcement of these forest areas means that encroachment is common and many of these reserves and parks are regarded as potential sources of new farmland, particularly with the advance of monoculture plantations that have particularly impacted communities in Zones 2 and 3 (see Figs. 4–6).

Recent commercial oil palm development has annexed yet more land in a manner that results in total loss of access to previously available agricultural land. This new development has been received with mixed feelings; some people see it as a great opportunity for development of their area and employment for them and their children, while others see it as a threat to the future of the village and their children in terms of future land shortages, particularly for small-scale agricultural expansion. The ever-increasing demand for agricultural land, especially for cocoa and more recently for oil palm, has also attracted considerable migration to the area, focused mainly along the roads (especially Zone 3). However, this influx has also extended to inaccessible areas (Zone 1) where land is considerably cheaper, land tenure systems are simple, and acquisition and ownership processes are relatively straightforward. As such, this migration and the concomitant economic activities will result in yet more forest loss in the future.

6. Indonesia

In Kupuas Hulu, Indonesia, the study, shows that the agrarian trajectory from diverse smallholder agricultural production towards more intensive agribusiness is having a major impact on the livelihoods of local people. Interestingly, communities showed concern over the decreased availability of agricultural lands in all three zones (Fig. 6) reflecting the expansion of oil palm estates in Zone 3, rubber agroforestry in Zone 2 and reduction in forest land available for swidden agriculture in Zone 1. More broadly this shift represents a transition away from a rotational system of shifting cultivation that requires large areas forest under different stages of the forest-field-fallow-forest transition (land sharing). In Zone 1 where almost all agricultural land is swidden, the distinction between forest, fallow and agricultural land is blurred whereas in Zone 3, oil palm estates establishes a strict delineation between forest and agricultural land (land sparing). The transition is accompanied by a simultaneous shift from fluid customary land tenure arrangements (overlapping with state defined national park boundaries) to strict, state-regulated demarcation of land use as well as a reduction in forest cover. In all three zones, local people perceived forest cover to be declining along with reduced availability of forest products (Figs. 4 and 5). Gaharu (*Aquilaria* spp.) is the most important forest product in Zones 1 & 2. It is an endangered species, and is declining in most forests across Kalimantan (Soehartono and Newton, 2001). Thus concern over declining forest resources applies both to loss of forest cover and over-extraction of particular high-value forest products.

7. Burkina-Faso

The parkland agroforestry landscapes of southern Burkina Faso show an interesting and much more historically rooted integration of forests, farm and markets for achieving food security. From our household surveys (n = 296), 56% were food secure for all 12 months in the year, the remainder (44%) faced 1–3 months of reduced food. On average households had sufficient food to have 3 meals a day for 10.6 months in the year. Foli and Abdoulaye (2016) found that annual household food provisioning from autonomous farms, forests or uncultivated sources and markets is at 61%, 23% and 16% respectively, across the three zones respectively. Reoccurring droughts, erratic rainfall and a short rainy season means rural households continuously rely on forests and wild foods for up to three months in the year to supplement diets (Foli and Abdoulaye, 2016; Koffi et al., 2016). Forests clearly play a role in buffering dietary diversity during lean agricultural months (Koffi et al., 2016). Obvious trajectories of intensification in the Burkina landscape are difficult to identify compared to the other landscapes. It shows "clusters" of intensification, rather than a linear temporal pattern of clear transition. The protection of important tree species that contribute to local food provisioning is historically embedded in local norms. Baobab (*Adansonia digitata*), Shea (*Vitilaria paradoxa*) and Néré (*Parkia biglobosa*) are examples of local tree species that are protected from felling under customary laws throughout of Burkina Faso (Coulibaly-Lingani et al., 2009). As such, these landscapes are managed to be as resilient as possible for the vicissitudes of climate and environment that persistently affect the region.

8. Zambia

Although between 74 and 86% of the respondents in this landscape—depending on the zone—derive income from agriculture. The main source of income for forested communities (Zone 1) is derived from farming, fishing and aquaculture (79%), while game ranches provide both formal and informal employment for some. In Zones 2 and 3, the main source of income is less diverse and is primarily derived from farm labour (Zone 2 = 12%, Zone 3 = 18%) and small-scale food production (Zone 2 = 73%, Zone 3 = 57%).

Interestingly, in Zone 1, aquaculture and fishing make up 30% of top three sources of income. This compares with 2% and 0% in Zones 2 and 3 respectively, which indicates that the forests in these villages are providing significant water related regulating and provisioning ecosystem services, that are either uneconomical to utilise commercially as people transition away from forest based landscapes or are degraded and lost as agrarian change progresses. The latter is likely is the case, as the value of forest resources is not reflected in the policy environment, which favours intensified agriculture over the forestry sector.

Ultimately this has resulted in a lack of understanding of the role of forests play in rural livelihoods and resource conflict at the agricultural frontier (Zone 1) where it is evident that there remains a strong reliance on forest resources to supplement agricultural income.

As with all countries and all Zones—the exception being the forested zone in Kapuas Hulu, Indonesia—the perceptions of change in the Zambian landscape are collectively ones of decreasing forest cover (Fig. 4) with 91%, 75%, and 93% of households perceiving some form of deforestation across Zones 1,2 and 3 respectively. Not surprisingly, perceived forest lost also resulted in a perceived reduction in the availability of forest products 92%, 75%, and 90% across Zones 1, 2 and 3 respectively (Fig. 5). This is congruent with collective perceptions on the availability of forest products among all other landscapes and zones within the study —with the exception of Cameroon. As there is zero indication from the income data that forest products are important in the Miombo woodlands, we could deduce that this indicates NTFPs are important for subsistence only or have cultural or medical significance (hence the perceived decline).

These perceptions of landscape change almost certainly have a basis in actual/real land use and landscape change. Yet somewhat counter-intuitively, when asked about the perception of the changes in the extent of agricultural land within their landscape, the majority perceived it to have also decreased (Fig. 6) (Zone 1 = 45%, Zone 2 = 50%, Zone 3 = 77%). Indeed, if the perceptions in the community are that both the extent of forest cover and the extent of agricultural land uses have decreased? Then it is logical to assume that some land use changes are unaccounted for in our survey or the scale of change is negligible and so local perceptions are not a significant indication of actual change at the landscape scale.

9. Bangladesh

The Chittagong Hill Tracts (CHT) has unique types of landforms due the many hills and valleys and a network of natural streams and rivers compared to the rest of the country, which is primarily deltaic and low-lying. As a result, shifting cultivation is only carried out in this region, with > 80% of the area exhibiting variable relief (Islam et al., 2007). Aside from government control, there is a sparse distribution of the small size of indigenous forest reserves ranging from 50 to 300 acres across the landscape. However, natural forests are declining in all cases for state-owned forests and community reserves based on the findings from interviews with government officials and community members. Forest loss is higher in remote and less accessible areas due to shifting cultivation, illegal felling and insecure tenure rights (Bala et al., 2013). Deforestation is relatively less problematic in the areas where monoculture plantations have increased in the recent past years, land use changes remain stable and land ownership is secure.

It was observed that 90% households experienced a decline of the forest cover over the last 30 years. The loss of forest area has caused shortage in the availability of forest products in 86% of households. Though the community discussion revealed an increase in tree cover during 1990–2000, a high proportion of the households (94%) perceived a loss of the forest products in the intensification zones (intermediate and distant from the forest). A significant proportion of households in intermediate (86%) and distant (85%) zones have experienced an increased decline of fuel wood than households (60%) near the forest. More than one-third of households (40%) near to the forest in Zone 1 reportedly collect wild foods compared with 28% and 27% in Zones 2 and 3 respectively. A higher dietary diversity was also found at households near to forest than in the intermediate and distant zones (weekly HDDS in Zone 1, 2 and 3 were 7.58 ± 1.41; 6.79 ± 1.52 and 6.70 ± 1.40 respectively).

Agriculture has been found to be equally dynamic along the forest and land use gradient. Overall, 50% households experienced a decline of their farm size across the landscape. Only 27% households have increased farming lands in Zone 1 near the forest area compared to Zones 2 (15%) and Zone 3 (14%). The expansion of agriculture is due to more households (86%) clearing lands to increase farm areas in new or fallow land in Zone 1 near the forest compared with Zones 2 (60%) and 3 (42%). As a result more households (> 90%) in Zone 1 near to forests have large numbers of livestock (1.77 ± 1.73 TLU) than Zones 2 (0.58 ± 0.97 TLU) and 3 (0.54 ± 0.88 TLU) respectively. Despite the expansion of farming area in Zone 1 yearly food security was found to be relatively low within households there (8 ± 3 months/year) than Zones 2 (10 ± 2.7 months/year) and 3 (10 ± 2.46 months/year). Conversely, a higher proportion of households (38%) possess stable farm areas in Zone 2 than Zones 1 (20%) and 3 (24%). A significant difference found on the farm size was higher in Zone 2 (5.15 ± 4.52 acre) than Zones 1 (3.04 ± 2.70 acre) and 3 (3.70 ± 4.95 acre). In addition, more households (70%) also possess home garden in Zone 2, as a compliment to their agricultural activities.

10. Discussion and conclusion

The Agrarian Change project aims to move land use debates forward from solely examining trade-offs between food production/security and biodiversity, to one of understanding potential synergies. The consequences of different land use strategies can only be fully understood within the wider context of local histories, culture, politics, and market dynamics. For example, land use decisions at the household level often influence what happens at the landscape scale, yet in a majority of cases such decisions are driven by strong externalities such as government policies, technological capacity, agricultural extension, and markets. In addition, local scale effects upon livelihoods, poverty, food security and nutrition have tended to be overlooked, or solely through sectoral lens'. Thus the Agrarian Change Project, addresses this research gap and attempts to advance our understanding of agricultural landscapes as integral social-ecological systems. It offers insights into the impacts of the transition from forest to agriculture, through the different Zones, in that Zone 1 can potentially become Zone 3 if the gradient of change is followed through in each case, thus allowing for early intervention based on findings per zone. Early indications suggest that the transformation of wildlands, notably forests, for agriculture has much more varied and complex impacts on livelihoods, nutrition and health than previously anticipated.

The study aims to challenge the perceived wisdom that suggests that rural communities with better access to markets, transportation and intensive agricultural systems are better fed, and are fiscally better off than those in the proximity of more isolated, forested landscapes (cf. Levang et al., 2005). Although historical evidence suggests the transition away from a forest-based economy leads to overwhelmingly better outcomes for poverty and human well-being (Sunderlin et al., 2007). From the early 1960s, pervasive growth based theories of agricultural development based on technological change were promoted as a solution to persistent rural poverty (Mellor, 1967). Yet local observers and village field researchers noted that rural development wasn't working as intended; the numbers of poor grew and some non-poor smallholders, fisherman, pastoralists subsequently became poor through loss of assets or common property resources, and overall health and nutrition benefits remained elusive. Larger farmers appropriated the land of smaller farmers, rural labourers were displaced by mechanisation and intensive farming depleted scarce water resources and affected soils. In short, as agricultural transformation takes place, there are inevitable winners and losers. Thus it might be argued that the assumptions that underpin notions of better livelihoods in terms of food, health and wealth as land becomes increasingly dominated by agrarian systems, rather than by natural vegetation could be challenged. For example, the loss of forest can ultimately cause increasingly negative livelihood impacts, such as described for Ethiopia where traditional grazing land provided by forests has been converted to agricultural fields with a concomitant loss of income to herders (Baudron et al., in press).

This is mirrored by the important contribution of forest resources in Burkina Faso, Cameroon and Zambia, albeit in different ways. At the other end of the spectrum, In Indonesia, commercialised agrarian systems, in this case characterised by rubber and oil palm, have had a somewhat negative impact on local diets and nutrition with access to the cash economy facilitating a nutrient transition to a diet of processed food (Ickowitz et al., 2016). The increase in tree cover through agroforestry practices in Bangladesh provides an indication of the value of trees within agricultural systems, despite the underlying chronic poverty of the population in the Chittagong landscape (see also Rahman et al., 2014).

Preliminary findings from the study support those by other authors such as Agrawal et al. (2013), who estimate that over 1.3 billion people utilise forests and trees *in some way* and that forested landscapes generate significant income for those that reside in and around them. Smallholders across the developing world may still derive as much income from foraging forests and wildlands as from cultivating crops (Wunder et al., 2014). The findings of the tropics-wide Poverty and Environment Network (PEN), also suggest that rural households rely far more on income and other services from their immediate natural environment than previously thought. The PEN project found that over 25% of household income is sourced from natural resources; this represents a greater annual household than that of agricultural production (Angelsen et al., 2014). Ickowitz et al. (2014), in a continent-wide study in Africa found a correlation between the presence of forests and trees and dietary diversity. Thus the evidence-base on the *synergies* between agriculture and the wider environment are being gradually, and increasingly understood, and it is those synergies that this project is attempting to articulate.

The results of the segregation of agriculture from forestry and other land uses has led to critical reflection as to how these seemingly conflicting land uses can be better integrated for improved outcomes (Sayer et al., 2013). As this paper attempts to illustrate, agricultural production in most tropical landscapes is not the linear process from the direct transition of tree cover to agricultural fields but more based on complex landscape mosaics that are managed for multiple benefits and a broad suite of goods and ecosystem services (Padoch and Sunderland, 2014). Although greatly under-estimated, the presence of forests and trees in these landscapes provides a framework for the integration of diverse cropping systems (Reed et al., 2016). They are also immensely valuable to the livelihoods and well-being of those that live in such environments.

At the end of 2015, the launch of the Sustainable Development Goals provided a unique opportunity to begin that process of integrating previously siloed disciplines into a more cogent development agenda, with a strong focus on landscapes as the convening factor (Van Vianen et al., 2015; Reed et al., 2016). In addition, the preamble of the historic COP 21 (UNFCCC, 2015) agreement also mentions food security from a broader perspective by "*safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change*", and also refers to human rights, gender, ecosystems and biodiversity, all issues that are central to agriculture. Thus the policy environment has become far more conducive to a more environmentally sensitive agriculture, with broader development aspirations such as improved nutrition etc. The development lexicon has certainly changed in recent years to reflect a broader system (or landscape) approach to food production in the context of the wider environmental benefits and yet systematic and empirically focused research to enable us to actually implement this has been largely absent from the discourse (Reed et al., 2015).

Therefore, as the studies in each country continue and more data becomes available in the subsequent stages of the project, it will allow a broader cross-site comparison of studies that will ultimately enable significantly more compelling conclusions to be drawn from this project. These intend to provide much needed insights into how landscape level land use trajectories manifest in local communities and advance our understanding of multi-functional landscapes as socio-ecological systems. Only by understanding the connectedness of intricate and complex socio-ecological systems through such integrated research methods are we able to fully appreciate the subtlety and nuance of these findings and the relationships between varying landscape components. As this research unfolds we aim to further test the hypotheses and answer the questions listed earlier in more detail. Agrarian change transitions are taking place all over the globe, but clearly not everyone benefits. Who does, how and why, will be the focus of further assessment.

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References

[BFD] Bangladesh Forest Department, 2015. Forest cover of Bangladesh. Accessed 20 June 2015. http://fd.portal.gov.bd/.

[FAO] Food and Agriculture Organization of the United Nations, [IFAD] International.Fund for Agricultural Development and [WFP] World Food Programme, 2013[FAO] Food and Agriculture Organization of the United Natio. The State of Food Insecurity in the World, 2013. The Multiple Dimensions of Food Security FAO, Rome. http://www.fao.org/docrep/018/i3434e/i3434e00.htm.

Adams, W.M., 2012. Feeding the next billion: hunger and conservation. Oryx 46, 157–158.

Agrawal, A., Shepherd, G., Bensen, C., Hardin, R., Cashore, B., Miller, D., 2013. Economic contributions of forests. In: Background Paper 1 for UNFF10. United Nations Forum on Forests, New York (132 pp.). http://www.un.org/esa/forests/pdf/session_documents/unff10/EcoContrForests.pdf.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N., Bauch, S., Borner, J., Smith-Hall, C., Wunder, S., 2014. Environmental income and rural livelihoods: a Global-comparative analysis. World Dev. 64 (1), S12–S28.

Asaha, S., 2015. Land Use Change, Rural Livelihoods and Food Security in the Manyemen-Nguti Forest Landscape, South West Region, Cameroon. A thesis submitted to the department of Development Studies, in partial fulfilment of the requirements for the award of a Master of Science (M.Sc) degree in Environment and Natural Resource Management Pan African Institute for Development–West Africa Buea, Cameroon.

Bala, B.K., Majumder, S., Altaf Hossain, S.M., Haque, M.A., Hossain, M.A., 2013. Exploring development strategies of agricultural systems of Hill Tracts of Chittagong in Bangladesh. Environ. Dev. Sustain. 15 (4), 949–966.

Baudron, F., Giller, K.E., 2014. Agriculture and nature: Trouble and strife? Biol. Conserv. 170, 232–245.

Baudron F, Duriaux Chavarria J-Y, Remans R, Yang K, and Sunderland T. Indirect contributions of forests to dietary diversity in Southern Ethiopia. Ecol. Soc. (in press).

Bennett, E., 2017. Changing the agriculture and environment conversation. Nature Ecology and Evolution 1, 10018.

Bennett, A.F., Radford, J.Q., Haslem, A., 2006. Properties of land mosaics: implications for nature conservation in agricultural environments. Biol. Conserv. 133 (2), 250–264.

Bharucha, Z., Pretty, J., 2010. The roles and values of wild foods in agricultural systems. Philos. Trans. R Soc. B: Biol. Sci. 365 (1554), 2913–2926.

Black, R.E., Victora, C.G., Walker, S.P., Bhutta, Z.A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., et al., 2013. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet 382 (9890), 427–451.

Bruinsma, J. (Ed.), 2003. World Agriculture: Towards 2015/2030. An FAO Perspective. Earthscan Publications, London.

Brussaard, L., Caron, P., Campbell, B., Lipper, L., Mainka, S., Rabbinge, R., Babin, D., Pulleman, M., 2010. Reconciling biodiversity conservation and food security:Scientific challenges for a new agriculture. Curr. Opin. Environ. Sustain. 2 (1–2), 34–42.

Byerlee, D., Stevenson, J., Villoria, N., 2014. Does intensification slow land conversion or encourage deforestation? Glob. Food Sec. 3, 92–98.

Clough, Y., Barkmann, J., Juhrbandt, J., Kessler, M., Wanger, T.C., Anshary, A., Buchori,

D., Cicuzza, D., Darras, K., Putra, D.D., et al., 2011. Combining high biodiversity with high yields in tropical agroforests. Proc. Natl. Acad. Sci. 108 (20), 8311–8316.
Coulibaly-Lingani, P., Tigabu, M., Savadogo, P., Oden, P.-C., Ouadba, J.-M., 2009. Determinants of access to forest products in southern Burkina Faso. Forest Policy Econ. 11 (7), 516–524.
Deakin, E., Kshatriya, M., Sunderland, T. (Eds.), 2016. Agrarian Change in Tropical Landscapes. Centre for International Forestry Research, Bogor, Indonesia (323 pp.). http://www.cifor.org/publications/pdf_files/Books/BCIFOR1601.pdf.
Ellis, E.C., Goldewijk, K.K., Siebert, S., Lightman, D., Ramankutty, N., 2010. Anthropogenic transformation of the biomes, 1700 to 2000. Glob. Ecol. Biogeogr. 19 (5), 589–606.
ESRI, 2012. ArcGIS Desktop: Release 10.1.
Fischer, J., Brosi, B., Daily, G.C., Ehrlich, P.R., Goldman, R., Goldstein, J., Lindenmayer, D.B., Manning, A.D., Mooney, H.A., Pejchar, L., et al., 2008. Should agricultural policies encourage land sparing or wildlife-friendly farming? Front. Ecol. Environ. 6 (7), 380–385.
Fischer, J., Abson, D.J., Butsic, V., Chappell, M.J., Ekroos, J., Hanspach, J., Kuemmerle, T., Smith, H.G., von Wehrden, H., 2014. Land sparing versus land sharing: moving forward. Conserv. Lett. 7 (3), 149–157.
Foli, S., Abdoulaye, R., 2016. Drivers and outcomes of changing land use in parkland agroforestry systems of central Burkina Faso. In: Deakin, E.L., Sunderland, T.C.H., Kshatriya, M. (Eds.), Agrarian Change in Tropical Landscapes. CIFOR, Bogor, Indonesia, pp. 269–299.
Gibbs, H.K., Ruesch, A.S., Achard, F., Clayton, M.K., Holmgren, P., Ramankutty, N., Foley, J.A., 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. Proc. Natl. Acad. Sci. 107 (38), 16732–16737.
Godfray, H.C.J., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Nisbett, N., Pretty, J., Robinson, S., Toulmin, C., Whiteley, R., 2010. The future of the global food system. Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 365 (1554), 2769–2777.
Green, R.E., Cornell, S.J., Scharlemann, J.P.W., Balmford, A., 2005. Farming and the fate of wild nature. Science 307 (5709), 550–555.
Gumbo, D., 2015. Nyimba Forest Project dataset. UNF:5:18pkbj/I/onhGlLNP0SI1g = = Center for International Forestry Research [Distributor]. V2 [Version]. http://hdl.handle/.net/11463/10055.
Hansen, M., Potapov, P., Moore, R., Hancher, M., Turubanova, S., Tyukavina, A., Thau, D., Stehman, S., Goetz, S., Loveland, T., Kommareddy, A., Egorov, A., Chini, L., Justice, C., Townshend, J., 2013. High-resolution global maps of 21st-century forest cover change. Science 342 (80), 850–853.
Hansen/UMD/Google/USGS/NASA, 2014. Forest Change Data Measure Tree Cover Loss, Tree Cover Gain, or Forest Disturbance. Creative Commons CC BY 4.0. Global Forest Watch, Washington, DC. http://50.18.182.188.6080/arcgis/rest/services/ForestCover_lossyear/Imageserver.
Ickowitz, A., Powell, B., Salim, A., Sunderland, T., 2014. Dietary quality and tree cover in Africa. Glob. Environ. Chang. 24, 287–294.
Ickowitz, A., Powell, B., Salim, A., Sunderland, T., 2016. The effect of tree cover on child nutrition in Indonesia: examining the relationship between tree cover and consumption of micronutrient-rich foods. PLoS One 11 (5), e0154139.
Islam, M., Alam, M., Mantel, S., 2007. Land use planning and environmental control in the Chittagong Hill Tracts. In: CHARM Project Report 3. International Soil Reference and Information Centre (ISRIC), The Netherlands (Dhaka, Bangladesh).
Jin, S., Yang, L., Danielson, P., Homer, C., Fry, J., Xian, G., 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sens. Environ. 132, 159–175.
Kerr, J., Ostrovsky, M., 2003. From space to species: ecological applications for remote sensing. Trends Ecol. Evol. 18, 299–305.
Khatun, K., Gross-Camp, N., Corbera, E., Martin, A., Ball, S., Massao, G., 2015. When Participatory Forest Management makes money: insights from Tanzania on governance, benefit sharing, and implications for REDD +. Environment and Planning A 47 (10), 2097–2112.
Khatun, K., Corbera, N., Ball, S., 2016. Fire is REDD +: offsetting carbon through early burning activities in south-eastern Tanzania. Oryx 51 (1), 43–52.
Koffi, C.K., Djoudi, H., Gautier, D., 2016. Landscape diversity and associated coping strategies during food shortage periods: evidence from the Sudano-Sahelian region of Burkina Faso. Reg. Environ. Chang. 1–12.
Law, E.A., Wilson, K.A., 2015. Providing context for the land-sharing and land-sparing debate. Conserv. Lett. 8 (6), 404–413.
Levang, P., Dounias, E., Sitorus, S., 2005. Out of the forest, out of poverty? Forests, Trees and Livelihoods 15, 211–235.
Loos, J., Abson, D.J., Chappell, M.J., Hanspach, J., Mikulcak, F., Tichit, M., Fischer, J., 2014. Putting meaning back into “sustainable intensification”. Front. Ecol. Environ. 12 (6), 356–361.
Lu, D., Mausel, P., Brondizio, E., Moran, E., 2004. Change detection techniques. Int. J. Remote Sens. 25, 2365–2407.
Masek, J., Vermote, E., Saleous, N., Wolfe, R., Hall, F., Huemmrich, K., Gao, F., Kutler, J., Lim, T.K., 2006. A Landsat Surface Reflectance Dataset for North America, 1990–2000. IEEE Geosci. Remote Sens. Lett. 3 (1), 68–72.
Matson, P.A., Parton, W.J., Power, A.G., Swift, M.J., 1997. Agricultural intensification and ecosystem properties. Science 277 (5325), 504–509.
Mellor, J., 1967. The Economics of Agricultural Development. Cornell University Press, Ithaca (403 pp.).
Meyer, W.B., Turner, B.L., 1992. Human-population growth and global land use cover change. Annu. Rev. Ecol. Syst. 23, 39–61.
Motes, W., 2010. Modern Agriculture and Its Benefits–Trends, Implications and Outlook. Global Harvest Initiative, Washington, D.C.
Perrings, C., Jackson, L., Bawa, K., Brussaard, L., Brush, S., Gavin, T., Papa, R., Pascual, U., De Ruiter, P., 2006. Biodiversity in agricultural landscapes: saving natural capital without losing interest. Conserv. Biol. 20 (2), 263–264.
Padoch, C., Sunderland, T., 2014. Managing landscapes for food security and enhanced livelihoods: building upon a wealth of local experience. Unasylva 64 (241) 2013/2. http://www.fao.org/docrep/019/i3482e/i3482e01.pdf.
Phalan, B., Balmford, A., Green, R.E., Scharlemann, J.P.W., 2011a. Minimising the harm to biodiversity of producing more food globally. Food Policy 36, S62–S71.
Phalan, B., Onial, M., Balmford, A., Green, R.E., 2011b. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. Science.
Pirard, R., Treyer, S., 2010. Agriculture and Deforestation: What Role Should REDD + and Public Support Policies Play? Institut du Developpment durable et des relations internationles (IDDRI), Paris (No.10/2010 December).
Powell, B., Thilsted, S.H., Ickowitz, A., Termote, C., Sunderland, T., Herforth, A., 2015. Improving diets with wild and cultivated biodiversity from across the landscape. Food Security 7 (3), 535–554.
R Core Team, 2015. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.
Rahman, S.A., Rahman, M.F., Sunderland, T., 2014. Increasing tree cover in degrading landscapes: ‘Integration’ and ‘intensification’ of smallholder forest culture in the Alutilla valley, Matiranga, Bangladesh. Small-scale Forestry 13, 237–249.
Reed, J., Deakin, L., Sunderland, T., 2015. What are “integrated landscape approaches” and how effectively have they been implemented in the tropics: a systematic map protocol. Environmental Evidence 4 (1), 2.
Reed, J., Van Vianen, J., Deakin, E., Barlow, J., Sunderland, T., 2016. Integrated landscape approaches to managing social and environmental issues in the tropics: learning from the past to guide the future. Glob. Chang. Biol. 22 (7), 2540–2554.
Reed, J., Van Vianen, J., Barlow, J., Sunderland, T., 2017. Have integrated landscape approaches to reconciled societal and environmental issues in the tropics? Land Use Policy 63, 481–492.
Sayer, J., Sunderland, T., Ghazoul, J., Pfund, J.L., Sheil, D., Meijaard, E., Venter, M., Boedhihartono, A.K., Day, M., Garcia, C., et al., 2013. Ten principles for a landscape approach to reconciling agriculture, conservation and other competing land uses. Proc. Natl. Acad. Sci. U. S. A. 110 (21), 8349–8356.
Sayer, J., Buck, L., Langston, J., Margulies, C., Reed, J., Riggs, R., Sunderland, T., 2016. Measuring the effectiveness of landscape approaches to conservation and development. Sustain. Sci. http://dx.doi.org/10.1007/s11625-016-0415-z.
Soehartono, T., Newton, A., 2001. Conservation and sustainable use of tropical trees in the genus Aquilaria II. The impact of gaharu harvesting in Indonesia. Biol. Conserv. 97 (1), 29–41.
Sunderland, T., 2011. Food security: Why is biodiversity important? Int. For. Rev. 13 (3, SI), 265–274.
Sunderlin, W., Dewi, S., Puntodewo, A., 2007. Poverty and Forests: Multi-country Analysis of Spatial Association and Proposed Policy Solutions. Occasional Paper 47 CIFOR, Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/OccPapers/OP-47.pdf.
Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I., Thies, C., 2005. Landscape perspectives on agricultural intensification and biodiversity-ecosystem service management. Ecol. Lett. 8 (8), 857–874.
Tscharntke, T., Clough, Y., Wanger, T.C., Jackson, L., Motzke, I., Perfecto, I., Vandermeer, J., Whitbread, A., 2012. Global food security, biodiversity conservation and the future of agricultural intensification. Biol. Conserv. 151 (1), 53–59.
[UNICEF] United Nations Children's Fund, 2011. Levels and trends in child mortality. In: Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation. United Nations Children's Fund, New York, NY. http://www.unicef.org/media/files/Child_Mortality_Report_2011_Final.pdf.
UNFCCC, 2015. Adoption of the Paris Agreement. Proposal by the President. (FCCC/CP/2015/L.9/Rev.1). 12 December 2015. http://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf.
Van Vianen, J., Reed, J., Sunderland, T., 2015. From Global Complexity to Local Reality: Aligning Implementation Frameworks with Sustainable Development Goals and Landscape Approaches. CIFOR Policy Brief No. 1. Centre for International Forestry Research, Bogor. http://www.cifor.org/library/5864/from-global-complexity-to-local-reality-aligning-implementation-frameworks-with-sustainable-development-goals-and-landscape-approaches/.
Wilson, E., Sader, S., 2002. Detection of forest harvest type using multiple dates of Landsat TM imagery. Remote Sens. Environ. 80, 385–396.
Wright, H.L., Lake, I.R., Dolman, P.M., 2012. Agriculture – a key element for conservation in the developing world. Conserv. Lett. 5 (1), 11–19.
Wunder, S., Angelson, A., Belcher, B., 2014. Forests, livelihoods, and conservation:broadening the empirical base. World Dev. 64, S1–S11.
Ziegler, A.D., Fox, J.M., Xu, J., 2009. Agriculture: the rubber juggernaut. Science 324 (5930), 1024–1025.