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Facilitating Smallholder Tree Farming in Fragmented Tropical Landscapes: Challenges and Potentials for Sustainable Land Management

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Abstract

Under changing land use in tropical Asia, there is evidence of forest product diversification through implementation of tree-based farming by smallholders. This paper assesses in two locations, West Java, Indonesia and eastern Bangladesh, current land use conditions from the perspective of smallholder farmers, the factors that facilitate their adoption of tree farming, and the potential of landscape-scale approaches to foster sustainable land management. Data were collected through rapid rural appraisals, focus group discussions, field observations, semi-structured interviews of farm households and key informant interviews of state agricultural officers. Land at both study sites is typically fragmented due to conversion of forest to agriculture and community settlement. Local land use challenges are associated with pressures of population increase, poverty, deforestation, shortage of forest products, lack of community-scale management, weak tenure, underdeveloped markets, government decision-making with insufficient involvement of local people, and poor extension services. Despite these challenges, smallholder tree farming is found to be successful from farmers' perspectives. However, constraints of local food crop cultivation traditions, insecure land tenure, lack of capital, lack of knowledge, lack of technical assistance, and perceived risk of investing in land due to local conflict (in Bangladesh) limit farmers' willingness to adopt this land use alternative. Overcoming these barriers to adoption will require management at a landscape scale, including elements of both segregation and integration of land uses, supported by competent government policies and local communities having sufficiently high social capital.

Keywords: land use, livelihood, landscape approach, community

Introduction

At the United Nations Conference on Sustainable Development (Rio+20) in 2012, the UN Secretary General proposed an ambitious goal to eliminate global hunger by 2025, the 'Zero Hunger Challenge' (Vira et al., 2015). This requires year-round access to food for the world's growing population[1], while enhancing livelihood security, by improving the productivity of agricultural systems, without causing ecological harm or compromising biodiversity and ecosystem services (Garnett et al., 2013; FAO, 2011). Furthermore, the state of tropical forest resources in most Asian countries has reached a critical point; never before have forest ecosystems been so greatly affected by human activities as during recent decades (Snelder and Lasco, 2008). In addition to declining forest area, the area of land suitable for productive agriculture is also dwindling, particularly in developing countries where approximately one quarter of all farmland has been degraded (Garrity, 2004), through unsustainable cultivation practices causing nutrient deficiency and loss of soil organic matter and physical structure.

The urgent need to reduce both rates of deforestation and forest degradation and the degradation of agricultural land, through improved sustainability of land use, has been widely recognized. This has triggered projects and programs on forest conservation, reforestation, and agroforestry aimed at the integration of trees in predominantly agricultural landscapes (Snelder and Lasco, 2008). Agroforestry practices by smallholder farmers are considered a potential strategy for poverty reduction (FAO, 2005; ICRAF, 2003). Agroforestry is increasingly important for sustainable food production (Ickowitz et al., 2014; Johnston et al., 2013; Rahman et al, 2013), and restoring and safeguarding ecological and socio-economic sustainability in agricultural landscapes (Roshetko et al., 2007a; Swallow et al., 2006; Garrity, 2002). Trees on farms can also relieve the pressure on remaining forest resources (Murniati et al., 2001).

There is evidence of spontaneous forest product diversification through implementation of tree-based farming by smallholders, especially in Asian countries (e.g. the Chittagong hill tracts, Bangladesh; North and West Sumatra, West Java, East Kalimantan, Indonesia; Cebu, Philippines) (Rahman et al., 2014; Roshetko et al., 2013; Snelder and Lasco, 2008; Michon, 2005). The state policies of banning logging or restricting forest product harvesting in countries such as Indonesia, Thailand and the Philippines are also leading smallholder farmers to search for alternative sources of tree products through integrating trees into their

[1] The global population was approximately 7.32 billion in 2015 and is predicted to reach over 9 billion by 2050. Consequently the issue of food security is increasing in importance in academic and policy debates, especially in relation to the global development agenda beyond 2015 (Vira et al., 2015; FAO et al., 2014).

farming systems. Moreover, it is expected that, with increasing population size and consequent land shortage, the number of farmers with smallholdings will remain high or may even increase in the near future.

The success of smallholder tree cultivation depends on farmers' ability to overcome a number of barriers. Previous research has indicated the importance of investment capital, sufficient production technologies and knowledge, secure tenure, and adequate physical infrastructure and policy support for the transport of tree products to market (Rahman et al., 2014; Rahman et al., 2008; van Noordwijk et al., 2008). However, due to socioeconomic and environmental challenges at a landscape scale – which are increasingly complex, widespread, and variable between landscapes – there is a debate on the sustainability of smallholder tree cultivation as a land use strategy, especially when compared with food crop agriculture and the sparing of land from agriculture for biodiversity conservation and the delivery of a range of ecosystem services (Sayer et al., 2013; van Noordwijk et al., 2012; van Noordwijk et al., 2008). The importance of the social and policy components of this challenge is increasingly recognised, yet remains under-represented in published research (Kiptot and Franzel, 2011; Mercer, 2004; Mercer and Miller, 1997). To contribute to this need, the present study addresses the agroforestry adoption gap by analyzing conditions of smallholder farmers that are relevant to the potential for adoption of tree farming in two contrasting tropical Asian locations – West Java, Indonesia and eastern Bangladesh. It specifically seeks to answer the following questions. 1. What are the most important challenges facing farmers in their current land use systems? 2. Which policies are most likely to be successful in facilitating farmer adoption of successful tree farming? 3. Which approaches are likely to work best across scales from the landscape (to reconcile food production and environmental goals) to the individual farm household? The results are synthesized for each of the major land use systems currently practiced by smallholders in the two locations, including their products and services; and the major land use challenges faced by the farmers. This informs a discussion focused on the potential for intensification of current farming practice through increased conversion to tree-based farming, what conditions facilitate successful tree-based farming, and the applicability of landscape-scale approaches (land sparing and land sharing) as a framework for the development of land use systems that are more sustainable from a local perspective. The assessment includes the policy context needed to support sustainable land management to provide both goods for local livelihoods and ecosystem services of wider societal benefit.

Materials and Methods

Study site

The study sites are located in Gunung Salak valley, Bogor District, West Java, Indonesia and Khagrachhari district, eastern Bangladesh. The Gunung Salak site lies between 6º 32' 11.31" S and 6º 40' 08.94" S latitudes and between 106º 46' 12.04" E and 106º47' 27.42" E longitudes. With an equatorial climate and average yearly precipitation of 1700 mm this area is more rainy and humid than most parts of West Java. Three villages, Kp. Cangkrang, Sukaluyu and Tamansari, in the northern part of Gunung Salak valley were purposively selected[2] for the study. Sukaluyu and Tamansari contain a mixture of households practicing both subsistence seasonal swidden farming and agroforestry, that form the major comparison of this study. Kp. Cangkrang is located in a different part of the valley, most of its households practice permanent monoculture farming, and it is included as an outgroup comparison. During the data collection in 2013, there were approximately 1600 households (10,200 people) living in these three villages. Agriculture is mainly a subsistence practice in the study site, conducted by small-scale farmers. Household incomes are mainly based on agricultural and forest products, sold in local and district markets, in addition to wage labor and retailing (Badan Pusat Statistik, 2013).

Khagrachhari district is part of the Chittangong hill tracts, which is the extensive hilly and forested area in Bangladesh, and lies between 21º 11' 55.27" N and 23º 41' 32.47" N latitudes and between 91º 51' 53.64" E and 92º 40' 31.77" E longitudes. The average yearly precipitation is 2540 mm (BBS, 2014). Two villages, Mai Twi Para and Chondro Keron Karbari Para, were purposively selected[3] for the study. During the data collection in 2013 there were approximately 135 households (750 people) living in these two villages. Agriculture is a subsistence practice practiced by small-scale farmers. Household incomes are mainly derived from wage labor and selling agricultural and forest products in local and district markets.

Data collection

Rapid rural appraisals (RRA) were used with the support of village mapping and key informant interviews for the socioeconomic and geographical characterisitics of the research sites (FAO, 2015; Angelsen et al., 2011). For each village, the mapping sessions and key informant interviews were conducted with the village head and three farmers. These three

[2] The villages were selected based on stratification by watershed location and having the largest sample size of farm households that practice their associated land use systems, i.e. in the lower watershed permanent monoculture (Kp. Cangkrang), and in the middle (Sukaluyu) and upper (Tamansari) watershed agroforestry and swidden.

[3] The area consists of hills, and the two villages were selected as those with the largest sample size of farm households that practice agroforestry and swidden.

farmers were selected purposively[4] based on their knowledge about the village and surrounding areas.

One focus group discussion (FGD) in each village[5] and field observations were used to collect information on local land use systems, the services that they deliver, and the land use challenges that local people face. Local farmer representative groups, consisting of eight to twelve farmers[6], and the village heads were selected for the FGD sessions. During the RRAs and FGDs, 70 locations were identified across the five villages for the field observations. During these observations, relevant information of local cultivation systems was noted with the assistance of expert local informants[7] and photographs were taken.

In Indonesia 20 permanent monoculture[8], 20 swidden and 20 agroforestry farmers; and in Bangladesh 40 swidden and 21 agroforestry farmers were purposively selected for semi-structured questionnaire interview. Before implementing the interview, the questionnaire was refined and finalized with the help of the expert local informants and during FGD sessions to make sure that the questions elicited the required information about the basic characteristics of each farm household, i.e. family size, land area, gross income, expenditure, savings, and interest in tree-based farming. Due to the variation in structure and management practices of the farms in each area, purposive sampling was used to identify households that were practicing a well-managed[9] form of each of the contrasted farming systems. Some of the farmers cultivate plots of land using different farming practices (i.e. agroforestry, swidden or permanent monoculture). Therefore, farmers were assigned to a group based on their dominant form of farming practice. In the Indonesian study area, we estimate that our sample represents 20%, 40% and 30% of the permanent monoculture, swidden and agroforestry farming populations respectively. In Bangladesh, they represent about 50% and 60% of the swidden and agroforestry farming populations respectively.

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[4] This selection was made with the help of expert local informants.

[5] One semi-structured questionnaire interview (village survey, consisting of a set of questions related to basic information about the village, e.g. demography, infrastructure and land use) was also conducted during the FGD.

[6] Farmers in each group were purposively selected with the help of expert local informants based on their knowledge of local cultivation systems.

[7] One person from each research site (country), who had considerable knowledge of local land use systems, products, markets and institutions, was employed as an expert local informant. These informants were present during the whole period of fieldwork, and helped check the validity of information obtained.

[8] In this research, permanent monoculture refers to growing a single crop (but there are differences in which single crop is grown) at given times of the year in a rotational system in the same area without abandoning the land.

[9] Well managed farms are those with active planting and efficient utilization of space and time. For example, some farmers started agroforestry farming but after a few years stopped understorey planting for various reasons (e.g. lack of management interest or capital). Thus many agroforestry farms were converted to simple tree orchards, which have been excluded from our sample.

Four key informant interviews with local state agriculture officers were conducted (two in each country) to elicit their vision about local land use systems and challenges (e.g. local modes of land use and the services that they deliver, land tenure, strength of government extension services, existing credit policy). Other supporting data were gathered from local state agriculture and forestry offices, and the World Agroforestry Centre (ICRAF) Southeast Asian Regional office and the headquarters of the Centre for International Forsetry Research (CIFOR) (both located in Bogor, Indonesia). Secondary data from published literature were used for background and to aid interpretation.

Results and Discusson

Local land use matrix, products and ecosystem services

Based on the information from RRAs, FGDs, field observations and the expert local informants, it was found that land in the study villages is typically fragmented. Most of this fragmentation occurred due to the pattern of land conversion from forest to agriculture and community settlement. Clearance of the forest vegetation has divided it into separate fragments of forest inter-mixed with patches of agricultural and settlement land. Slash-and-burn farming practice produces a dynamic mixture of currently cropped and fallow land. Across both study sites, we have categorised four major land use types each of which deliver a different combination of products and services to local people (Supplementary Material Table 1).

Land use A: intensive agriculture

In this type, farmers cultivate various crops generally in monocultures (e.g. upland rice, maize, vegetables, spices, fruits and timber) in permanent agriculture fields. Agroforestry is a component in this type, where trees are grown together with seasonal and perennial crops. Production is mainly subsistence oriented but some farmers have replaced traditional crops such as rice, maize and vegetables with high value cash crops, e.g. taro, pineapple, banana, papaya and the tree crop teak. Intensive agriculture includes the practices of mulching, strip cropping and rotational cropping together with the use of fertilizer to maintain soil productivity.

Land use B: extensive agriculture

In this type, farmers prepare new areas of land (including by converting forest land) using the traditional swidden (slash-and-burn) method. Production is mainly subsistence-oriented dominated by food crops, such as upland rice, maize and vegetables. Crop cultivation is

rotated between fields to maintain soil productivity; this practice is very dependent on the availability of land. No specific soil fertility management is followed, except for rotational fallow for 2-4 years after cropping for 1-3 years.

Land use C: forest

Forest land in the study villages consists of a mixture of tropical evergreen and deciduous woody plant species. The forests can be categorized into two types [10] natural and plantations, which can be monocultures or mixed species. In Bangladesh, about 60 percent of village forests are natural and 40 percent plantation[11]. In Indonesia, about 90 percent and 10 percent are natural and plantation respectively. Forests provide a wide variety of useful products and services for local households in both study sites. Firewood, rattan, bamboo and forest foods, e.g. mushrooms, wild fruits and vegetables, are the key NTFPs reported by the informants in both study sites. Some NTFPs (e.g. mushrooms and vegetables) are sold in markets for supplementary household cash income or traded for essentials such as rice.

Land use D: settlement

Local village communities mostly live in dwellings located close to one another comprising several hamlets. However, a few households are more isolated being scattered over the landscape with their location based on the availability of crop land, as local livelihoods mainly rely on subsistence agriculture. Hamlets are formed for social and security reasons. Nearly all land surrounding the hamlets is farmed. Other important infrastructure in the villages is roads, markets, shops, playing fields and communal buildings (e.g. educational or religious). Villages are permanent, however intra- and inter-village transition of dwellings (relocation of household) does occur.

Land use challenges

Farmers in both study sites stated that several factors create pressure on the existing land use systems especially on crop land, which is already limited in extent. Land use challenges are intensifying due to increasing population size, weak tenure, low family income, weakness of decision-making at the community scale and poor government services, as discussed in this section.

[10] In this study, natural forest is defined as composed of indigenous trees, not planted by humans. Plantation forest, on the other hand, comprises stands established by planting and/or seeding in the process of afforestation or reforestation (after FAO, 2012).

[11] The names of common tree species are provided in Suppmentary Material Table 2.

Population pressure

Focus group discussion respondents, government agricultural officers and expert local informants reported that the lack of awareness of family planning among village people, and in-migration[12], are causing rapid population growth in the study sites. In Bangladesh, the situation is exacerbated by growing spontaneous migration in recent years. As a result, even the remote small communities in our study site have grown from approximately 550 persons (95 households) to 750 persons (135 households) over the past 10 years[13]. In the Indonesian site, the in-migration rate was high because it is just 15 km from Bogor City which generates many economic opportunities (e.g. off-farm employment) compared with other remoter parts of Gunung Salak valley. The current population of the Indonesian study site is approximate 10,200 (1,600 households), which has increased from 9,000 (1,390 households) in just 10 years[14]. In both study sites, the increasing population[15] intensifies land needs for subsistence and shelter, causing land shortages, fragmentation and degradation. In addition, the expert local informants reported that land fragmentation increases when adult household members marry, make their own family, and manage land separately. Households also need to expand their land area (by forest clearing or purchasing) for more food production due to an increase in family members. However, expansion of household land area may not be possible if there is a scarcity of available land and, as a result, many households shorten the fallow period, which was stated by FGD respondents to result in a decrease in soil fertility.

Forest land degradation due to agricultural expansion

FGD respondents at both sites reported that forest land is heavily degraded (Figure 1) and that the limited land available for cultivation results in crop yields that are insufficient for families' needs. They reported that this results in agricultural expansion being the main cause of local defforestaion. When slash-and-burn cultivators leave a field to lie fallow they often need to search for new land to cultivate, frequently by clearing forest. Forest fires, often caused by uncontrolled burning during land clearance for cultivation, may destroy larger areas of forest vegetation. They also noted that shortened fallow periods due to

[12] The government policy of settlement in Bangladesh has created a huge stream of immigrants guided to the study region since 1976 (Rahman et al., 2012).

[13] The population in this district (Khagrachari) increased from 92,380 in 2001 to 111,833 in 2011 (BBS, 2015).

[14] The population in this regency (Bogor) increased from 3,829,053 in 2005 to 4,771,932 in 2011 (which was projected to have reached 5,131,798 in 2014) (Badan Pusat Statistik, 2015).

[15] Population pressure is a common national problem for both Bangladesh and Indonesia. It is estimated that, with an annual growth rate of 1.2 percent for both countries, the total population of Bangladesh may increase from 160.9 million in mid 2015 to 202.20 million in 2050; and in Indonesia, from 257.56 million in mid-2015 to 322.23 million in 2050 (ESCAP, 2015).

limited land availability may prevent the regeneration of many forest species before the next cultivation period. We observed in both study sites that the farmland which had been created by slash-and-burn is now fragmented and much of the land currently under forest cover is severely degraded[16].

Forest product impoverishment

Focus group discussion respondents and the local expert informants at both sites stated that, traditionally, local people collect forest products to support their livelihoods, but due to deforestation and over-exploitation of local forest resources they are now experiencing a scarcity of forest products. At the Bangladesh site, some forest products such as forest ginger (*Zingiber* spp.) and alpinia (*Alpinia galangal*) are only found ≥ 3 km from the villages, and rattan is almost no longer collected due to its scarcity. In the Indonesia site, villagers have to spend more time to find forest products such as bamboo shoots, mushrooms and firewood[17].

Insecure land tenure

All the land at both study sites is owned by the national government[18]. Local people use the land but do not have permanent land use rights. Information obtained from the FGDs corroborates the knowledge of the local expert informants that tenurial insecurity discourages local people from making long-term investment in the land (e.g. by tree farming), including fallow management. For example, in Bangladesh, the Chittagong Hill Tracts Forest Transit Rules 1973, and subsequent administrative orders, control the harvesting and marketing of timber and other forest products even if they are produced from trees planted by farmers on the land that they manage; permission has to be obtained from government offices (Rahman et al., 2012; Rasul, 2005). As a result, smallholder farmers are forced to sell timber to local traders at a price lower than the market, which also discourages them from establishing tree plantations. FGD participants also stated that, tenurial insecurity limits access to the formal credit available from the goverment or NGOs that would otherwise be a valuable source of funding for initial investments and the subsequent inputs needed to

[16] In Bangladesh, one eighth of the country's land area is affected by deforestation due to conversion to agriculture, principally in the form of shifting cultivation in the hill forests (Rahman et al., 2014; Rahman and Rahman, 2011). Similarly, small-scale agricultural expansion is one of the main reasons for massive deforestration in several districts in Java (West Java, Central Java, Jogyakarta, and East Java) and other islands of Indonesia (Brun et al., 2015; Prasetyo et al., 2009; Rudel, 2009).

[17] Scarcity of forest products has also been documented by other studies in the Chittagong Hill Tracts of Bangladesh, and Java as the least forested island of Indonesia (Nawiyanto, 2015; Margono et al., 2014; Rahman et al., 2012; Goltenboth et al., 2006).

[18] This type of land ownership pattern is common in the Chittagong Hill Tracts area (Islam, 2013; Rahman et al., 2012), rural Java and other remote parts of the Indonesian archipelago (Resosudarmo et al., 2014; Kusters et al. 2013; Manurung et al., 2008).

improve land use practices, as land without secure tenure does not qualify as collateral (see also Rahman et al., 2012).

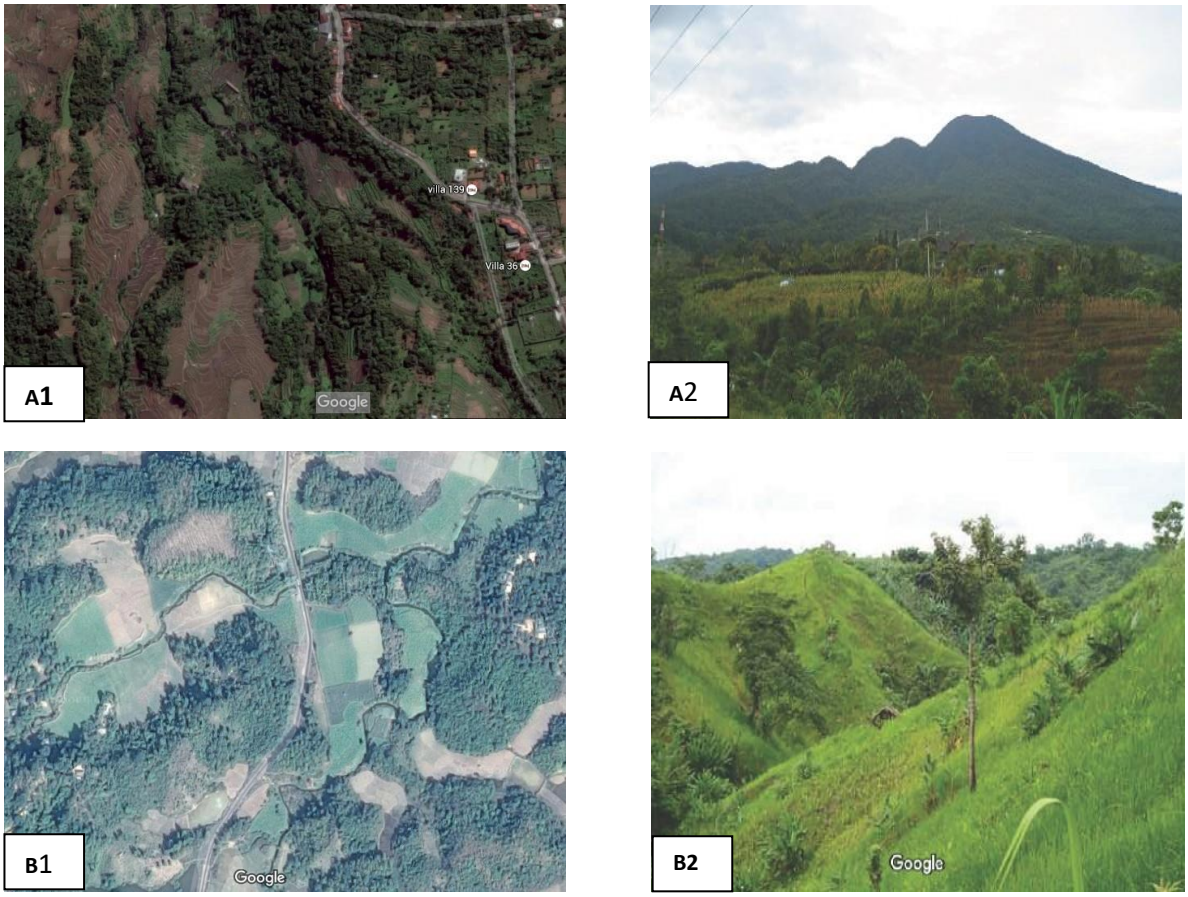


Figure 1. Degraded forest land in the study sites (A, Indonesia; B, Bangladesh), A1 and B1 satellite images, A2 and B2 photos of the studied landscapes. © Google Earth (2015).

Poverty and lack of capital

The annual gross household income of the majority of our interviewed farmers is below US$2500 and US$1500 in Indonesia and Bangladesh respectively (Figure 2). The low household income and low savings[19] of all of our interviewed farmers in both study sites classifies them as "poor" based on international criteria (World Bank, 2015) (Table 1). Low income and poverty continues to be a national problem, with 31.5% and 11.3% of people living below the poverty line in Bangladesh and Indonesia respectively (ADB, 2016a). Government subsidies, e.g. pension allowances, and disabled and vulnerability schemes,

[19] The savings of the Bangladesh farmers are higher than those of the Indonesian farmers, because there is a farmers' credit association in the Bangladesh study site where each member has to pay a fixed amount of money (each month/week) to build up their level of savings. Likewise, the debts of Bangladeshi farmers are higher than the Indonesian farmers, because they are able to borrow heavily from this association.

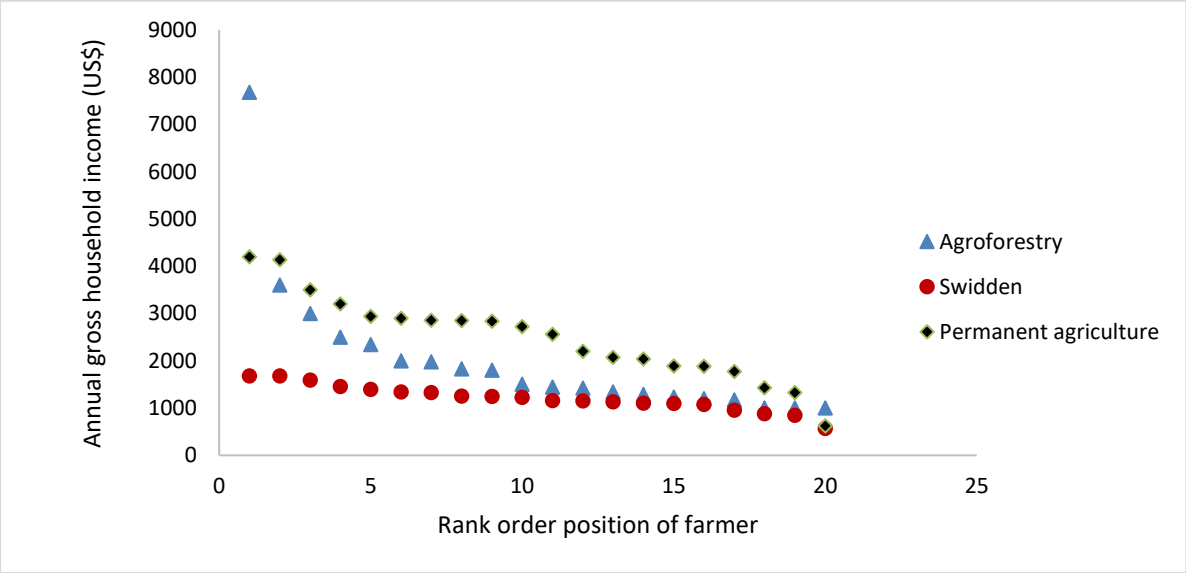
are rare and no interviewed farmers had received in-kind agricultural subsidies from government or NGOs. During interviews government agricultural officers stated that an increase in farm production helps to meet household needs, and that it can be achieved by practicing more intensive land use systems. They specifically cited agroforestry as the exemplar of a more productive intensive system. However, in the FGDs it was reported that the poor farmers who currently practice extensive agriculture do not have sufficient capital to be able to adopt such new farming technologies.

Table 1. Mean (and standard error of the mean) value of family size, farm size, income, expenditure, savings and dabt of surveyed farm households by group of all three villages in the Indonesia study site and both villages in the Bangladesh study site.

Characteristics	**Indonesia**			**Bangladesh**	
	AF (n=20)	SW (n=20)	PM (n=20)	AF (n=21)	SW (n=40)
Family size	6.7 (0.41)	4.7 (0.40)	4.9 (0.40)	4.7 (0.35)	4.8 (0.25)
Total land area (ha)	0.98 (0.24)	0.77 (0.05)	0.26 (0.08)	3.72 (0.62)	2.22 (0.21)
Total annual gross income (US$)	2015 (336.47)	1207 (62.59)	2497 (203.11)	1380 (138.22)	1076 (82.63)
Total annual expenditure (US$)	1454 (184.85)	1114 (65.42)	2109 (239.02)	1397 (158.98)	1069 (73.53)
Total savings in a bank/credit association (US$)	126 (99.42)	172 (39.57)	168 (40.35)	481 (172.29)	241 (122.99)
Total outstanding debt (US$)	8.50 (8.50)	7.50 (5.47)	9.50 (5.69)	177.01 (100.94)	182.56 (55.32)
Income per day per family member (US$)	0.82	0.70	1.39	0.80	0.61

Note: AF= Agroforestry farmer, SW= Swidden farmer, PM= Permanent monoculture farmer.

a)



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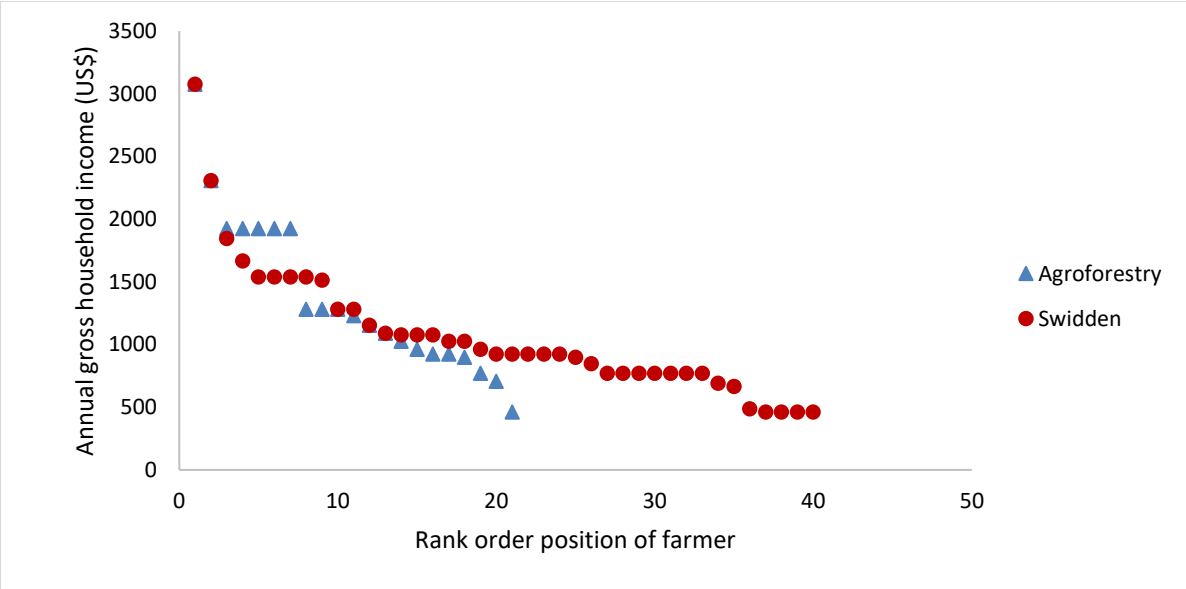

Figure 2. Annual gross household income (US$) of surveyed farmers by group: a) agroforestry, swidden and permanent agriculture in Indonesia; b) agroforestry and swidden in Bangladesh. Within each group the farmers are arranged in rank order from the highest to the lowest income.

Lack of community control

Synthesis of the results from the FGDs shows that the power structure in all villages in both sites is mainly community-oriented with each household being a single primary constituent unit of the political hierarchical system (Figure 3). However, they act individually in land use

decision-making based on their own household's needs. The clan is a close-knit group of several interrelated households which has a single head, whose responsibility is mainly limited to maintaining the customs of the clan, and who does not generally interfere in land-use decision of the households. The most powerful and respected person is the village headman, who is at the top of this hierarchy. He is mainly in charge of protecting traditional culture, e.g. through settling cases of violation of traditional rules and conflicts. The positions of village religious leaders, school teachers and elders are respected in the community and their opinions are respected by the community members. Good examples are the advocacy by religious leaders to protect local forests because of their importance for the worship of ancestral spirits, and the advocacy of school teachers and elders of the benefits of planting trees. However, the key informants in both sites stated that this power structure, which functions by a customary governance mechanism, is mainly targeted at maintaining traditional customs and rules, and it has little effect on community-level land-use decision making due to the priority of individual households to produce enough food for their survival, and competition for land due to population growth. As a result, no attempt is made to conduct community-based land managment, e.g. there are no forest user group in any of our five study villages. This is likely to contribute to the lack of control of forest product collection and forest conversion in all of the villages. In contrast, several studies have emphasized the importance of effective community participation for better land use planning processes (Jeremy 2016; Brooks et al., 2012; Campbell et al., 2010; Ostrom, 1990); some good examples are the dudukuhan tree farming systems in West Java (Manurung et al., 2008), participatory land-use planning in Sanggau District, West Kalimantan (Kusters et al., 2013), and the betagi and pomora social forestry project in the Chittagong Hill Tracts, Bangladesh (Rahman et al., 2010).

Underdeveloped markets

Both the agroforestry farmers participating in the FGD sessions and the expert local informants in both sites reported that for tree products there is price instability, poor market information and poor market infrastructure, which is in accordance with the findings of previous studies (ADB, 2016b; Perdana and Roshetko, 2015; Rahman et al., 2012; Roshetko et al., 2012). In contrast with the staple food grains, especially rice and wheat, which have a stable market price, agroforestry products such as fruits have volatile prices. Farmers selling agroforestry products do so in an open market with poor infrastructure, which is extremely unfavorable especially in the rainy season.

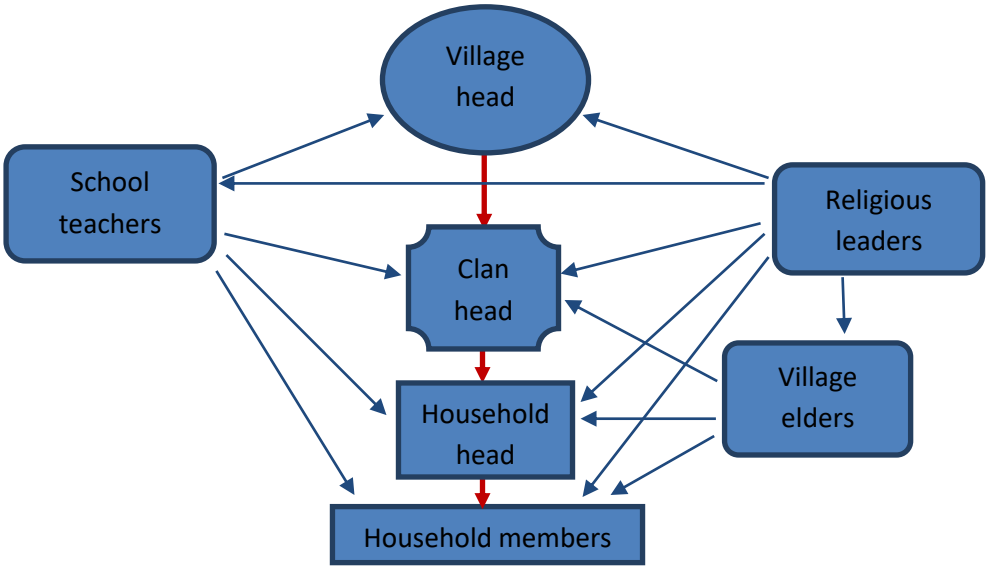

Figure 3. Customary community power structure of all three villages in the Indonesia study site and both villages in the Bangladesh study site as revealed in the focus group discussions. Within the hierarchy of positions of the principal actors the bold red arrows point to the actor who has power over those lower down in the diagram. The thinner arrows illustrate the influence of different actor groups (i.e. school teachers, religious leaders, village elders) being reported in the discussions.

Lack of involvement in government policy making process

FGD participants and expert local informants at both sites reported that local people (e.g. local tree growers) have little involvement in, or influence on, goverment policy formulation and decision-making processes. Consequently, their needs and views about local land use systems are rarely considered.

Poor government extension services

The expert local informants and government agricultural officers at both sites stated that the capacity of government agricultural extension services is very poor. The district extension workers lack resources, and tend to be demotivated by the low incentives that they receive, so they seldom visit the five remote villages of this study. Moreover, most of the demonstration plots that have been established by the government are located closer to major towns and are more intensely managed to increase the probability of success.

Farm intensification by tree-based farming

Informants participating in our FGD sessions and expert local informants at both study sites stated that tree-based farming is not a new concept as a range of forms of agroforestry were already being practiced, i.e. homegardens, multistrata systems, timber gardens, fruit orchards, and forest and crop systems[20] (Table 2). During the FGDs, some agroforestry farmers[21] reported that agroforestry has increased their livelihood security as a "safety-net" function, which helps their households through periods of increased vulnerability, e.g. due to crop failures and illness. All of these respondents stated that agroforestry systems are used to support subsistence needs, income generation through the sale of surplus produce, as well as strengthen their tenure situation. In both sites tree fruits and timber provide major sources of income, as we have reported elsewhere (Rahman et al., 2017; Rahman et al., 2016).

In both study sites, agroforestry farmers have limited financial resources (Table 1), however in the FGDs all of them reported that their tree-planting has generally been successful from their own perspective. This is because they have made a conscious investment in the trees that they plant, which they generally restrict to the number of trees that they are able to maintain together with their annual food crop production. Their tree management practices (especially allocation of available land, labour and other resources) are targeted at their objectives, which are generally for the highest possible yields of tree products. The expert key informants and most of the agroforestry farmers stated that the farmers' familiarity with their land, leading to careful selection of small sites for tree planting, together with good tree husbandry (e.g. decaying trees being individually replaced whenever needed), results in high tree establishment and growth rates. These findings are similar to those from other tree farming communities in Southeast Asia (Roshetko, 2013).

Barriers to the adoption of tree-based farming

Some farmers in the two study sites persist with less profitable traditional swidden crop cultivation (Rahman et al., 2017; Rahman et al., 2014). The semi-structured questionnaire interviews with these farmers revealed key factors underlying non-adoption by these farmers (Figure 4) of forms of agroforestry that could be widely practiced in their agricultural fields, i.e. multistrata systems, timber gardens and fruit orchards (Table 2). In both sites the most

[20] Forest and crop systems are only common in the Indonesian study site.

[21] Agroforestry farmers are considered to be those who are practicing any of the three systems (multistrata systems, timber gardens or fruit orchards) that are widely practiced on farmland at both study sites.

common single factor cited by farmers was a lack of motivation, however it was surpassed by the sum of the factors related to lack of capacity. In Indonesia the lack of capital was the main factor identified as constraining initial investment in agroforestry (by 80% of farmers), followed by insufficient knowledge (35%). Whereas in Bangladesh no capacity factor was mentioned by a majority but management risk (i.e. lack of security for long-term investment on land due to ethnic conflict in the area[22]) was mentioned by 20% of farmers, with the lack of capital mentioned by 12.5%. The motivational factor, 'no interest' in agroforestry practice, has a strong cultural basis, as swidden practice is deeply rooted in the farming tradition at both sites, having been practiced by generations. Both the FGD discussions and the expert local informants reported that this lack of interest was related to insecure land tenure and the insecurity management risk (in Bangladesh), which discourage farmers from long-term investment in agroforestry on the land that they use. 'Lack of capital' is of particular concern to swidden farmers in Indonesia as their cultivation practices are largely subsistence-oriented and insufficient capital constrains investment in agroforestry (Table 1). In both countries lack of technical assistance was the least mentioned factor (of those that were mentioned at all). Expert local informants and government agricultural officers at both sites stated that farmers may be unaware of what assistance is offered by government programs to promote agroforestry. They stated that there has been a general lack of interaction of extension workers with the study villages and a specific lack of agroforestry extension.

[22] Due to ethnic conflict which is often violent in this area, there is a risk for farmers that: (a) they may have to abandon farm land on which they have invested in tree planting due to lack of personal security to them and their family, (b) the trees or their produce often being stolen by other people because of the poor state of law enforcement in the area.

Table 2. Types of agroforestry system in the two study sites. Except for the combined forest and crop systems, these are all common to the Indonesia and Bangladesh sites.

Types	Brief description	Components (W= woody, H=herbaceous)	Area of practice
Timber gardens	Even-aged rotational timber trees planted with understory crops	W: fast growing timber species H: common agricultural crops	Agricultural land
Fruit orchards	Even-aged fruit trees planted with understory crops	W: local fruit species (e.g. mango, lychee, jackfruit, durian) H: common agricultural crops	Agricultural land usually near to dwellings for easy protection
Multistrata systems	Multi-species, multi-layered dense plant association	W: fruit and timber species H: common agricultural crops	Agricultural land that is easy to access and manage
Multi-purpose homegardens	Multi-layered and scattered association of various species	W: multi-purpose trees including shade and fruit trees H: common agricultural crops (emphasis on tubers, spices and vegetables)	Within homestead boundaries
Forest and crop systems [only common in the Indonesian study site]	Association of understory crops within forest vegetation	W: forest species H: common agricultural crops (emphasis on shade-tolerant annual crops, e.g. banana and pineapple)	Forest areas bordering homestead and farm lands

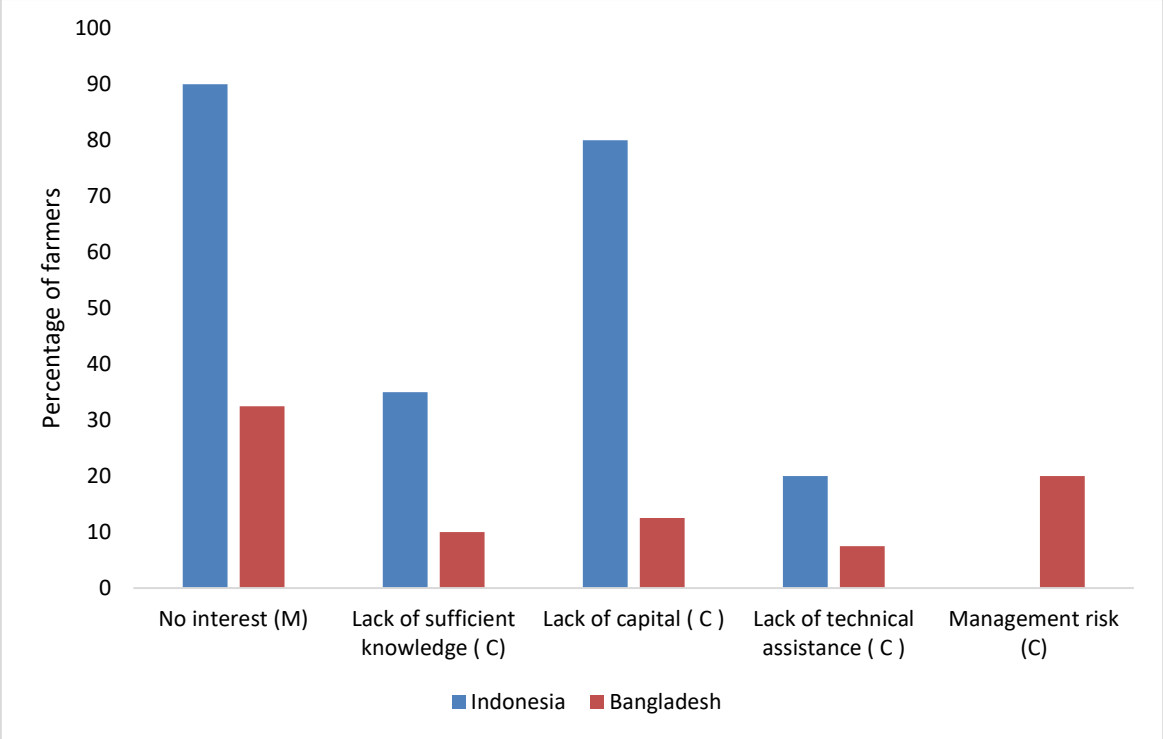

Figure 4. Constraints on the adoption of agroforestry mentioned by 20 and 40 key informant swidden farmers in Indonesia and Bangladesh respectively during semi-structured questionnaire interviews. The motivational factor is marked with M and factors related to capacity are marked with C.

What types of conditions facilitate successful smallholder tree farming?

A decline in local forest area and consequent reduced access to forest resources has been reported to increase the motivation of smallholder farmers to expand tree-farming systems in Sri Lanka, Bangladesh, the Philippines and Kenya (Roshetko, 2013). Based on the findings of the present study, the following suggested conditions can favour the development of successful tree farming in its Indonesia and Bangladesh research sites.

- Securing land tenure, management security and introduction of a flexible credit policy: Secure land tenure and tree use rights are important for the successful implementation of smallholder tree planting activities (Rahman et al., 2014; Roshetko et al., 2007b; Tomich et al., 2002). Where they lack secure rights to use land and to harvest produce from its trees, smallholders are unlikely to plant or tend trees. In addition, without permanent land title smallholder farmers are deprived of access to the credit required for the initial capital to invest in tree planting (Rahman et al., 2012; Roshetko et al., 2007b). Policy reform to provide permanent land title to local farmers can be important to enable agroforestry adoption. In addition, a flexible policy by the institutions

providing credit to support farmers who lack parmanenet land tenure, may also be important to facilitate this land use change. In Bangladesh specifically, the state needs to ensure an effective solution to the current lack of management security of farmers who grow trees in the study area.

- Tailored market system: Several studies have demonstrated that smallholders generally have weak market linkages and poor access to market information (Rahman et al., 2012; Arocena-Francisco et al., 1999; Hammett, 1994). Even where there is proximity to major urban centres, as is the case for our Indonesia site close to Bogor City, smallholder access to markets and relevant information can be poor. Wijaya et al. (2012) attributed this to limited production volume per family due to small landholding size and low education levels. Poor accessibility of appropriate markets has been found to limit the profitability of smallholder tree farming (Shamsuddin and Mehdi, 2003; Landell-Mills, 2002; Predo, 2002; Scherr, 1999). While adoption of agroforestry practices will enable farmers to produce higher value commodities, getting these products to market may impose higher costs, e.g. for processing and transport (Dahlia et al., 2012). Therefore, there remains a need to develop a market system for agroforestry products that increases farmers' awareness of, and physical access to, specialty markets. Improved institutions to enable co-operation amongst agroforestry farmers and between farmers and traders could play an important role in achieving this (Perdana et al., 2013).

- Integrating trees into traditional food crop systems: The natural forest in both research sites has been greatly reduced, mainly because of land conversion to subsistence seasonal food cropping. Therfore, integration of tree culture, i.e. multistrata systems, timber gardens, and fruit orchards (Table 2), into seasonal food cropping systems may be important both to serve farmers' subsistence needs (i.e. food, timber, fuel, etc.) and increase their income. This also has the potential to increase the net benefit from other ecosystem services and biodiversity at the landscape scale. This strategy also needs to consider the specific locations in which local people prefer to establish individual systems, e.g. land that is easy to access and manage for multistrata systems (Table 2). Incorporation of tree species into subsistence agricultural systems for the economic and cultural value of their products (fruit, timber and firewood) can also enhance household well-being by providing a more diverse diet of higher nutritional quality, both from the harvested fruit and from foodstuffs that can be purchased with the income generated. Therefore, farming families may increase their food sovereignty through improved access to healthy and culturally appropriate food (Vira et al., 2015; Edelman et al., 2014), which can provide a powerful motivation for tree farming.

- Strengthening community capacity: Even though land use decisions are made by individual households in the studied villages, strengthening the communities' collective capacity to collaborate in this decision-making, especially by involving the village elders, religious leaders and school teachers whose opinion is respected, can be important for the adoption of tree farming through knowledge and motivation sharing. In the long-term, support from key community institutions (e.g. organized farmer groups and religious centers) can make a significant contribution to increased adoption of successful agroforestry by smallholders (see also Roshetko, 2013). This can be synergistic with increased awareness within communities of the value of family planning, child education, and sustainable management of local natural resources that deliver ecosystem service benefits to the community[23]. By understanding local drivers associated with different land use options, supporting local communities to make their local knowledge, experience, and aspirations more visible in local and national level land-use planning is crucial (Wollenberg et al., 2008).
- Involving local people in decision-making processes: Sustainable land use and management requires the participation of the people who directly depend on those resources (Rahman and Rahman, 2011). However, local people (e.g. farmers who grow trees) in both of our research sites have little involvement in local government policy formulation and decision-making processes. Therefore, their needs and views about local land use systems are rarely considered. The increasing concern about this issue shows that the policy formulation process should be made participatory by involving a broad cross-section of local people and their aspirations in planning and decision-making processes related to the use and management of local resources (Colfer and Pfund, 2011).
- Useful extension services: Lack of sufficient knowledge and technical assistance are constraints that were mentioned by farmers in both the study sites (Figure 5.). Good knowledge of tree management was also found to be important to motivate smallholders to adopt agroforestry and make a succes of this system at another site in Bangladesh by Rahman et al. (2008). Therefore, government extension services need to be useful for local farmers, which requires more than just establishing some demonstration plots close to major towns. Farmers have to know which trees are suitable for their specific land type, how to manage the trees, and how to market agroforestry products.

[23] A series of government-backed structured workshops can increase such awareness.

- Agroforestry research: In the longer term, there is a need to identify and address critical knowledge gaps in agroforestry research. Agroforestry involves social and ecological processes that interact in a complex dynamic system, which often involves immediate livelihood needs and longer-term interests of environmental conservation (CGIAR, 2015). There is scope to work on this complex system towards better and more integrated strategies for which governance regimes can provide options to better manage the trade-offs without compromising rural livelihoods or wider societal goals. Valuable approaches include identifying locally suitable, more productive agroforestry components that are likely to be increasingly important as high rates of population growth and consequent agricultural land expansion destroys local forest ecosystems.

  Expanding trade and investment in global and domestic markets is driving local production trends (CGIAR, 2015), therefore it is also crucial to focus on future household-level production trends and identify novel methods that could foster local agroforestry adaptation. Furthermore, farmer participatory research and knowledge sharing may play a valuable role in tree domestication and the ecological functioning of agroforestry systems (Leakey et al., 2012; Witcombe et al., 1996).

The landscape approach: land sharing or land sparing?

There is a very strong case that for land-use solutions to successfully deliver both sustainable local livelihoods and a high level of ecosystem services they must work at the landscape scale (Sayer et al., 2013; Sunderland et al., 2008). From this, a key question is whether increases in tree cover should be segregated (intensive agricultural separated from natural forest - land sparing) or integrated (land sharing in multifunctional landscapes, e.g. agfororestry) (van Noordwijk et al., 2014). There are a number of arguments for favouring either segregated or integrated approaches with respect to different environmental functions at a landscape scale (Reed et al., 2015; Gilroy et al., 2014; van Noordwijk et al., 2014; Tscharntke et al., 2012; Phalan et al., 2011). From the biodiversity conservation perspective, segregated areas of natural forest with minimum human disturbance are considered very important. In this sense none of the ‘integrated’ land uses can be a substitute for strict protection areas (van Noordwijk et al., 2014; Sayer et al., 2013). However, in purely agricultural areas, ‘integration’ may be the best way to provide a range of livelihood needs, e.g. income and food, as well as biodiversity conservation. Segregated areas are unlikely to be respected by local communities unless there are clear benefits associated with such respect (van Noordwijk et al., 2014).

At both research sites retention of natural forest will require its protection from the currently high levels of human disturbance. Thus, based on an understanding of local modes of land use as discussed in the previous section, a sustainable solution at the landscape scale will require a component of segregation (i.e. forest + intensive agriculture, Table 3) that will demarcate the boundary of forest to protect it from further human disturbance, while ensuring sufficiently productive agriculture to meet local needs on the other land. However, as we have reported elsewhere (Rahman et al., 2017; Rahman et al., 2016), in the non-forest agricultural areas of the two sites of the present study there are benefits from a major component of integration, as the inclusion of a tree component in the land use system (i.e. agroforestry) increases farmer incomes, while maintaining food production. It also potentially provides additional benefits for biodiversity conservation and a range of ecosystem services. This approach is compatible with the 'agroforestry-matrix hypothesis' that, in landscapes which are mosaics of agricultural and natural vegetation areas, the value of the conservation of natural vegetation is greater if the agricultural landscape is dominated by agroforestry (Atangana et al., 2014). The landscape of the present study sites is typical of many other tropical Asian areas, with remaining patches of natural forest being situated in a matrix of agricultural land, and their effective size often being gradually reduced by agricultural expansion, which may also be exacerbated by policy failure (Nagendra et al., 2009). Therefore, land sharing versus land sparing appears to represent an over-simple dichotomy. Instead, a component of integrated land sharing can be beneficial for enabling the land sparing retention of segregated areas of natural forest in our study sites, as is the case for combining conservation and development objectives in a broader landscape context (Pfaff et al., 2014; Sayer et al., 2012; Beier and Brost, 2010; Tilman et al., 2002).

To support such a mixed approach in our study sites (Table 3), not only government initiatives, but also community participation through strengthened capacity, is necessary. An indicator of this success would be increased respect for the boundary between forest and agricultural areas. Researchers have found that, under the right conditions, natural resources can be sustainably managed at the community level (Sayer et al., 2013; Watts and Colfer, 2011; Agarwal and Gibson, 1999). After studying several cases of community-level natural resource management, Ostrom (1990) proposed a set of criteria that can ensure success, focusing on several dimensions. The first is where the resource being managed has clearly defined boundaries. The subsequent criteria focus on village-level institutions, in terms of rules and processes for managing and monitoring their natural resources. The final criterion involves horizontal and vertical linkages with higher-level authorities, such as the right to organize, which often requires agreement from authorities

and the need for nested enterprises if the resources belong to larger systems (Watts and Colfer, 2011).

Table 3. Suggested application of a combination of segregation and integration landscape approaches to addressing each of the major land use challenges identified in the Indonesia and Bangladesh study sites, and their expected outcomes in the two sites (segregation = natural forest + intensive agriculture; integration = agroforestry, both within a multifunctional landscape).

Local land use challenge	Consequence	Suggested landscape approach	Expected outcome
Population pressure	Food shortage, land fragmentation, degradation and longer-term deforestation	Segregation, including a major component of intensive agricultural monocropping + Integration, including high yielded tree species with a variety of annual and perennial crops to meet household and market needs	Farm diversification, enhancement of farm food and wood production, leading to improved household welfare, and longer-term forest protection
Shortage of farmland and high current rates of deforestation	Food shortage, land degradation, income loss	Segregation, including a major component of intensive agricultural monocropping with soil conservation methods + Integration, including fast-growing tree species that yield a variety of products	Enhancement of farm food production, soil erosion control and fertility improvement, integrated land use securing longer-term food and fuel security, income generation from tree products, and forest protection
Forest product impoverishment	Food shortage, income loss	Integration, including tree species that yield a variety of products, e.g. fruits, fodder, firewood, timber + Segregation, including major component of intensive agricultural monocropping	Reduced reliance on forests by increasing farm tree products, securing income generation and increasing forest protection
Swidden cultivation	Land fragmentation, land degradation, deforestation	Segregation of agricultural production with soil conservation methods + Integration of trees with annual and perennial crops to diversify products and promote soil conservation	Increased farmer investment in more permanent farmland leading to soil fertility enhancement, farm diversification with improved soil erosion control on more vulnerable sites, forest protection

A key component of the adoption and success of these suggested mixed approaches in the study sites will be the spatial arrangement of segregated intensive agriculture (i.e. monocroping) and integrated agroforestry (Table 3) (Tscharntke et al., 2012; Robiglio and Sinclair, 2011). Its success will be highly dependent on local motivation, and how well the

new pattern of land use accommodates the complex interaction of local environmental and socioeconomic factors (i.e. population pressure, shortage of farmland and consequent deforestation, forest product impoverishment, and pressure for continuation of swidden cultivation). Therefore, it will be best determined by decision-making within the community, with policy support from government, e.g. to promote community field schools (CFS) with their regular operation inspiring farmers to adopt more sustainable farming and environmental conservation practices by providing collective knowledge and motivation. A particular policy focus should be the decision-making of farmers who are allocating their land between intensive monocropping or extensive swidden food crop production, to promote the allocation of part of their land to more resilient agroforestry systems. A key aspect of our recommendations is that segregation and integration should not be seen as two mutually exclusive options (van Noordwijk et al., 2014; Tscharntke et al., 2012). To facilitate adoption by poor farmers, an incremental increase in tree cover within or around fields that continue to be used predominantly for traditional practices of cultivating, e.g. bananas, vegetables and upland rice, can lead to notable improvements in the sustainability of agricultural production, delivery of other ecosystem services and eventually protection of remnant forests.

Conclusions

Land conversion to agriculture due to population pressure remains the main reason for degradation of forest landscapes at the study sites of West Java and eastern Bangladesh. Facilitating smallholder tree farming is a viable strategy to protect remaining forest resources and to enhance livelihood security by farm diversification, despite challenging local land use conditions. Various types of policy support (i.e. improved land and tree tenure rights, flexible credit, improved market access, strengthening of community capacity, local peoples' involvement in decision-making processes, more useful extension services, and improved knowledge from agroforestry research) are needed to facilitate tree farming by overcoming barriers to its adoption. Furthermore, a carefully designed mixed landscape approach, including elements of both the land sharing and land sparing strategies, is needed to achieve both environmental protection and livelihoods benefits. Therefore, competent government policies, with the participation of local communities, are important for sustainable natural resource management at the landscape scale. A longitudinal study designed to use more sophisticated research tools (e.g. GIS) will be important to monitor the effects of changes in socio-economic and policy conditions, by providing time-series data on the changes in local land use systems, e.g. extent of agroforestry, other farming practices

and remaining forest. A more in-depth study of community-based land managment, e.g. local rules and policies affecting land management, and relationships between social capital and sustainable land management, is required. Such informed development of policy may be essential to reduce rural poverty whilst coping with climate change impacts on land use systems.

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Supplementary Material

Table 1. Land use matrix and the products and services that it supplies in the study sites reported by surveyed farmers group, state agriculture officers, FGD participants, and from field observations.

Forest land		Agricultural land				Settlement
		Intensive			Extensive	
Natural	Plantation	Permanent monoculture agriculture	Agroforestry	Single species tree crop production (e.g. teak)	Swidden	Dwellings, homegardens**, communal buildings, shops, markets, roads
1= b, c, d, e, f 2= a, b, d 3= a, b, c, e, f 4= b, c, d, e	1= b, d, e, f 2= a, b, d 3= a, c, e, f 4= b, c, d, e	1= a, b, c, e, f 2= c 3= c, e 4= a, b, c, e	1= a, b, c, d, e, f 2= a, b, c 3= a, b, c, d, e, f 4= a, b, c, d, e	1= c, d, e, f 2= a, b 3= a, d, e, f 4= a, b, c, d, e	1= a, b, c, e, f 2= c 3= c, e 4= a, b, c, e	1= b, c, d, e, f 2= a, b, c 3= a, b, c, d, e, f 4= a, b, c, d, e

Products and Services:

1. Food: a) cereals, b) vegetables, c) fruits, d) nuts, e) spices, f) fodder.
2. Income generation: a) timber, b) tree products (e.g. fruits, rubber, resin), c) other agricultural crops (e.g. cereals, spices, vegetables), d) NTFPs.
3. Livelihood safety nets: a) shelter, b) food in the lean season, c) medicine, d) emergency cash support, e) nutrition, f) firewood for cooking.
4. Other services: a) cultural identity, b) aesthetic, c) genetic resources, d) wildlife habitat, e) microclimate.

** The listed products and services from the settlement land are all derived from homegardens.

Table 2. Common tree species of natural forests and plantations at the Indonesia and Bangladesh research sites

Country	Tree species	
	Natural forest	Plantation
Indonesia	*Altingia excelsa* *Antidesma ghaesembilla* *Castanopsis acuminatissima* *Dacrycarpus imbricatus* *Ficus melinocarpa* *Nyssa javanica* *Podocarpus neriifolius* *Quercus lineata*	*Anthocephalus cadamba* Dipterocarpaceae *Tectona grandis*
Bangladesh	*Anthocephalus chinensis* *Artocarpus chaplasha* Dipterocarpaceae *Duabanga grandiflora* *Pterygota alata* *Swintonia floribunda* *Tetramefes nudiflora* *Trewia nudiflora*	*Acacia mangium* *Anthocephalus cadamba* *Swietenia mahagoni*