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Incorporation of trees in smallholder land use systems: Farm characteristics, rates of return and policy issues influencing farmer adoption

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INCORPORATION OF TREES IN SMALLHOLDER LAND USE SYSTEMS: FARM CHARACTERISTICS, RATES OF RETURN AND POLICY ISSUES INFLUENCING FARMER ADOPTION

Syed Ajijur Rahman

PhD Thesis, 2017

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Incorporation of Trees in Smallholder Land Use Systems: Farm Characteristics, Rates of Return and Policy Issues Influencing Farmer Adoption

A Thesis Submitted as Fulfilment of the Requirements for the Degree of Doctor of Philosophy

By

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Department of Food and Resource Economics

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&

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April 2017

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SUMMARY

One of the main causes of tropical deforestation is conversion to agriculture, which is continuously increasing as a dominant land cover in the tropics. The loss of forests greatly affects biodiversity and ecosystem services. Tree-based farming, in a range of agroforestry systems, has been proposed as a mechanism for sustaining both biodiversity and its associated ecosystem services in agricultural areas, by increasing tree cover, while maintaining agricultural production. The main aim of this thesis is to assess the rate of return resulting from incorporating trees into food-crop-based smallholder agricultural systems, in order to assess the economic potential of agroforestry systems that may also help protect local forest, the barriers to their widespread adoption, and how the landscape approaches (land sharing and land sparing) work best in the study sites in eastern Bangladesh and West Java, Indonesia.

The four papers included in the thesis specifically address the following issues. 1. The types of agroforestry practiced, in order to characterize their differences in basic structure, management and associated crop plant diversity, and the problem of classifying them into a specific land-use category (i.e. agriculture or forestry). 2. The economic and social potential of agroforestry systems and the barriers to their widespread adoption, as a land use alternative to swidden cultivation, which may potentially help protect local forest. 3. The trade-offs between income and tree cover when incorporating trees into food-crop-based smallholder agricultural systems, and the associated factors that influence farmers' choice of tree-based farming in place of seasonal cultivation. 4. The major challenges facing farmers using current local land-use systems, the conditions and policy context that could facilitate smallholder tree farming, and how landscape-scale approaches work best in a local perspective to reconcile agricultural and environmental goals. 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. Data have been analysed through narrative qualitative methods, and through quantitative methods such as descriptive statistics, analysis of variance, and cost-benefit analysis.

Five main agroforestry systems (homegarden, fruit tree, timber tree, mixed fruit-timber, and cropping in the forest understory) exist in the Java study area, and can be categorized into two main types, i) integral, rotational and ii) integral, permanent, both of which exhibit a noticeable diversity in terms of both species composition and utilization. In both Java and Bangladesh the inclusion of tree crops in seasonal agriculture improved the systems' overall economic performance (NPV), even when it reduced understorey crop production. In the Java study area, tree ownership was associated with more permanent rights to farmland and was prestigious in the community, which also helped strengthen social cohesion when the products (fruit, vegetables, etc.) were shared with neighbours. In the Java study area, agroforestry farmers were less involved in forest clearing and forest product collection indicating that agroforestry may contribute positively to reduce pressure on local forests. However, seasonal agriculture (food-crop-based monoculture agriculture in Java, and swidden in Bangladesh) has a higher income per unit of land area used for crop cultivation compared with the tree establishment and development phase of agroforestry systems. There is thus a trade-off between short-term loss of agricultural income and longer-term economic gain from planting trees in farmland. However, constraints of local food crop cultivation traditions, insecure land tenure, insufficient investment 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. Various conditions can facilitate tree farming, including a carefully designed landscape approach, with the elements of both segregation and integration of land uses, supported by competent government policies and local communities having sufficiently high social capital. In land-use classifications agroforestry systems are not recognized as forestry, but like forests they provide tree products and services. Classification will always be problematic if a binary system is applied, thus a more sophisticated approach should be adopted that incorporates the economic and environmental characteristics of a wider range of systems.

RESUMÉ (DANISH SUMMARY)

En af de vigtigste årsager til afskovning i troperne er rydning af skov til landbrusjord. Landbrug som arealanvendelse er i fortsat vækst og er den dominerende arealanvendelse i troperne. Tabet af skov påvirker biodiversitet og økosystemtjenester meget. Landbrug, hvori træ indgår i varierende grad, har været foreslået som en måde at sikre både biodiversitet og de tilhørende økosystemtjenester gennem øget trædække uden at miste landbrugsproduktion. Denne afhandlings primære formål er at vurdere fordelagtigheden af at indarbejde træ i fødevare-planteproduktion i små landbrugssystemer for derigennem at estimere de økonomiske potentialer for skovlandbrugssystemer som også kan hjælpe med at beskytte lokal skov, barrierer for deres udbredelse samt spørgsmålet om hvordan landskabstilgangen (land sharing & land sparing) bedst udformes i to udvalgte case-områder i det østlige Bangladesh og Vest Java, Indonesien.

De fire artikler som indgår i afhandlingen adresserer følgende emner: 1) En identifikation af skovlandbrugssystemer som praktiseres. Dette bruges til at kunne karakterisere deres forskelle i basale strukturer, forvaltning og afgrødediversitet; samt problemet med at klassificere dem ind i specifikke landbrugskategorier (land- og skovbrug). 2) De økonomiske og sociale potentialer af skovlandbrugssystemer og barrierer for udbredelse som alternativ til skiftende afgrøder (for derigennem potentielt at sikre lokal skov). 3) De trade-offs der måtte være mellem indkomst og trædække når man indarbejder træ i fødevareproducerende planteproduktion hos småbønder; og de tilhørende faktorer som kan påvirke bønders valg af træbaseret landbrug i stedet for sæsonbetinget dyrkning. 4) De største udfordringer bønder har i nuværende landbrugssystemer, de forhold som kan facilitere småskala skovlandbrug og hvordan en tilgang baseret på et landskabsniveau bedst passer ind i et lokalt perspektiv for at opnå landbrugs- og miljømål.

Data er indsamlet gennem “rapid rural appraisals”, fokusgruppediskussioner, feltobservationer, semistrukturerede interview med bønder og nøgleinformanter fra statslige landbrugskontorer. Data er analyseret gennem narrative kvalitative metoder, kvantitative metoder såsom deskriptiv statistik, variansanalyse og cost-benefitanalyse.

I case-området i Java er der fem hovedskovlandbrugssystemer (haver, frugttræer, tømmertræ, blandet frugt og tømmer, og dyrkning af landbrugsafgrøder i underskoven), og de kan blive kategoriseret i to overordnede typer: i) integreret, roterende, ii) integreret, permanent. Begge har en høj diversitet i forhold til både arter og udnyttelse. I både Java and Bangladesh blev systemernes overordnede økonomi (NPV) forbedret – selv når det reducerer landbrugsafgrødernes udbytte. I casestudiet i Java er det at eje træer forbundet med mere permanente rettigheder til landbrugsjord og bliver set som prestigefyldt i samfundet, noget som også hjælper med at styrke social sammenhængskraft når udbytterne (frugt, grøntsager, mv.) deles med naboer. I casestudiet i Java er skovlandbrugsbønder mindre involveret i skovrydning og samling af skovprodukter end andre – noget som indikerer at skovlandbrug kan bidrage positivt til at mindske presset på lokal skov. Ikke desto mindre har sæsonlandbrug (mad-afgrøde-baserede monokultur landbrug i Java, og swidden i Bangladesh) en højere indkomst per arealenhed end afgrøder med etablering af træer. Der er derfor et trade-off mellem tab af landbrugsproduktion på den korte bane og langsigtet økonomisk gevinst ved at plante træer. Forskellige forhold kan facilitere trædyrkning eftersom nogle bønder er tilbageholdende med at skifte til skovlandbrug. Ikke desto mindre begrænses bøndernes villighed til at adaptere denne dyrkningsform af begrænsninger i lokal landbrugskultur, usikre ejerforhold, utilstrækkelig kapital, manglende viden, mangel på teknisk hjælp og den subjektive risiko ved at investere i land pga lokale konflikter (Bangladesh). Forskellige forhold kan facilitere skovlandbrug, herunder en landskabstilgang med elementer fra både segregering og integrering af landbrug, støttet af kompetent ledelse og politik og tilstrækkelig høj lokal kapital. I arealanvendelsesklassifikationer er skovlandbrug ikke anerkendt som skov, men ligesom skov leverer de træprodukter og tjenester. Klassifikationer vil altid være problematiske hvis et binært system bruges. Der er derfor et behov for en mere nuanceret tilgang som indarbejder de økonomiske og miljømæssige karakteristika fra et langt bredere spektrum af dyrkningssystemer.

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Syed Ajijur Rahman

April, 2017

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Chapter One

Introduction

This thesis investigates the types of local agroforestry systems that exist in the study area, relating to these results to the debate about the binary classification of rural land use (between agriculture and forestry), the rates of return from agroforestry and its role in protecting local forests, the barriers to widespread adoption of agroforestry, and how landscape approaches can work best from a local perspective to reconcile agricultural and environmental objectives (in particular land sharing versus land sparing). This chapter introduces relevant concepts to build a conceptual framework to identify the research gaps that are then addressed in the subsequent four chapters of the thesis i.e. chapter 2, 3, 4 and 5).

The multiple benefits provided by forests

Forests, particularly tropical forests, have received increasing attention due to the multiple benefits of products and services that people derive from them (Vira et al., 2015; Sheil and Liswanti, 2006; Arnold and Perez, 1998). They serve as income sources as well as providing shelter and consumption goods, such as food, fodder, fuelwood, timber and even clothing for local communities (Angelsen and Wunder, 2003). The number of people that use forest to meet their needs is in the billions (FAO, 2014). It is estimated that, approximately 1.2 to 1.6 billion people depend to some extent on forests for their subsistence, which includes 60 million indigenous people who almost wholly rely on forests (Vira et al., 2015; Agrawal et al., 2013; Vinceti et al., 2013). At the national level, forest resources can help foreign exchange earnings through export of forest products (FAO, 2006; Wiersum et al., 2006). Putting this into perspective, the economic contribution of the forestry sector was US$606 billion, i.e. 0.9 percent of global gross domestic product (GDP) and formal employment of 0.4% of the global labour force in 2011 (FAO, 2014). This figure is more than double total official development assistance (ODA) for 2010, although actual figures might be much higher considering the limitations in data availability[1]. Besides such cash returns from forests, other ecosystem service benefits are far greater (FAO, 2014). They include climate regulation through carbon sequestration[2], regulation of water quality and flood risk and air quality, maintenance of supporting

[1] With the exception of formal employment figures, forestry administrations have little information on the actual benefits of forests, moreover, the data which is currently available is often weak (FAO, 2014).

[2] In the tropics, forests could absorb as much as 2.8 billion tons of carbon per year (Pan et al., 2011).

services providing primary production through nutrient cycling (minimize nutrient losses and enriching soils through nitrogen fixation), and protecting crops from wind damage (Danielsen et al., 2005; Daily and Ehrlich, 1999; Crook, 1998). Therefore, forests have important potential to contribute to sustainable development and thereby to a greener economy.

Extent, causes and consequence of deforestation, and forest transition

The rate of global forest loss over the last 20 years is alarming (Roshetko, 2013). The state of forest resources in countries world-wide has reached a critical point; never before have forest ecosystems been so rapidly affected by human activities as during recent decades (Snelder and Lasco, 2008). In 2015, the world's total forest area was estimated to be approximately 3.9 billion hectares and the net change in forest area in the period 2010-2015 is estimated at -17 million hectares, -3 million hectares per year (FAO, 2015), which is equivalent to the size of Belgium. Most forest losses occur in tropical countries. The highest rate of forest loss in Asia has been recorded for Indonesia followed by Myanmar (Table 1, Figure 1).

The establishment of large-scale forest plantations has been initiated to counteract this forest loss (Snelder and Lasco, 2008). In fact, the area of plantation forests has increased throughout the world, at an estimated rate of 3 million hectares per year during the period 2010-2015 (FAO, 2015). However, forest plantations have not been equally successful across all regions. For example, while Asia as a whole experienced a net gain in forest area over the period 2010-2015, as a result of large-scale afforestation by China, the Philippines, India and Viet Nam (FAO, 2015), most other countries, e.g. Indonesia, Papua New Guinea, Myanmar, Cambodia, Bangladesh, experienced a net loss of forest area (World Bank, 2015).

Table 1: Countries reporting the greatest annual forest area reduction (2010–2015).

Rank	Country	Annual forest loss	
		Area (000 ha)	% of 2010 forest area
1	Brazil	984	0.2
2	Indonesia	684	0.7
3	Myanmar	546	1.7
4	Nigeria	410	4.5
5	United Republic of Tanzania	372	0.8
6	Paraguay	325	1.9
7	Zimbabwe	312	2.0
8	Democratic Republic of the Congo	311	0.2
9	Argentina	297	1.0
10	Venezuela (Bolivian Republic of)	289	0.5

Source: FAO, 2015.

Deforestation has well documented negative impacts on natural capital and ecosystem services, including biodiversity loss, climate change, desertification, soil erosion and watershed degradation (Lawrence and Vandecar, 2015; Werth and Avissar, 2002; Barraclough and Ghimire, 1995; Gupta, 1993). At a local and national level deforestation may cause substantial economic losses as solving the consequential environmental problems has high costs (Rahman and Rahman, 2011). The conversion of forest land into other land use systems may result in the destruction of valuable forest products, industrial timber production and thus threatens foreign exchange earnings (Shen et al., 2009; Stenberg and Siriwardana, 2007).

Figure 1: Indonesia, conversion of forest to agricultural land, with associated degradation of site natural capital. Photo © CIFOR.

Deforestation is most often caused by the expansion and development of agriculture (Babigumira et al., 2014; Hosonuma et al., 2012; Hersperger et al., 2010; Mena, 2001; Angelsen and Kaimowitz, 1999). Sharma (1992) categorized the causes of deforestation into direct and indirect. The direct causes include agricultural land expansion, overgrazing, fuelwood gathering, commercial logging, urbanization and conflict. Indirect causes are typically population pressure coupled with poverty, as people often have to convert forest into agricultural land use to meet their demands for food, beyond the capacity of existing farmland (see also Humphreys, 1996; Kramer et al., 1995; CSAEHT, 1993). Exploitation of existing forests to meet the increasing demand associated with population increase for fuelwood and other products can lead its degradation.

Market and policy failures also significantly affect the sustainability of forest management. Market failures can for example be due to externalities, or goods being common or public. As a consequence of market failures policy interventions may be needed. However, these may also contain failures, if not being efficient or fair. Important example of such failures is the exclusion of local communities and indigenous people from the planning process for long-term forest management (Kramer et al., 1995; Sharma, 1992). Poor economic performance and high external debts also push the national policy of countries to speed up forest exploitation in order to generate income and foreign currency (Humphreys, 1996; Sharma, 1992). At the aggregate level, the causes of deforestation and degradation are often interlinked and referred to as 'wicked problems' (Howes and Wyrwoll, 2012; Noble, 2012).

A general theoretical framework of deforestation and the forest transition sequence with economic development from net deforestation to stasis and even increase in forest area has been supported by evidence from several countries (Meyfroidt, 2015; Meyfroidt, 2011; Angelsen, 2007; Mather and Needle, 1998). The time required from deforestation to forest expansion is often prolonged by the time lag in natural processes of forest regeneration, or by the transaction costs of afforestation through plantation methods (i.e. the costs in transferring, defining and protecting property rights of land and forests) (Zhang, 2000). 'Forest transitions' need to be understood based on the pattern and drivers of change, with the resulting consequences for ecosystem goods and services. Tree-based farming can play an important role in the reduction of the net rate of loss of tree cover, or even its increase, depending on the stage of 'forest transition' and the pattern of landscape configuration (segregation or integration) (van Noordwijk et al., 2012). Therefore, forest transition theory needs to be linked to process acting at the landscape scale. It is at the landscape scale that key transitions may operate through the increased use of trees in diversified agricultural production in smaller areas (especially in arable land areas), and the abandonment of agriculture from some larger areas (e.g. degraded pasture land) that can then be available for reforestation through planting or natural regeneration (van Noordwijk et al., 2014; Mather and Needle, 1998).

Population pressure, expansion of agriculture and land degradation

In the past 40 years, the human population has doubled and is projected to increase by the same amount again in the next 40 years (Hooke and Martín-Duque, 2012). As population estimates for 2050 reach over 9 billion (Vira et al., 2015), and as most of the world’s population resides in Asia (60% of the world's current population) (WPR, 2016; Worldometers, 2015), this will increase the demand for, and consumption of, forest and wood products throughout Asia and the rest of the world (Roshetko, 2013). In addition, the expansion of agriculture due to this population growth has quickened the pace of land transformation and degradation, and the current rate of land transformation to agriculture is unsustainable (Hooke and Martín-Duque, 2012). This problem is compounded by the agricultural intensification currently being practiced in some areas in order to increase crop production and provide food security being accompanied by serious forms of land degradation (Snelder and Lasco, 2008; Garity, 2004). Nearly 20 million km^2 of land, or ~40% of the global agricultural land area, has already been degraded. Of this, over half is so degraded that farmers lack the means to restore it (Hooke and Martín-Duque, 2012).

Evidence from a number of studies also indicates declining growth in yields under intensive cropping even on some of the better land, e.g. the Indo-Gangetic plains (Vira et al., 2015; FAO, 2011; ILEIA, 2000). Farmland is affected by soil nutrient depletion and soil physical degradation due to repeated cultivation without periodic application of fertilizers and manure (Snelder and Lasco, 2008).

Swidden agriculture (also known as slash-and-burn farming), is a less intensive age-old subsistence farming practice in the tropics, where 300–500 million people directly or indirectly carry out this system. It can be detrimental to the environment by directly causing deforestation and forest degradation (Li et al., 2014; Schuck et al., 2002; Goldammer, 1988). As the fallow period between swidden cultivation cycles declines due to increase in demand for land, it is leading to the loss of top soil and land degradation, as well as deterioration of faunal and microbial organisms (Rahman et al., 2012; Gafur, 2001). Therefore, farmers are facing a bleak future, with swidden cultivation becoming increasingly unsustainable, and alternative land conservation technology generally requiring high capital inputs (Li et al., 2014; Rahman et al., 2012; Miah and Islam, 2007).

In response to the urgency to stop, or at least control, the destruction of remaining forests and the degradation of agricultural land, a wide spectrum of solution-oriented measures of sustainable land use has been recognized. This recognition has triggered projects and programs of forest conservation, reforestation and agroforestry aimed at integrating trees into denuded and predominantly agricultural landscapes (Snelder and Lasco, 2008). This thesis is focused on one of these, i.e. agroforestry, which is addressed in further detail in the following sections.

Agroforestry: the tree-based potential land use solution

As a sustainable land use solution, agroforestry has well-established research evidence of its potential to enhance farm production (e.g. of food, fodder, fibre, firewood and timber), protect biodiversity, and support sustainable development (Dagar et al., 2014; Rahman et al., 2014; Idol et al., 2011; Leakey, 2010; Roshetko et al., 2008; Garrity, 2004).

As an interdisciplinary subject, agroforestry gained international prominence during the 1980s largely as a development imperative in the tropics (Sinclair, 1999). Agroforestry systems can meet financial, social and environmental objectives by diversifying farm products and services for society (Garrity, 2004; ASB, 2001). By producing some important forest products, e.g. timber, firewood, agroforestry may relieve pressure on local forest (Garrity et al., 2002; Murniati et al., 2001). Agroforestry systems also enable farmers to better adapt to climate change as the fruit, nut and berry trees in the systems are often more tolerant than seasonal crops and so can increase the diversity and resilience of food production and enhance food security (Nguyen et al., 2012). Furthermore, it can improve soil fertility by enhancing nutrient cycling, conserve soil moisture and protect soil from erosion (Lasco et al., 2014; Idol et al., 2011; Jose, 2009). Agroforestry systems also improve ecosystem function in a way that enhance delivery of services through carbon sequestration, biodegradation of excess nutrients and pesticides, microclimate moderation, and diversification of habitats for wildlife and humans, on the same land that is delivering the provisioning of food (ASB, 2001; Sinclair, 1999; University of Minnesota, 1996; Nair, 1990). Therefore, while their delivery of many ecosystem services per land area is less than forests, the importance of agroforestry systems will only increase as the global forest resource continues to shrink and human populations expand (Snelder and Lasco, 2008; Roshetko, 2013).

Concept and classification of agroforestry

Agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Mead, 2004). There are various definitions of agroforestry systems, but the most widely accepted definition is that of the World Agroforestry Centre (ICRAF), which was cited by Nair (1990):

> ‘Agroforestry is a collective name for land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components’.

There are two main components in this definition. The first is the deliberate integration of trees with agricultural crops and/or animals on the same piece of land, and the second is the ecological and economic interactions between woody and non-woody components. The systems that lack one of these two components cannot be classified as agroforestry (Rahman, 2011). Various types of agroforestry systems exist (some examples are given in Table 2), however, based on their structure and function they can be classified into three major categories (CSAEHT, 1993; Nair, 1990): (i) agrisilvicultural systems, which are combination of crops and trees, e.g. alley cropping, multilayer tree gardens, multipurpose trees and shrubs on crop lands (Figure 2), homegardens, windbreaks and shelterbelts, live-hedges, fuelwood production and integrated multistory mixtures of plantation crops, (ii) silvopastoral systems, which are combinations of pastures and/or animals and trees, including multipurpose fodder trees on or around farmlands, live-fences of fodder hedges and shrubs, trees and shrubs on pastures, as well as integrated production of animals and wood products, and (iii) agrosilvopastoral systems, which are combinations of crops, pastures and/or animals and trees. They include homegardens with animals, multipurpose woody hedgerows, and integrated production of crops, animals and wood.

Figure 2: Examples of agrisilvicultural systems (multi-purpose trees in crop lands) in West Java, Indonesia (left) and eastern Bangladesh (right). Photo © Syed Rahman (left) and M. Bahauddin (right).

Table 2: Example of some agroforestry systems.

Agroforestry system type	Brief description	Components (W= woody H= herbaceous)	Primary role of woody components (Prt= protective Prd= productive)	Agro-ecological adaptability
Improved or enriched fallow	Woody species planted and left to grow during the fallow phase	W: fast growing, preferable leguminous H: common agricultural crops	Prt: soil fertility and stability Prd: wood products	In swidden cultivation areas
Taungya	Combined stand of woody and other crop species during early stages of establishment of plantations	W: forest species, e.g. *Swietenia macrophylla* H: common agricultural crops	Prt: soil erosion control Prd: additional income from forest species	In most ecological regions
Multi-layer tree gardens (multistrata)	Multi-species, multi-layer, dense plant associations	W: various woody components of varying form H: usually absent	Prt: soil conservation, efficient nutrient cycling Prd: various	Areas with fertile soils, good availability of labour, high human population pressure
Multi-purpose trees in crop lands (multistrata)	Trees scattered or arranged according to some pattern within crop land boundaries	W: multi-purpose trees including fruit trees H: common agricultural crops	Prt: fencing, plot demarcation, social values Prd: various tree products	In all ecological regions, especially in subsistence farming areas; sometimes integrated with animals
Plantation with crop combinations (multistrata)	Integrated multi-story mixtures of plantation and crops, arranged in some pattern, with possibly some shade trees , e.g. coffee gardens	W: varies species, e.g. coffee, coconut, fruit trees, forest species H: usually common agricultural crops present, especially with intercropping arrangements	Prt: shade, windbreak, soil protection Prd: large number of products	In humid and sub-humid regions (depending on tolerance of plantation species); usually in smallholder subsistence systems

Note: Adapted from Sinclair, 1999; Nair, 1990.

Classification of agroforestry is important in order to provide a framework for evaluating systems, as well as developing policy and action plans for their improvement (Sinclair, 1999; Nair, 1985). Besides the basic agroforestry categories described above, there are plenty of other studies classifying different agroforestry systems that occur at various landscape scales (Rahman et al., 2008b; Snelder and

Lasco, 2008; Michon, 2005; Sinclair, 1999; Nair, 1985). However, not enough is known about the dynamics of the systems and their corresponding contribution to delivery of services, because of the multitude of systems that do exist (Snelder and Lasco, 2008; FAO, 2006). People from various landscape settings have diverse traditions of practicing agroforestry, and such practice is often influenced by the changing needs of socioeconomic and environmental sustainability (Rahman et al., 2008b; Michon, 2005). In order to understand current and potential contribution of agroforestry to rural development and ecosystem services, extensive research and good statistical data on various agroforestry systems practiced in different landscape settings are required, and such statistics are often absent from most official documents (Snelder and Lasco, 2008; FAO 2006; Sinclair, 1999).

Even though agroforestry is progressively becoming a recognized land-use discipline, its intermediate status between agriculture and forestry perpetuates some confusion, and often creates challenges with the sector-based system regulatory framework (FRA, 2015; Roshetko et al., 2008; van Noordwijk et al., 2008; Torquebiau, 2000). Many planted and/or domesticated tree crops in smallholder agroforestry systems across the Indonesian archipelago are found to have many characteristics in common with secondary or even primary forests[3] (Michon, 2005; Michon and de Foresta, 1997). However, the FAO definition of forest (Box 1.1), which is a mixture of confusing criteria (i.e. ‘intention of the planter’ and ‘management plans’), excludes the stands of trees in agroforestry systems as they are primarily used for agricultural production. For example, according to the current FAO definition, rubber tree plantations from which timber to be harvested at the end of the productive latex-yielding phase is intended to be the primary product are now classified as ‘forest’, whereas if the primary product is intended to be latex, this same system is not considered as ‘forest’ (FAO, 2015). Furthermore, temporary unstocked areas can still be classified as forest as long as there is a plan for future tree regeneration (van Noordwijk et al., 2008). The windbreaks, shelterbelts and corridors of trees that surpass 0.5 hectares and a width of 20 m, which are often established as component of agricultural systems for the protection of crops (ICRAF, 2016; Nair,

[3] Such as, benzoin gardens in North Sumatra; damar agroforests in Pesisir, Lampung; fruit and timber agroforests in Maninjau, West Sumatra; fruit agroforests in Jambi and Palembang; Illipe-nut forests (tembawang) in West Kalimantan; spice and nut agroforests in the Moluccas; sugar palm and salak agroforests in Bali and Lombok.

1987) are also confusingly included in the forest category. As the terms ‘forest’ and ‘agroforestry’ are generally associated with the concept of multifunctionality (i.e. environmental, economic, social, and cultural), they have many types and dimensions that often overlap with each other, therefore instead of a simple binary objective-based classification, a new approach should be adopted to classify the systems that will incorporate multiple functions and land use objectives and to benefit the land users.

Box 1: The operational definition of forest used in FAO’s Global Forest Resource Assessment 2015 (FAO, 2015).

Forest is ‘land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use’.

It includes

- Areas with young trees that have not yet reached but which are expected to reach a canopy cover of at least 10 percent and tree height of 5 meters or more. It also includes areas that are <u>temporarily unstocked</u> due to clear-cutting as part of a forest management practice or natural disasters, and which are expected to be regenerated within 5 years. Local conditions may, in exceptional cases, justify that a longer time frame is used.
- Forest roads, firebreaks and other small open areas; forest in national parks, nature reserves and other protected areas such as those of specific environmental, scientific, historical, cultural or spiritual interest.
- <u>Windbreaks, shelterbelts and corridors of trees</u> with an area of more than 0.5 hectares and width of more than 20 meters.
- Abandoned shifting cultivation land with a regeneration of trees that have, or are expected to reach, a canopy cover of at least 10 percent and tree height of at least 5 meters.
- Areas with mangroves in tidal zones, regardless whether this area is classified as land area or not.
- <u>Rubberwood</u>, cork oak and Christmas tree plantations.
- Areas with bamboo and palms provided that land use, height and canopy cover criteria are met.

It excludes

Tree stands in agricultural production systems, such as fruit tree plantations, oil palm plantations, olive orchards and agroforestry systems when crops are grown under tree cover.
Note: Some agroforestry systems such as the “Taungya” system where crops are grown only during the first years of the forest rotation should be classified as forest.

The economics of smallholder agroforestry practices

Smallholder agroforestry practices can lead to an increase in farm income and create jobs for the rural poor (Rahman, 2011; Nath et al., 2005). It is estimated that more than 1.2 billion people across the world depend on some form of services from agroforestry, with approximately 560 million living in landscapes that include agroforestry (Zomer et al., 2009). Using five sub-Sahara African case studies, Franzel and Scherr (2002) showed that agroforestry has potential to increase farm income. Studies conducted elsewhere in the tropics provided evidence that, the net present value (NPV), internal rate of return (IRR), benefit-cost ratio (B/C), return-to-land and return-to-labour of agroforestry are much higher than those of seasonal agricultural systems (Roshetko et al., 2013; Rahman et al., 2008a; Rahman et al., 2007; Alavalapati and Mercer, 2004). The higher income from agroforestry is mainly used for purchasing or leasing land, buying bullocks and agricultural implements, meeting educational and health expenses of family members, contributing to expensive commitments such as marriage, and paying back loans (Siddiqui and Khan, 1999; Alam et al., 1996). In Cagayan de Oro, Philippines, growing trees of *Gliricidia sepium* with fodder grasses helped farmers increase their income from livestock production, and reduce farm labour (for herding and tethering) (FAO, 2005; Bosma et al., 2003). The income generated by temporary migration of young people to cities in central and eastern Java, resulted in tree farming being developed on their family's land as a 'living savings account' (Roshetko et al., 2008), as smallholders see investment in tree farming as a longer-term means of diversifying farm production, enhancing family income, and reducing risk (Schuren and Snelder, 2008).

Benefits of the establishment of trees in agroforestry farms also include the strengthening of property rights over land, reinforcement of local identity and helping to maintain social status, i.e. that of a prestigious agroforestry farmer (Rahman et al., 2013; Michon, 2005). The strength of a family's agricultural property holding often comprises the amount of both land and labour that is utilized on-farm (Rahman and Rahman, 2011). Farmers involved in different cultivation practices often define themselves as 'damar farmers', 'rattan farmers' 'shifting cultivators', etc. Those who have trees growing on their farm often define themselves as 'agroforestry farmers' rather than by any other economic activity (Michon, 2005).

Besides supporting local livelihoods, smallholder agroforestry systems also make a significant contribution to national economies (Roshetko, 2013). In 2011, Indonesian smallholder agroforestry farmers produced most of the country's coffee and cacao, 80% of rubber, 39% of palm oil, and 26% of tea (DGEC, 2012). Other products of smallholder agroforestry systems in Indonesia include sandalwood, damar, benzoin, candlenut, rattan, forest honey, gaharu, cinnamon, cloves and nutmeg (Roshetko, 2013; Michon, 2005; Rohadi et al., 2003; Sunderlin et al., 2000). In Sri Lanka, agroforestry provided 80% and 73% of the nation's fuelwood and timber respectively (Gunasena, 1999). Smallholder farmers in Kerala, India produced 83% of the state's wood production and up to 90% of fuelwood (FAO, 1998).

Economic analysis of agroforestry systems

Economic research into agroforestry systems has utilized a range of different analyses, e.g. cost-benefits analysis (CBA), farm budgeting, and determination of the best production mix for the 'survival algorithm'[4] (Atangana et al., 2014; Elevitch and Wilkinson, 2000; Hosier,1989; Lipton, 1968). As smallholder agroforestry farmers grow not just one crop, but combine multiple crops for subsistence or for sale (Cerda et al., 2014; Snelder and Lasco, 2008; Hoekstra, 1983), CBA is an important tool for assessing the economic performance of the system in a specific area (Atangana et al., 2014; Rahman et al., 2008a; Elevitch and Wilkinson, 2000). Sensitivity analysis is the method used to explore the issues related to variation of production input and output prices. It is a valuable component of the planning and design of agroforestry projects, both before and during the implementation phase. Smallholders have to carefully consider the input and output mixes and the possible risk factors (e.g. fluctuating market demand and prices, pests and diseases) to measure the success rate of a project (Elevitch and Wilkinson, 2000; Hosier, 1989). Local market conditions for farm products may also provide a useful indicator of project success (Roshetko et al., 2016; Manurung et al., 2008; Shamsuddin and Mehdi, 2003).

Agroforestry practices differ considerably between and within landscapes (FAO, 2005), depending on local traditional wisdom, knowledge, and technology as well as land capability, economic and tenure factors (Vira et al., 2015). The complexity has

[4] The survival algorithm is based on survival analysis, a technique for analyzing the survivability of a project, e.g. against a higher discount rate or production output decrease.

resulted in a shortage of reliable empirical data with which to assess and model the total distribution of underlying economic profitability of these practices (Snelder and Lasco, 2008; Hosier, 1989). Examples of contrasting practices observed by the author illustrate the wide range of combinations of trees and crops grown in agroforestry systems by communities in different locations, e.g. the durian system in Java, the pomelo and coconut system in Thailand (Figure 3), and the mango system in Bangladesh[5]. Moreover, agroforestry is not generally recognized as a distinct practice and rarely features in development strategies, therefore, policy makers need to be updated about the economic benefits of various agroforestry systems, that they can use it to support development agenda (Snelder and Lasco, 2008; Garrett and Buck, 1997; Williams et al., 1997; Current and Scherr, 1995).

Figure 3: The pomelo, coconut and banana agroforestry system in Samut Songkhram, Thailand. Photo © Syed Rahman.

[5] As personally observed by the author of this thesis during the period of 2008 to 2013, while working on various agroforestry projects.

Farm intensification and reduction in pressure on local forest

To meet their livelihood needs, many communities heavily depend on products and services from nearby forest (Roshetko, 2013; Snelder and Lasco, 2008; Michon, 2005; Salafsky and Wollenberg, 2000). However, due to agricultural expansion and over exploitation of forest products (e.g. firewood and timber), forests are becoming depleted at a high rate in many locations (Babigumira et al., 2014; Hosonuma et al., 2012; Mena, 2001; Angelsen and Kaimowitz, 1999), as discussed in the earlier section of this chapter. 'Protected areas' are viewed as having a key role in forest conservation, however, especially in the developing world, this approach is very difficult to implement for various reasons, e.g. it is hard to stop agricultural expansion and over-exploitation of forest products by local communities due to lack of government resources, and weak management capacities and legal systems (Angelsen and Kaimowitz, 1999; Salafsky and Margoluis, 1999; Margoluis and Salafsky, 1998; Rao and Geisler, 1990). This is often connected with a failure to pay sufficient attention to the severe opportunity costs for resource-poor local people resulting from the designation of protected forest areas and enforcement of their protection (pullin et al., 2013). As a result, in many cases the challenges of implementing protected area projects have been beyond the capacity of managers (Salafsky and Wollenberg, 2000). Therefore, more attention needs to be focused on the contribution of interventions to increase biodiversity on farmland, e.g. through agroforestry (i.e. 'trees outside forests') as a contribution to conservation (Snelder and Lasco, 2008). The best solution may be integrated policies at a landscape scale that combine community participation, with agroforestry and enhanced protection of the best remaining areas of (semi-)natural forest.

Through tree-based farm intensification, agroforestry can be provide a potential substitute for some important forest products (e.g. timber, firewood and fodder) that local people rely on for their livelihoods (Snelder and Lasco, 2008; Michon, 2005), and may relieve pressure on local forest. Some studies conducted in West Sumatra, Indonesia (Murniati et al., 2001), Mindañao, the Philippines (Garrity et al., 2002), and Kavrepalanchok District, Nepal (Pandit et al., 2014) found a link between increased agroforestry practices and a reduction in pressure on local forest (see also Schroth et al., 2004; Ravindranath and Hall, 1995). Such results support the 'agroforestry-deforestation' hypothesis that agroforestry practices can reduce deforestation (Atangana et al., 2014). This hypothesis is based on the single case study conducted in Peru by Sanchez and Benites (1987), which showed that adoption of 1 ha of improved cropping system through agroforestry is likely to save 5 ha of natural forest. From this evidence, Sanchez and colleagues extended the scale of this effect applying it to the global warming and deforestation debates, by arguing that every hectare of sustainable land management technology can save 5-10 ha/year of forest from deforestation (Sanchez, 1990; Sanchez et al., 1990; Brady et al., 1993).

The original study of Sanchez and Benites (1987) is, however, based only on a single case study from Yurimaguas, Peru, and may only be relevant to a narrow set of similar conditions.

Angelsen and Kaimowitz (2004) argued that the link of agroforestry to reduced deforestation is heavily dependent on farmers' constraints (of labour, land and capital), and in that case agroforestry may reduce deforestation. However, like any profitable form of land use, agroforestry can have contradictory effect on farmers' decision-making on forest conversion. While obtaining a greater profit from currently farmed land through agroforestry may reduce farmer's motivation to increase their farmed area by deforestation (especially if labour is a limiting resource or deforesting creates risks, e.g. of prosecution), it can actually increase motivation for deforestation in order to increase income. The latter effect can be exacerbated if knowledge of agroforestry profitability attracts new migrant farmers to an area (see also Angelsen and Kaimowitz, 2001).

As the hypothesis linking agroforestry to a reduced rate of deforestation is yet to be proven widely in the tropics (Atangana et al., 2014), it is important for new research to target this knowledge gap across a range of different biophysical, social, and economic conditions. The key question is whether farmers are really ceasing or reducing forest clearing activity as a result of adopting agroforestry practices. If so, this would provide a powerful justification for the development and promotion of agroforestry technologies.

Barriers and adoption of tree growing in smallholder land use systems

Tree growing by smallholder farmers is often associated with multiple objectives which are influenced by their livelihood necessities, local culture and land use condition (Rahman et al., 2012; Rahman et al., 2008a; Schuren and Snelder, 2008; van Noordwijk et al., 2008; Arnold and Dewees, 1999; Scherr, 1995). Based on the multiple benefits that can be provided by agroforestry (Roshetko 2013; Alavalapati and Mercer, 2004; Garrity, 2004), smallholder farmers have many agroforestry options, e.g. in terms of the tree species that they could add to their farming systems, dependent on the priority that they place on, e.g. the production of timber, firewood, fruit and other tree food, and fodder as a safety net for their livelihoods (Snelder and Lasco, 2008). However, despite this flexible potential agroforestry adoption remains low in many locations as smallholder farmers often face barriers to tree growing (Jerneck and Olsson, 2013; Rahman et al., 2008a; van Noordwijk et al., 2008). These barriers are associated with the particular social and environmental settings for a farmer, such as their stage of land use intensification (van Noordwijk et al., 1997; Arnold and Dewees, 1995). The current state of literature emphasizes that these barriers are related to multiple factors, such as local cultivation tradition, weak land tenure, insufficient production technology, inadequate physical infrastructure and policy support, and underdeveloped markets for tree products (Rahman et al., 2008; Snelder and Lasco, 2008; van Noordwijk et al., 2008). Farmer’s capacity to adopt agroforestry is also affected by their individual circumstances, such as age, education, family size, land size, investment capital and access to credit (Rahman et al., 2012; Schuren and Snelder, 2008). Decisions to adopt agroforestry are driven by farmers’ expectation of the productivity increase and output stability through risk reduction that this would achieve compared with other land use alternatives (Salam et al., 2000; Scherr, 2000; Arnold and Dewees, 1995).

There are various theories that have examined technology adoption, such as expected utility theory of choice, which assumes that decision to adopt a particular system (from various alternatives, including traditional practices) is related to the maximization of utility, e.g. in the form of profit, subject to land, labour, credit and other constraint factors (Mercer, 2004). Portfolio theory views the decision of land allocation as a process where farmers also want to maximize the profit and minimize the risk in order to maximise the utility, thereby assuming risk aversion. Risk aversion is individual and it may thereby depend on socioeconomic variables such as age, education and wealth (Feder and Umali, 1993). The gain of agroforestry may, to a large extent, be in the form of minimisation of risk, which could be measured by portfolio theory. The safety-first model is another choice-making model for uncertain alternatives, where it is assumed that the minimum gaining aim is to be above a certain risk level (e.g. to secure specified safety margins such as subsistence) (Bigman, 1996; Feder et al., 1985). Learning-by-doing and farmer-experimentation models, developed by Foster and Rosenzweig (1995), show that insufficient knowledge is a barrier of adoption.

Choosing one specific model may help empirical analysis of adoption, however it can lead to estimation bias and error (Feder and Umali, 1993). As farmers exhibit different adoption patterns depending on their attitudes to a number of factors (e.g. risk tolerance and conservation priorities) (Marcer and Pattanayak, 2003), and since preferences are difficult to measure accurately, and depend on many variables such as age, education, income, savings, family size, farm size and socio-cultural status, there are many factors that need to be incorporated into an analysis of adoption decisions (Pattanayak et al., 2003).

As the agroforestry adoption rate is slow in many locations (i.e. across community, region and landscape level) and this adoption gap is not fully explained (Jerneck and Olsson, 2013), social studies of agroforestry are a high priority, yet several review articles have highlighted how rare they are (Kiptot and Franzel, 2011; Mercer, 2004; Mercer and Miller, 1997). Several studies have suggested that agroforestry adoption research should be researcher-led and based on participatory methods (e.g. focus group discussion, participatory rural appraisal, participatory action research) (Scherr, 1991a, 1991b; Chambers et al., 1989; Byerlee and Collinson, 1980). These methods are crucial to obtain evidence about the complex socioeconomic and biophysical circumstances across the landscapes that influence adoption of a particular system. Improved understanding of these circumstances is crucial for improvements to policy making that does succeed in making feasible, acceptable and ultimately profitable for farmers (Franzel and Scherr, 2002). A major challenge is to extend from research evidence obtained about the particular adoption barriers for individual communities to policy recommendations that will be effective at much larger landscape and even regional scales.

The 'landscape approach' to reconciling agriculture and conservation

In tropical landscapes, as the substantial land use transformations are leading to the conversion and degradation of forests (Labrière et al., 2015), land demand for agricultural production is on a collision course with increasing demands for environmental protection (Sayer et al., 2013). FAO estimated that a 70% increase in agricultural production is needed by 2050 to feed a projected population of 9.1 billion, and this has to be combined with improved nutritional quality, poverty alleviation, and conservation of the environment to enable sustainability (Sayer et al., 2013; FAO, 2009). In the search for solutions to reconcile trade-offs between development and conservation, the concept of the 'landscape approach' has gained prominence in the global development agenda in recent years[6] (Sayer, 2009). A landscape approach is a framework to combine policy and practice for multiple competing land uses through allocating and managing land to achieve economic, social, and environmental goals (Reed et al., 2015; Sayer et al., 2013). It is a long-term, multi-faceted and collaborative process that aims to integrate the interests of multiple stakeholders to provide solutions at multiple scales, with the objective of 'winning more' and 'losing less' (Sayer et al., 2013).

In response to increasing concerns about trade-offs between development and conservation, landscape approaches have been refined (Sayer et al., 2013). In a complex land use matrix, various landscape approaches have widely proposed to meet the challenge of satisfying multiple objectives (Sayer et al., 2013; Pfund, 2010). To combine biodiversity conservation with agricultural production, much of the literature has been framed as a choice between so-called 'land sharing' and 'land sparing' approaches (Gilroy et al., 2014; van Noordwijk et al., 2014; Tscharntke et al., 2012; Phalan et al., 2011). Land sharing is an integrated approach of combining

[6] The landscape approach was, in fact, promoted by early conservation theory, but the *de facto* acceleration in the use of this approach has only occurred in the late 20th century as many conservation organizations developed integrated conservation and development projects (Sunderland, 2012; Sayer, 2005; Kingsland, 2002).

agricultural production and biodiversity conservation on the same land, using wildlife-friendly farming methods. Land sparing is a separation of land for conservation from agricultural land, on the basis that intensive high-yielded farming can meet food needs while remaining natural habitats are protected from agricultural expansion (Phalan et al., 2011). Assessment of these two alternative approaches is complex, as high crop yields do not guarantee the sparing of other land from agriculture, and land sharing does not guarantee biodiversity benefits on farmed land (Ewers et al., 2009; Matson and Vitousek, 2006). However, considering growing need of high yielded monoculture agriculture and tree based farming system to provide food, fodder, fibre, firewood, timber, as well as environmental services functions which is generally associated with ‘forest’, we have to acknowledge a wide spectrum of landscape design that can meet these demands (Roshetko, 2013; van Noordwijk et al., 2008). As the agroforestry system is generally associated with the term ‘multifunctionality’ by enhancing agricultural production, income generation, and biodiversity conservation (Dagar et al., 2014; Idol et al., 2011; Leakey, 2010; Garrity, 2004), it can potentially consider as an important element in the landscape level configuration (van Noordwijk et al., 2008).

For landscape-scale approaches to be effective, it should address the needs and priorities of local people who live in, use and ultimately shape these landscapes (Lawrence, 2010). Therefore, people-centred landscape approaches have gained special attention (Sayer et al., 2013; Watts and Colfer, 2011; Agarwal and Gibson, 1999). Many conservationists now recognise that conservation objectives cannot be achieved unless food production needs are also met, and are therefore now focusing on wider multifunctional landscapes, and not only within protected areas (Sayer, 2009; Laven et al., 2005). Therefore, there is a need to address the current gap in evidence-based people-centred effective landscape approaches that are informed by local reality at a range of scales (Figure 4, see also Sayer et al., 2013). However, landscapes differ in their inherent characteristics and the pressures that influence them, so work at this scale is inherently challenging (Josh et al., 2015).

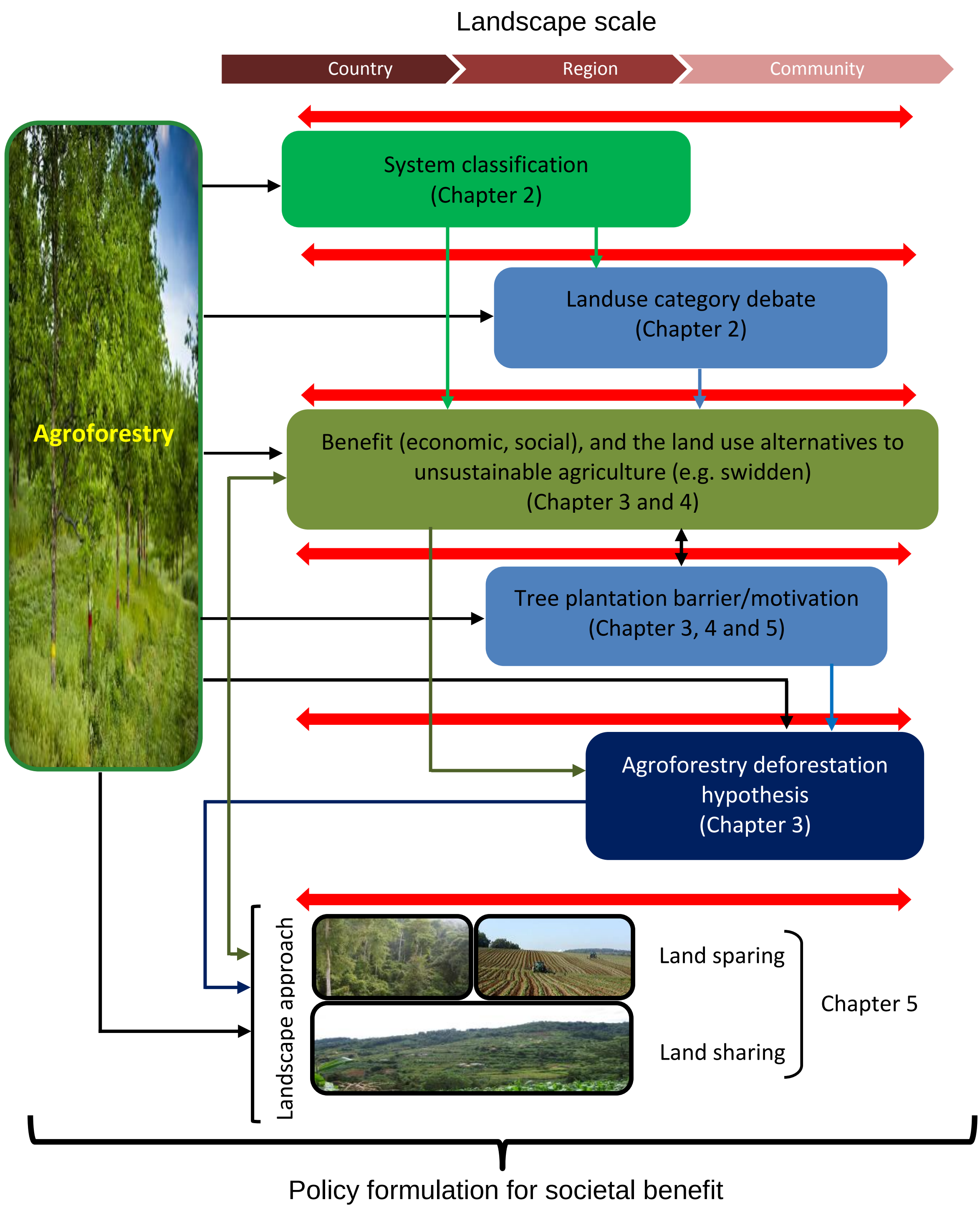

Figure 4: Conceptual framework showing how various concepts described in this thesis section are related to each other, where the red arrows show the knowledge gap at a landscape scale related to each corresponding concept.

From the discussion of above sections, we can see that there is a knowledge gap to classify wide range of agroforestry systems, their corresponding benefits and the barriers to more widespread adoption in a various landscape level (Figure 4). Existing binary land use classification, i.e. agriculture and forestry, suggested by FAO is confusing. The agroforestry deforestation hypothesis is yet to be proven in a wider landscape level. There is a need of effective landscape approaches that can fit best in various challenging local land use situation to reconcile agriculture and environmental goals.

Classification of various agroforestry systems that are practicing in various landscape level, is important to analyze their corresponding benefits, and to fit them in the proper land use categories (see the inter linkages of various concepts presented in Figure 4). There is a possibility that classifying agroforestry in a specific land use category can influence on the systems' perceived benefit, e.g. additional income prospect from payment for environmental services (PES) or negative prospect from harvesting restriction, if classify it into a forest category (see also Chapter 2 of this thesis). There may be also a possibility that good agroforestry income can attract more farmers to practice agroforestry, or low profit can demotivate them, therefore benefit of agroforestry and motivation are interlinked (Figure 4). It is assumed that the rate of agroforestry adoption and the income prospect may have contradictory effect on farmers' attitude towards forest clearing, thus both of them are linked to agroforestry deforestation hypothesis. Therefore, it is important to test agroforestry deforestation hypothesis in the effective local land use planning process. Furthermore, agroforestry system with good income prospect can be an important component of the land use configuration, and an effective land use configuration with agroforestry component can make agroforestry systems more feasible and accessible for the farmers to get more benefit from it.

Research Approach and Questions

The overall aim of this thesis is to assess the economic potential of smallholder tree-based farming, which may also help to protect local forests, the barriers to its widespread adoption, and how such land-use change might work best at a landscape scale. The approach of the thesis is to make these assessments mainly from the perspective of the economics of the local farmers concerned therefore it quantifies the rates of return resulting from smallholder farmers incorporating trees into their land use systems. This thesis also investigated the types of local agroforestry systems highlighting existing binary land use category debate (i.e. agriculture and forestry).

It supports this research with qualitative and quantitative methods, and explores the landscape contexts and institutional constraints that also influence the decision-making of farmers about whether to change their land-use practices by incorporation of trees. It addresses these aims by using two case study locations, in West Java, Indonesia and eastern Bangladesh.

Why smallholders?

It is increasingly recognised that land controlled by smallholders is important for both sustainable food production and safeguarding ecosystem services (Snelder and Lasco, 2008). This research targeted to assess the economic effects of smallholder farmers growing a range of tree species in their food-crop-based agricultural systems, and the potential for more smallholders to adopt this practice as a means of risk reduction and livelihood diversification under various conditions, including secure land tenure and market access. It can assumed that, due to population growth and land shortage, the number of smallholder famers will remain high and even increase in the near future. Thus this research also considered such assumption to strengthen the recognition of smallholder tree-based farming as an important contribution to meet local economic objectives while maintaining food production and environmental goals. Moreover, tree growing by smallholders has received insufficient attention in scientific research, when compared with large-scale tree planting (Snelder and Lasco, 2008), despite its key role in the achievement of sustainable land management in tropical developing countries. Therefore, it is currently a priority research area of the CGIAR[7] research program on Forests, Trees and Agroforestry (FTA) targeting 80 countries across Asia, Africa and Latin America (CGIAR, 2015).

[7] CGIAR (the Consultative Group for International Agricultural Research) is a global partnership addressing agricultural research for development, whose work contributes to the global effort to tackle poverty, hunger and major nutrition imbalances, and environmental degradation.

Specific research questions

1.1. What local agroforestry practices exist in the research site and how do they differ in structure, management and associated crop plant diversity? (Chapter two)

To classify the existing agroforestry systems in a specific land use context, chapter two set out to determine what are the current local agroforestry practices in the Indonesian study site, and how they differ in terms of their structure, management and associated crop plant diversity. Chapter two further uses these results to assess the policy consequences of the classification of such agroforestry systems between the standard binary land-use categories of forest and agriculture.

1.2. Are there existing agroforestry practices that show economic and social potential as a land use alternative to swidden cultivation, and lead to reduced pressure on local forest? (Chapter three)

1.3. If practices matching these criteria are found to exist, what are the barriers to their more widespread adoption? (Chapter three)

Focusing on the Indonesia study site, chapter three set out to assess, economically and socially, the existing agroforestry practices that have already been adopted by a subset of smallholder farmers as an alternative to swidden agriculture. It also evaluated the evidence that this adoption affects the quantity of product harvesting from local forests as well as forest clearance compared to swidden farmers. It then went on to assess the sociocultural, economic, and institutional factors that have limited farmers' willingness to adopt this practice.

1.4. What are the trade-offs between income and tree cover when incorporating trees into smallholder food-crop-based seasonal agricultural systems? (Chapter four)

1.5. Which factors influence farmers' choice to adopt tree-based farming in place of seasonal cultivation? (Chapter four)

Utilising results from both the Indonesia and Bangladesh study sites, chapter four assesses the trade-offs between income and tree cover when incorporating trees into smallholder food-crop-based seasonal agricultural systems. Crucially it incorporates into the economic analysis the effects of tree cover reducing the yield of understorey crop production, and how the net economic impact of the agroforestry practices changes over the tree establishment/production cycle. It further investigates how the probability that a farmer may adopt agroforestry is conditional on a set of influential factors: farmer age, education, land area, family size, income and access to credit availability.

1.6. What are the most important challenges farmers face using current local land use systems? (Chapter five)

1.7. Which policies are predicted to facilitate increased farmer adoption of successful tree farming? (Chapter five)

1.8. How can landscape approaches (land sharing and land sparing) work best from a local land use perspective to reconcile agricultural and environmental objectives? (Chapter five)

Chapter five makes a wider assessment of the current land use challenges. It has a major focus on the issue of scale from the individual farm to the wider landscape. It assesses a range of factors including land tenure, low income, community structures, and technical assistance. The barriers and facilitating factors of tree-based farming. The potential for policy interventions, including landscape-scale approaches, to overcome some of these barriers, and so achieve a more successful synergy between food security and environmental protection, are explored.

Research Sites

This research was conducted in Gunung Salak valley, Bogor District, West Java, Indonesia (which 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), and Khagrachhari district, eastern Bangladesh (which 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) (Figure 5). Expansion of subsistence agriculture, due to rapid population growth, is a major contributing factor to forest loss and environmental degradation in West Java and eastern Bangladesh (EST, 2015; Rahman et al., 2014; Galudra et al., 2008). The sustainability of livelihoods in these communities, like many other parts of Indonesia and Bangladesh, is threatened by overall poverty with low income and poor infrastructure development (BBS, 2014; Badan Pusat Statistik, 2013). Moreover, gradual expansion of areas under forest protection and restrictions on the harvest of some products (e.g. timber) from natural forest provide an economic incentive for smallholders to integrate trees into their farming systems. Hence, the two locations are a complementary pair of examples for our analysis, and representative of a large proportion of tropical Asian agricultural landscapes.

Selection of the villages

For the field data collection, three villages, Kp. Cangkrang, Sukaluyu and Tamansari, located at the northern valley of Gunung Salak in the Java study area were selected. These three villages were purposively selected based on their locations in different parts of the valley, and having the largest sample size of farm households that practice the land use system associated with their area, i.e. in the lower watershed food-crop-based monoculture (Kp. Cangkrang), and in the middle (Sukaluyu) and upper (Tamansari) watershed agroforestry and swidden. Gathering useful information about the area (i.e. security situation, characteristics of the local communities, households, farming practices, watershed locations) from CIFOR and ICRAF scientists at Bogor, who have work experience in the Gunung Salak area, was helpful for the selection of the villages.

At the Bangladesh study site, two villages, Mai Twi Para and Chondro Keron Karbari Para, were purposively selected. They both include a mixture of households practicing each of the two land use systems that form the major comparison of this study: subsistence seasonal swidden farming and agroforestry. The area consists of hills, and food-crop-based monoculture is rarely practiced, thus the two villages were selected on the basis of having the largest sample size of agroforestry and swidden farm households in the area. The author of this thesis has previous research experience in this area, however, collecting up-to-date information (on the security situation, characteristics of the local communities, households, farming systems and geography) from the district agriculture office, NGOs and environmental journalists at Khagrachhari, was helpful for selecting the villages.

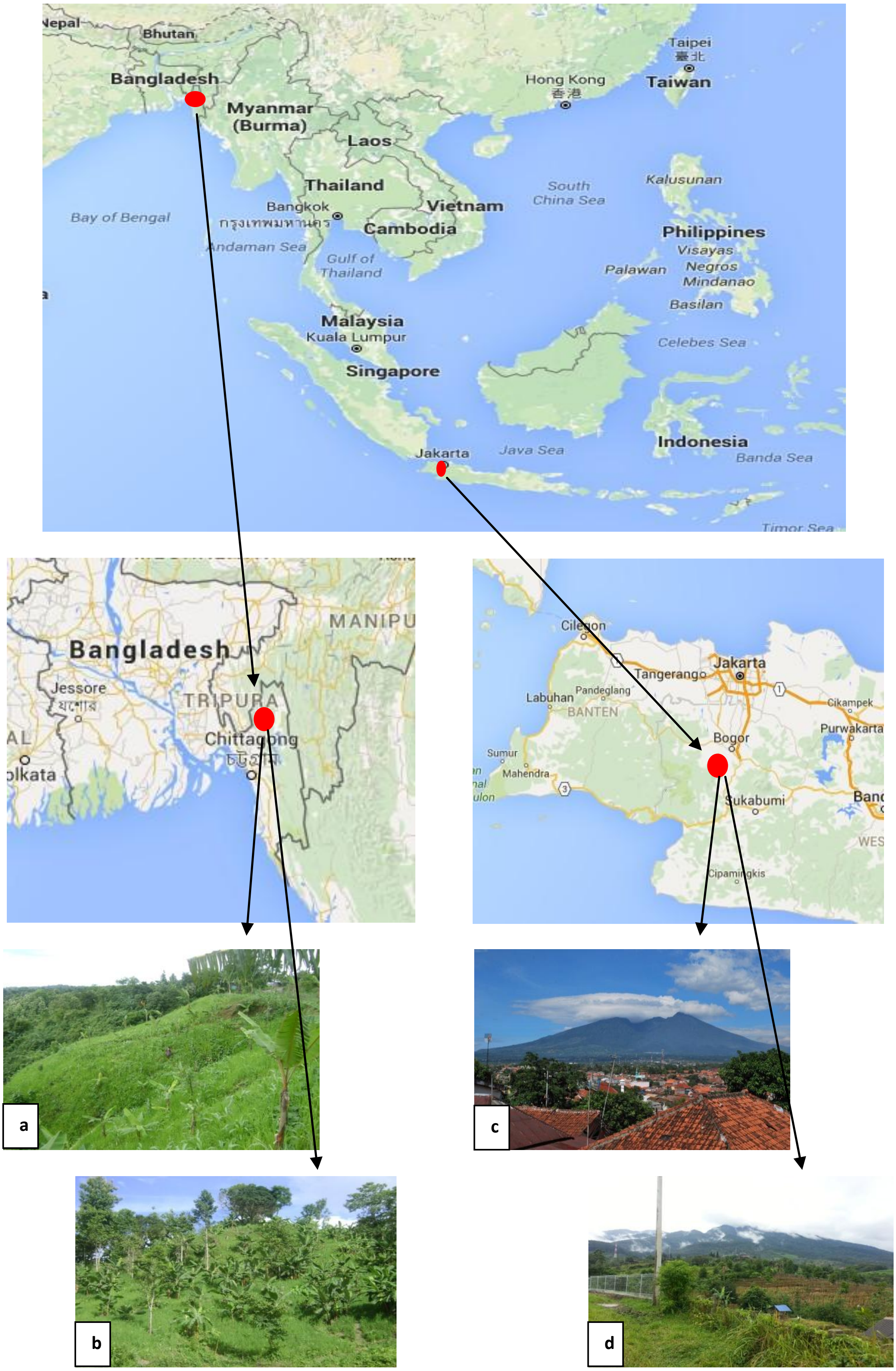

Figure 5: Study sites in Bangladesh (a, b) and Indonesia (c, d) showing swidden (a, d), agroforestry (b) and the Gunung Salak volcano (c). Map ©2015 Google, Photo © Google (c) and Syed Rahman (a, b, d).

Before final selection of the villages in both the Indonesia and Bangladesh study sites, several field visits were made by the author with the help of local guides to make sure that the villages were suitable for data collection. Table 3 is an overview of the study sites and a detailed description of the research sites is provided in each chapter (paper).

Table 3: Basic characteristics of the research sites.

Characteristics	**Gunung Salak valley, West Java**	**Khagrachhari, eastern Bangladesh**
Average precipitation (mm/year)	1700	2540
Average relative humidity (%)	70	66
Average temperature (˚C)	26	24
Soil	Highly fertile derived from volcanic and sedimentary rocks	Highly fertile of variable depth above broken shale or sandstone as well as mottled sand
Main economic activities	Agricultural and forest products, wage labor and retailing	Agricultural and forest products, wage labor
Main source of forest products	Natural forest	Natural and secondary forest
Forest products collected	Firewood, rattan, bamboo, fruits, vegetables	Firewood, timber, bamboo, rattan, wild fruits, vegetables
Agricultural markets	Village and district	Village and district
Local land use	Household dwelling units, home gardens, agricultural fields and forests	Household dwelling units, home gardens, agricultural fields and forests
Land tenure	State *de jure* owner. Private and community *de facto* user	State *de jure* owner. Private and community *de facto* user

Data source: BBS, 2014; BBS, 2013; Badan Pusat Statistik, 2013; Wiharto et al., 2008; Local Agricultural Office; RRA and village survey in this study.

Research Methods

Data collection

Research data were collected during January-August, 2013 through rapid rural appraisals (RRA), focus group discussions (FGD), field observations, questionnaire interviews, and key informant interviews. These methods are also widely used to obtain baseline data on agroecosystems, the nature of local resources use, social power structures and value systems of local communities, etc. (e.g. Atangana et al., 2014; Rahman et al., 2014; Parker and Burch, 1992). For the effective application of each method, its selection should consider specific local conditions (e.g. socioeconomic, geographic), which vary from site to site. Therefore, before the data collection, exploratory visits were made to the research sites, in order to understand local conditions as a basis for the selection of the above research methods for this study, which are described in detail below.

Rapid rural appraisal (RRA)

Rapid rural appraisals were used to obtain basic socioeconomic and geographical characteristics in both research sites (see FAO, 2015; Angelsen et al., 2011). During RRAs, mapping sessions and key informant interviews were conducted by involving the village head and three farmers in each village. Based on their good knowledge about the socioeconomic and geographical characteristics of the village and its surroundings, these farmers were selected purposively with the help of an expert local informant[8]. All of the selected farmers were male, as the both research sites are male-dominated and there were no female farmers in the area during the time of the field work.

During the village mapping session, a map (for each village) was drawn on a large sheet of paper (Figure 6) with the support of a research assistant[9] and the expert local informant. The village head and the farmers were asked to show the locations of various feature on the map, e.g. hamlets/households, shops, agricultural field sites

[8] One person from each research site (country), who had considerable knowledge of the village community, 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.

[9] One research assistant from each country, a university graduate who had considerable knowledge of socioeconomic methods and experience of field-level data collection, was employed. These research assistants were present to support the whole period of fieldwork.

(including agroforestry and swidden), ponds, rivers and forests. To get the most accurate result, it was helpful to draw the roads and significant landmarks (e.g. school, mosque, pagoda) of the village first. When one participant had given an answer about the location of a feature on the map, it was verified by other participants by asking whether they agree, disagree or want to add something more. The key informant interviews were conducted with the support of a research assistant and the expert local informant by involving the village head and farmers to gather information about land use systems, agricultural and forest products, markets, ethnic/religious groups, institutions, and the community structure of the village. In both study sites, two days in total were allocated for each village to complete the RRA session.

Figure 6: Village mapping during RRA in Bangladesh. Photo © M. Bahauddin (research assistant, Bangladesh).

The main reason for conducting RRA was to obtain basic socioeconomic and geographical information about the study sites from local people in a timely, cost-effective, and participatory manner. However, this information does not provide a detailed in-depth picture. While stratification of the participants from as broad a base of community members was attempted, because of own belief and interest, during the RRA it was not possible to eliminate possible sources of bias amongst participants. To minimse the impact of such potential biases on the reliability of the information obtained, the conduct of the RRA included the verification of the reported information by all of the participants, as well as the expert local informants, before taking them into a final account. By using this approach, the author of this thesis found that the information obtained by RRA crucially helped to collect other research data from the right place (e.g. selecting field observation sites), provided by the right people, while saving precious time and funds.

Focus group discussion (FGD)

In both study sites, FGD session (one in each village) was conducted by involving local farmer representative groups (consisting of eight to twelve farmers), and the village head. Farmers in each group were purposively selected with the help of expert local informants based on their knowledge of local farming systems and the socioeconomic and geographic states of the village and its surroundings. A set of key FGD questions[10] was prepared that guided the open discussion amongst the participants.

The research assistant in each research site (country) was appointed as a moderator, as the research assistant was familiar with the local language and dialect, which is essential to successfully run FGD session with local participants. The key FGD questions were clearly explained to the participants so that they could fully understand each issue covered. Participants were also free to react on the viewpoints of others with which they may agree or disagree. A report was prepared immediately after the session by the author of this thesis summarising the answers and opinions given by the participants.

The FGD participants in both research sites were all male, as this was the wish of the dominant community members in these male-dominated societies. It was not possible to include any female participants due to the social norms. Including a short tea break, the duration of each FGD session was approximately 3 to 3.5 hours. Each FGD session was targeted at obtaining the following information:

1. Local land use systems and their challenges
2. Causes of local deforestation
3. Farming systems practiced in the area (swidden, food-crop-based monoculture and agroforestry) and their products

[10] The questions used for the FGDs are provided in the appendix.

4. The economic and socio-cultural contribution of farming practices to local livelihoods
5. Risks associated with swidden and food-crop-based monoculture practices
6. Reasons for practicing traditional swidden and food-crop-based monoculture
7. Barriers to agroforestry adoption
8. Local market conditions
9. Local land tenure system
10. Types of off-farm work and their availability
11. Characteristics of the local community and its power structure
12. Government-community relationships

A separate semi-structured questionnaire interview (VQ)[11], consisting of a set of questions about the village (e.g. population and infrastructure), was also conducted by the research assistant during the FGD.

Through FGD it was easy to interact with the participants in their own village environment, and to ask follow-up questions that probe more deeply to aid understanding of the specific issue. Participants also felt more comfortable in voicing their views in the context of enjoying each other's company. The resulting dynamic and free discussion amongst the participants also stimulated their own thoughts regarding the subjects discussed. It is, however, important to note that the information collected may well be subject to gender bias: because of local institutional and cultural constraints, all of the FGD participants in both research sites were male. Nonetheless, in these societies it is male household heads who dominate decision-making about farm land and farming practices, where were the main focus of the research. Another potential source of bias is that, while the objective of using the FGD method was to document the perceptions and knowledge of all participants, some outspoken participants might over-influence those collective results, i.e. some shy participants may not have revealed their important insights. While the conducted FGD sessions were not replicable within each village, to check its validity, the summarized FGD information was verified by the participants.

[11] A copy of the questionnaire for the village surveys is provided in the appendix.

Field observation

In both research sites, field observations were conducted by the author of this thesis to collect information on the local land-use systems (e.g. forest, agriculture and settlement), the services that they deliver (e.g. timber, firewood, food and aesthetic), the land use challenges (e.g. deforestation and land degradation) that local people face, the farming practices (e.g. agroforestry and swidden) and their structure, species, management and products. Across the five villages, observations were carried out in a total of 70 locations selected based on the information gathered during the RRAs, FGDs and by the help of expert local informants. The duration of each observation period was between 20 and 60 minutes, during which several pictures were taken (e.g. Figure 7), and relevant information was noted with the help of expert local informants. Pictures were taken as visual supporting evidence to aid data analysis and interpretation.

Figure 7: Pictures from field observations in Bangladesh, a. swidden farm, b. agroforestry farm, c. firewood collection from forest, d. degraded land. Photo © M. Bahauddin (research assistant, Bangladesh).

It is assumed that people may not always be able to accurately express the true situation with respect to various issues during interviews or group discussions, therefore direct field observations were used to help gather independent information in the specific geographical and socioeconomic settings within the research sites, including local farming practices, and occurrence of deforestation and land degradation. These observations complemented the data gathered from RRAs, FGDs and questionnaire interviews, and helped in their interpretation. As a stratified set of observation sightes were carefully selected by the author of this thesis with the help of expert local informants and the information obtained by RRA and GFD, minimal sampling bias is expected to have occurred. However, it is worth noting that observations might be influenced by the specific situation and time of observation. By understanding such issues, the observational data was carefully verified by the expert local informants, who have considerable knowledge about the study sites.

Questionnaire interview

In the Indonesian study site 20 food-crop-based monoculture[12], 20 swidden[13] and 20 agroforestry farmers; and in the Bangladesh study site 40 swidden and 21 agroforestry farmers were purposively selected for the semi-structured questionnaire interviews (Figure 8). Due to the variation in structure and management practices of the farms in each study site, the purposive sampling technique was used to identify farmers who were practicing a well-managed[14] form of each of the contrasted farming systems[15]. In the Indonesian study site, it is estimated that they represent 40%, 20% and 30% of the swidden, food-crop-based monoculture and agroforestry farming populations respectively. In the Bangladesh site, they represent about 50% and 60% of the swidden and agroforestry farming populations respectively. In the Bangladesh study site as food-crop-based monoculture is rarely practiced, with

[12] In this study, food-crop-based 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 without abandoning the land.

[13] In this study, swidden refers to a cultivation system where land is cleared by burning.

[14] For example, some other farmers started agroforestry farming but after a few years gave up planting the understorey, for various reasons (may be because of lack of management interest or capital). Thus many agroforestry farms were converted to simple tree orchards, and we excluded these from our sample.

[15] Many farmers cultivate plots of land under different farming practices (swidden, food-crop-based monoculture or agroforestry). Therefore, farmers were assigned to a group based on their dominant farming practice.

insufficient farmers in the studied villages to provide an adequate sample, it was not included in the study.

Before conducting the interviews with farmers, questionnaires (HQ1, HQ2, HQ3)[16] (Table 4) were refined and finalized with the help of the expert local informants and from information provided in the FGD sessions to make sure that the questions did elicit the required information. Four data collectors in each country, who were familiar with the local communities, language, and land use systems were employed to conduct the interviews. The author of this thesis trained all of the data collectors with the help of graduate research assistants and expert local informants, and observed them closely while carrying out interviews to provide supportive instructions whenever needed. The sampling design was made by the author of this thesis with the help of expert local informants that minimised the risk of observer biases.

The following basic information was collected using the questionnaire interviews:

- Household information: family size, age structure, education, income and assets, savings, expenditure, land ownership, access to credit, housing condition, distance of house from village centre and from forest, etc.
- Farming practices: farming system types, amount of land allocated to each farming system, species cultivated, farm product types, production costs and income, labour requirements, fertilizer and agrochemical applications, reasons for practicing each farming type, etc.
- Other: Crisis and unexpected expenditures, welfare perceptions and social capital, forest services (tourism, carbon projects, biodiversity conservation), forest clearance (types of forest cleared, amount, reason), collection of products from forest, interest in tree-based farming, etc.

[16] A copy of each of the three questionnaires used is provided in the appendix.

Figure 8: Interview with agroforestry farmer in the Indonesian study site. The expert local informant is on the left, the farmer in the centre and the data collector on the right. Photo © Syed Rahman.

Table 4: Types of interview questionnaire[17] used for this research.

Questionnaire type	Respondents
Farm household interview HQ1	Agroforestry farmers
Farm household interview HQ2	Swidden farmers
Farm household interview HQ3	Food-crop-based monoculture farmers
Village survey VQ	FGD participants (for basic information about the village, e.g. demographic, infrastructure, land use)

Additionally two agroforestry (i.e. agroforestry 1: durian and cassava, and agroforestry 2: teak, yam and maize) and two swidden (i.e. swidden 1: upland rice, and swidden 2: maize) farmers were purposively selected from Indonesian study site to ask additional in-depth questions about the actual and envisaged costs and benefits of each cultivation system needed for cost-benefit analysis specially for

[17] The questionnaire used for this study is a modified version of the prototype questionnaire of the PEN-CIFOR study (http://www1.cifor.org/pen/research-tools/the-pen-prototype-questionnaire.html).

chapter 3. The interviews were conducted by the research assistant with the presence of the author of this thesis. These four farm types were selected by the author of this thesis based on the information gathered from FGDs and field observations, as being popular (commonly adopted at a wider range) and providing the highest incomes among the Indonesian farm populations in the agroforestry and swidden farming categories.

The interviews were intended to collect the information mentioned above from the farmers in a timely and cost-effective way. As the data collected by interview were mainly quantitative, it was possible to analyse them quickly using appropriate statistical software packages, SPSS and R. However, while conducting the interviews, it was not possible to tell how truthful a respondent was being, and how much thought they put into their answers. Therefore, the likelihood that the respondents can give inaccurate information (e.g. about the exact amount of product collected from farms in the past season), or may not be able to think within the full context of each question, was also taken into account in the interpreptation of the results. A careful check was made for compatibility of responses amongst the interviewees in each set, with a particular focus on obvious outliers using the researchers expert knowledge. It was also possible that the individual respondents differeed in their understanding of some questions, introducing an additional source of subjectivity. While such issues are often inevitable during social science data collection, to minimize this source of error and so maximize the validity of the results, the enumerators who conducted the interviews at each site were selected based on their familiarity with the local community, language and land use practices. In addition, the critical questions were explained carefully to each respondent and sufficient time allowed for them to think carefully about each issue.

Key informant interview

Four face-to-face key informant interviews with local state agriculture officers were conducted (two from each country) by the author of this thesis (with the help of local expert informants) to elicit their perception about local modes of land use and the services that they deliver, land tenure status, strength of government extension services, and existing credit policy. The purpose of the key informant interviews was to collect information from their expert knowledge, experience and understanding.

The interview sheet contained an outline script, which is a list of open-ended questions relevant to the discussion topics. The answers from the discussion were noted instantly.

The responses of the key informants will clearly be heavily influenced by their own knowledge, experience and perceptions. In some cases it is possibility that they did not feel able to express their real opinions (e.g. for government employees, concerning the limitations of government policy and its effectiveness). However, the information gathered from the key informants was carefully cross-checked against the relevant published literature, the information gathered during FGDs sessions and field observations, and the views of the expert local informants.

The various methods used to collect data for this study are also suggested and commonly used in many other socio-economic studies (e.g. Yuliani et al., 2016; Colfer and Minarchek, 2012; Rahman et al., 2014; Rahman et al., 2012; Chambers, 1994). The main reason for selection of the mixed methods used in this study was to capture a wide spectrum of information, reflecting the range of perspectives of the different stakeholders. Collecting very accurate data in social science research is often challenging. As people vary so much in many characteristics, it was expected that there would be variation in the data collected from different respondents depending on age, education, land holding area, income, assets, perceptions and motivation. Two strategies were used to combat this challenge for validity and reliability of the results: (i) to maximise the verification of data amongst the different respondents and methods used in the field work; (ii) during the data analysis to examine the variation of observed variables, whenever that was possible.

Data analysis

Qualitative and quantitative methods were used to analyze the data.

For the qualitative part of the analysis, data were carefully organized point-by-point according to the responses on each topic gathered from this study. The interpretation (e.g. concerning the local land use system and challenges faced by farmers, basic structural differences and social aspects of the agroforestry systems) were then made by using the narrative qualitative analysis method (e.g. Jerneck and Olsson, 2013; Colfer, 2008; Colfer et al., 1997).

For the quantitative part of the analysis, cost-benefit analysis was used to assess the overall economic performance of different farming systems on the basis of a 30-year time period[18]. As agricultural projects may face a wide variety of risks (e.g. price fluctuation, landslides, lava flows, storms, pests), it should be accounted for in the financial analysis. Therefore, sensitivity analysis was conducted on changes in discount rate[19], and variation in yields. Descriptive statistics were used to analyse the basic household and farming characteristics (age, education, family size, farm size, yearly income and expenditure) of the different farmer groups using SPSS V 22 in a Windows platform. The total farm size and proportion of land used for different cultivation practices were also compared amongst the farmer groups. To compare two farmer groups, a two-sample un-paired Student's t-test (t) was used. ANOVA was used to test differences amongst three farmer groups, with F-statistics reported as F (a, b), where a and b are the between- and within-group degrees of freedom, respectively. Analyses were performed in a Windows platform using R, version R 2.15.0 (R Core Team 2015).

Means were compared (independent sample t-test using SPSS V 22) to assess the factors that may affect the decisions of non-agroforestry farmers to adopt agroforestry, by determining the conditional probability that a farmer will adopt tree-based farming given a set of independent influencing factors, i.e. land area, family size, income, age, education, and credit availability.

The research questions, hypotheses, field research methods, collected data and analysis methods are summarised in Table 5.

[18] Once trees are included in the farming system, its lifespan can be considered indefinite. However, for simplicity, the project life in this analysis is considered to be 30 years as this may be a realistic time horizon to cover one full production rotation of fruit trees, e.g. durian, and three rotations of timber trees, e.g. teak, besides 30 cultivation cycles of annual crops, as it is also suggested by other similar studies (see Rahman et al., 2014; Rahman et al., 2008).

[19] Calculation using increased discount rate is a suggested method to include risk factors, which reflects the added yearly risk of a project (Elevitch and Wilkinson, 2000).

Table 5: Matrix of research questions, hypotheses, relevant data and their collection and analysis methods reported in each chapter of the thesis.

	Research questions	Hypotheses	Data collected	Data collection methods	Data analysis methods
Chapter two	1.1. What local agroforestry practices exist in the research sites and how do they differ in structure, management and associated crop plant diversity?	1.1.1. Various agroforestry practices exist that differ in structure, management and associated crop plant diversity.	i) Basic structure of the systems. ii) Farm management. iii) Farm components (species). iv) Farm products. v) Basic socioeconomic and geographical state and land use systems of the study area. vi) Socioeconomic characteristics of farm households.	RRA, FGD, field observation, questionnaire interview of farm households, and information from expert local informant.	Quantitative analysis using descriptive statistics. Narrative qualitative analysis.

	Research questions	Hypotheses	Data collected	Data collection methods	Data analysis methods
Chapter three	1.2. Are there existing agroforestry practices that show economic and social potential as a land use alternative to swidden cultivation, and lead to reduced pressure on local forest? 1.3. If practices matching these criteria are found to exist, what are the barriers to their more widespread adoption?	1.2.1. Some agroforestry practices exist which are viable alternatives to swidden cultivation in terms of their economic and social potential. 1.2.2. Agroforestry systems can reduce peoples' need to access local forest resources by supplying alternative forest products on farm, and contribute to forest protection. 1.3.1. Local culture of practicing seasonal cultivation, weak land tenure, lack of capital (for initial investment) and technical assistance are the main barriers to widespread agroforestry adoption.	i) Basic socioeconomic and geographical state of the study area. ii) Types of local cultivation systems. iii) Farm size, components (species) and products of swidden and agroforestry. iv) Rates of return of swidden and agroforestry. v) Social potentials of agroforestry. vi) Amount of forest products collection by agroforestry and swidden farm households. vii) Forest land cleared in the last five years by agroforestry and swidden farm households. viii) Barriers to practicing agroforestry from the perspective of swidden farmers'.	RRA, FGD, field observation, questionnaire interview of farm households, and information from expert local informant.	Quantitative analysis, using descriptive statistics, cost benefit analysis (NPV, B/C, payback period). Narrative qualitative analysis.

	Research questions	Hypotheses	Data collected	Data collection methods	Data analysis methods
Chapter four	1.4. What are the trade-offs between income and tree cover when incorporating trees into smallholder food-crop-based seasonal agricultural systems? 1.5. Which factors influence farmers' choice to adopt tree-based farming in place of seasonal cultivation?	1.4.1. Trade-offs exit between the benefit of products from on-farm tree plantations and the cost of production output (income) loss of specific crops (e.g. rice) due to competition from the trees. 1.5.1. Factors associated with farmers' age, family size, education, land size and income can influence choice to adopt tree-based farming in place of seasonal cultivation.	i) Basic socioeconomic and geographical state of the study area. ii) Types of local cultivation systems. iii) Farm products and their values. iv) Farm size and allocation of land for cultivation of different crops. v) Basic characteristics of the farmer: age, family size, land area, education, income. vi) Non-agroforestry farmers' interest in adopting agroforestry (yes/no)	RRA, FGD, field observation, questionnaire interview of farm households, and information from expert local informant.	Quantitative analysis, i.e. descriptive statistics, t-test, ANOVA, cost-benefit analysis, comparison of means.

	Research questions	Hypotheses	Data collected	Data collection methods	Data analysis methods
Chapter five	1.6. What are the most important challenges farmers face using current local land use systems? 1.7. Which policies are predicted to facilitate increased farmer adoption of successful tree farming? 1.8. How can landscape approaches (land sharing and land sparing) work best from a local land use perspective to reconcile agricultural and environmental objectives?	1.6.1. Important land use challenges are associated with multiple factors including population pressure, agricultural land expansion, deforestation, low incomes, weak land tenure. 1.7.1. By understanding local modes of land use, competent government policies, which generate the support of local communities, could facilitate adoption of tree farming. 1.8.1. Landscape approaches will work best if their design carefully considers local perspective of land use challenges.	i) Basic socioeconomic and geographical state of the study area. ii) Local land use system and the benefits that they deliver. iii) Land use challenges that local people face. iv) Present barriers to the adoption of tree-based farming. v) Supportive policy literature on sustainable land use options.	RRA, FGD, field observation, questionnaire interview of farm households, information from expert local informant, interview of state agricultural officer.	Quantitative analysis using descriptive statistics. Narrative qualitative analysis.

Organization of the Thesis and List of Publications

The thesis is organized into six chapters. The first chapter is introductory; it reviews the existing state-of-knowledge of the study area and identifies the knowledge gaps that this research is designed to fill. Chapters two, three, four and five correspond to the four papers listed below. The last chapter (six) is the synthesis of the main findings and conclusions of the preceding chapters. This chapter also included a section describing the limitations of this research and future research needs.

Chapter two: **Rahman S.A.**, Sunderland T., Roshetko J. M., Basuki I., Healey J. R., (2016). 'Tree Culture of Smallholder Farmers Practicing Agroforestry in Gunung Salak Valley, West Java, Indonesia', *Small-scale Forestry,* 15(4): 433-442. DOI 10.1007/s11842-016-9331-4. [Due to space limitation of the journal, this paper is a short version of full Chapter (two) that included in this thesis].

Chapter three: **Rahman S.A.**, Jacobsen J. B., Healey J. R., Roshetko J. M., Sunderland T., (2017). 'Finding Alternatives to Swidden Agriculture: Does Agroforestry Improve Livelihood Options and Reduce Pressure on Existing Forest?' *Agroforestry Systems*, 91: 185-199. DOI 10.1007/s10457-016-9912-4.

Chapter four: **Rahman S.A.,** Sunderland T., Kshatriya M., Roshetko J.M., Pagella T., Healey J.R., (2016). 'Towards Productive Landscapes: Trade-offs in Tree-cover and Income across a Matrix of Smallholder Agricultural Landuse Systems'. *Land Use Policy,* 58(2016):152-164. DOI 10.1016/j.landusepol.2016.07.003.

Chapter five: **Rahman S.A.,** Sunderland T., Roshetko J.M., Healey J.R., (2017). 'Facilitating Smallholder Tree Farming in Fragmented Tropical Landscapes: Challenges and Potentials for Sustainable Land Management'. *Journal of Environmental Management.* (Under review after revision).

Main Findings of the Research

Research question 1.1: What local agroforestry practices exist in the research site and how do they differ in structure, management and associated crop plant diversity? (Chapter two)

Five main different agroforestry systems exist in the Indonesian study area: homegardens, fruit tree system, timber tree system, mixed fruit-timber system, and cropping in the forest understory. They can be categorized into two main types: i) integral, rotational and ii) integral, permanent (Chapter two, Figure 3), both of which exhibit a noticeable diversity in terms of both species composition and utilization. The diverse species in the agroforestry systems, selected by farmers' based on their own interest, have different structures and management practices. The agroforestry systems documented in this study are not only a form of forest like 'cultivated trees', but also of 'anthropogenic vegetation'. Growing trees is a traditional practice in the study area, which has been derived from agricultural antecedents, e.g. swidden, through farmers' long experience of trials of new practices and has mainly been used to produce livelihood necessities. The canopy cover of integrated trees on agroforestry land ranged between 30% and 70%. However, this land still lies outside the FAO (2000) definition of forest. While it does have a tree canopy cover > 10% and often exists in patches > 0.5 ha, it does not meet the criterion of being "not primarily under agricultural or urban land use". The FAO definition of forest (Chapter one, Box 1) specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations (which is the dominant use of trees in the agroforests of the study area). However, the FAO definition of forest is not a matter of function, as both 'forests' and 'agroforestry' systems provide tree products and services. Rather it is an arbitrary distinction of perception. Given the properties that such agroforestry systems share with both agricultural and forest systems, their classification will always be problematic if a binary system is applied. Therefore, a more sophisticated approach should be adopted that incorporates the economic and environmental characteristics of a wider range of systems.

Research question 1.2: Are there existing agroforestry practices that show economic and social potential as a land use alternative to swidden cultivation, and lead to reduced pressure on local forest? (Chapter three)

Research question 1.3: If practices matching these criteria are found to exist, what are the barriers to their more widespread adoption? (Chapter three)

In the Indonesian study area, the two investigated popular agroforestry systems (the durian - cassava system, and the teak – yam - maize system) have higher net present value (NPV) (IDR122,077,993 and IDR330,154,427 respectively) and benefit-cost ratio (B/C) (10.36 and 16.19 respectively) than the two popular swidden cultivation systems (upland rice, and maize) (IDR120,937,885 and IDR114,433,314; and 6.91 and 5.24 respectively) (Chapter three, Table 2). While the teak-based agroforestry system imposes some additional costs during its rotation, these are well offset by the higher return from selling timber, and it is the most profitable cultivation system. The sensitivity analysis revealed that, regardless of the discount rate used, teak-based agroforestry remains the most profitable system, whereas durian-based agroforestry provides a lower NPV than the two swidden systems for discount rates of 20% and above (Chapter three, Table 3). However, when sensitivity to the decrease in agricultural crop yields due to tree completion was analysed, the NPV of both agroforestry systems was always positive and higher than swidden systems (Chapter three, Table 4). It was also found that tree ownership creates more permanent rights to farmland and is prestigious in the community. Agroforestry products (fruit, vegetables etc.) have high monetary value and help strengthen social cohesion when shared with neighbours. Farmers practicing agroforestry are less involved in forest clearing and forest products collection than swidden farmers (Chapter three, Table 6) indicating that this system may reduce pressure on local forests. However, farmers are reluctant to implement agroforestry. Stated reasons are related to both motivation (i.e. no interest) and capacity (i.e. lack of sufficient capital, knowledge or technical assistance) (Chapter three, Table 5). Increasing the adoption of agroforestry farming in the study area can be increased by the implementation of supportive policies and measures (including capital support and technical assistance) by government and non-government organizations.

Research question 1.4: What are the trade-offs between income and tree cover when incorporating trees into smallholder food-crop-based seasonal agricultural systems? (Chapter four)

Research question 1.5: Which factors influence farmers' choice to adopt tree-based farming in place of seasonal cultivation? (Chapter four)

Results from both the Indonesia and Bangladesh study sites indicate that, for their seasonal agriculture, farmers spread their production over a wide diversity of crops, e.g. cassava, yam, turmeric, maize, upland rice and banana. Among the crops, yam generates the highest income (mean income US$1,531.40 ha^{-1}, NPV= US$14,436.38 ha^{-1}) for Indonesian farmers, and banana (mean income US$6,175.00 ha^{-1}, NPV= US$58,211.00 ha^{-1}) for Bangladeshi farmers (Chapter four, Table 4). Inclusion of tree crops in the seasonal agriculture improved the systems' overall economic performance (NPV) (Chapter four, Table 5 and 6). This finding holds across a wide range of percentage reductions in understorey crop production when trees become mature and their canopies close. However, seasonal agriculture has higher income per unit of land area used for crop cultivation compared with the tree establishment and development phase of agroforestry farms (Chapter four, Table 3). There is thus a trade-off between the short-term loss of agricultural income and longer-term economic gain from planting trees in farmland.

A comparison of means is further used to investigate the conditional probability that a non-agroforestry farmer may practice agroforestry given a set of influential factors: farmer age, total years of schooling, land area, family size, income and access to credit. In both study sites, the mean values of these factors do not differ significantly between those farmers who have an interest in adopting agroforestry and who have not, except that this interest is significantly associated with total years of schooling for swidden farmers in Indonesia (p-value = <0.001) (Chapter four, Table 7). Therefore, with this exception, there is no evidence that the above factors have a significant influence on farmer choice to adopt agroforestry. The tendency to continue practicing seasonal agriculture, which is deeply rooted in local traditions, remains a more powerful factor influencing the motivation of most farmers.

Research question 1.6: What are the most important challenges farmers face using current local land use systems? (Chapter five)

Research question 1.7: Which policies are predicted to facilitate increased farmer adoption of successful tree farming? (Chapter five)

Research question 1.8: How can landscape approaches (land sharing and land sparing) work best from a local land use perspective to reconcile agricultural and environmental objectives? (Chapter five)

From the perspective of farmers', local land use challenges in both the Indonesia and Bangladesh study sites are associated with population pressure, poverty, deforestation, forest product impoverishment, weakness of management at a community scale, weak tenure, underdeveloped markets, poor extension services, and government decision-making having insufficient involvement of local people. Various policy changes can help overcome such challenges and facilitate adoption of tree farming, including the careful management of landscape, for which a mixed approach incorporating elements of both land sharing and land sparing strategies may be best. The suggestion of a dichotomous choice between land sharing and land sparing appears to be over-simplified. Instead an element of integrated land sharing through agroforestry can be beneficial for enabling the land sparing retention of segregated areas of natural forest in the landscapes of the study sites. Therefore, a key component of the adoption and success of our suggested mixed approach in these landscapes will be the spatial arrangement of segregated intensive agriculture (i.e. monocroping) and integrated tree farming (Chapter five, Table 4). To support such a mixed approach, not only government initiatives, but also community participation through strengthened capacity, is necessary.

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Chapter Two

Tree Culture of Smallholder Farmers Practicing Agroforestry in Gunung Salak Valley, West Java, Indonesia

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This chapter is based on: **Rahman S.A.**, Sunderland T., Roshetko J. M., Basuki I., Healey J. R., (2016). 'Tree Culture of Smallholder Farmers Practicing Agroforestry in Gunung Salak Valley, West Java, Indonesia', *Small-scale Forestry,* 15(4): 433-442. DOI 10.1007/s11842-016-9331-4. [the published paper is a short version of this chapter due to space limitation of the journal].

Abstract

Indonesia boasts a number of agroforestry systems that integrate biophysical and socio-economic functions. This paper investigates the types of agroforestry system that exist in Gunung Salak Valley, West Java, Indonesia in order to characterize the differences in their basic structure, management and associated crop plant diversity. Data were collected through rapid rural appraisal, field observation and focus groups, followed by household survey of a sample of 20 agroforestry farmers. Five main agroforestry types (homegardens, fruit tree system, timber tree system, mixed fruit-timber system, and cropping in the forest understory) exist in the study area, and can be categorized into two: i) integral, rotational and ii) integral, permanent, both of which exhibit a noticeable diversity in terms of both species composition and utilization. Products from farming accounted for an average 24% of household income. They comprised agroforestry products which contributed IDR 3.25 million/year and other agricultural products contributing IDR 1.66 million/ year. The observed agroforestry systems include not only a form of forest dominated by 'cultivated trees', but also an anthropogenic vegetation formation derived from agricultural antecedents. In land-use classifications agroforestry systems are not recogniged as forestry, but like forests they provide tree products and services. Classification will always be disfunctional if a binary system is applied, thus a more sophisticated approach should be adopted that incorporates the economic, social and environmental characteristics of a wider range of systems.

Keywords: anthropogenic vegetation, species diversity, *hortus*, income

Introduction

The important and historic relationship of local people and forests is widely reported. The romanticism that external observers often associate with indigenous forest people is strong (Bahuchet et al., 2001; Hutterer, 1998), particularly the image of nomadic bands of a few individuals living in hunter-gatherer communities, in harmony with nature. Tropical rainforests have often been perceived as 'virgin nature' and described as largely uninhabited, with only scattered groups of 'indigenous forest people' (Mann, 2011; Michon, 2005). However, as is the case elsewhere in the tropics, in Southeast Asia, at present the vast majority of forested landscapes are inhabited by large groups of smallholder farmers, living in permanent villages and practicing either swidden (slash-and-burn) agriculture or some form of permanent farming, in addition to off-farm activities (Peng et al., 2014).

Several ethnobotanists consider the process of plant domestication and cultivation to have followed two divergent models (Michon, 2005; Barrau, 1970; Geertz, 1966; Haudricourt and Hédin, 1943). i) The *ager* model is an agricultural practice in open fields. It reflects the productivist mentality of a genetically homogeneous and even-aged plant population, with a clear focus on a single commodity. In this practice, cultivation involves a clear distinction between the cultivated field and the natural ecosystem, as well as between wild and domesticated plants. ii) The *hortus* model refers to the cultivation of crops in 'gardens'. Diversity is a key charecteristic in the 'garden model', ranging from plant types, including herbs, tuberous perennials, trees and lianas, to species and genotypes, and includes architectural as well as product diversity.

In Indonesia, most agroforestry systems[1] are established in swidden agricultural fields, as selected tree species are retained during forest clearing and/or planted in the swidden together with annual food crops, which relates more to *hortus* than to *ager* (Michon, 2005; Michon and de Foresta, 1997). The relationship between forests and farming systems is often argued to support the livelihoods of local people (de

[1] There are various definitions of agroforestry systems, but the most widely accepted definition is of the World Agroforestry Center (ICRAF), which was cited by Nair (1990): 'Agroforestry is a collective name for land-use systems and technologies where woody perennials are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components'.

Foresta et al., 2000).In Indonesia the diverse agroforestry practices fit a range of models that integrate both biophysical and socio-economic benefits. Examples of these models include: the *repong* dammar resin producing system of Krui, Lampung; the jungle rubber systems of Jambi and South Sumatra; the *tembawang* (fruit and timber products) system of West Kalimantan; the *pelak* (complex) system of Kerinci, Jambi; the durian system of Gunung Palung, West Kalimantan; the *parak* system (tree gardens located on the slopes between the villages and the forest reserve) in Maninjau, West Sumatra; and the *talun* systems (intensified land use system for swidden agriculture) of West Java (Mizuno et al., 2013; de Foresta et al., 2000; Michon et al., 1986). Promotion of more widespread adoption of agroforestry as an alternative to current simpler agricultural systems may require development of national policies that provide incentives to farmers and other stakeholders, through the adoption of economic instruments, increase in fiscal support, and revision of land tenure and benefitsharing schemes (Roshetko et al., 2013), however it will important that these policies do not undermine the diversity of locally adapted systems.

This paper investigates the types of agroforestry system that exist in the Gunung Salak Valley, West Java, Indonesia, and the basic structural differences between them. This investigation is important because farmers in Indonesia have developed various practices for managing tree plantations that do not follow conventional models[2], but usually exhibit an interesting species diversity of cultivated trees crops, management intensities and harvested products (Michon, 2005). Understanding such locally-developed agroforestry practices can help inform improvements to policy, planning and institutional frameworks to make them more compatible with local land-use practices. In addition, the history of agroforestry and the complex relationships between agriculture and forestry explain some misunderstandings about the concepts and classification of agroforestry. Contrary to common perception, the development of agroforestry practices has often been more closely related to agriculture than to forestry (Torquebiau, 2000), although Michon (2005) found that in Sumatra agroforestry systems are closer to forestry. This paper will further inform this debate with evidence from West Java.

[2] The conventional models in Indonesia involve timber extraction through the concession system, and large-scale plantations of fast-growing tree species for the pulp and paper industry by large private or corporate firms, able to invest heavily and having close connections to policymakers and political institutions.

Materials and Methods

Study site

The Gunung Salak region 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, in Bogor District, west Java, Indonesia. The criteria for selecting this site are that the area is suffering from deforestation due to expansion of upland monoculture agriculture, which is the dominant economic land use, but various agroforestry systems are also practiced, so their basic structural differences can be investigated. This evidence can improve understanding of local modes of cultivation practice by government agencies that want to support agroforestry farmers whose livelihoods are threatened by the expansion of monoculture agriculture plantations.

The climate in this region is equatorial with two distinct seasons[3], dry (April-October) and rainy (November-March), which is more humid and rainy than in many other parts of west Java. The annual average relative humidity and precipitation are 70% and 1700 mm respectively. The soils are highly fertile and predominantly derived from volcanic sedimentary rocks. Given the proximity of large active volcanoes, the area is considered highly seismic (Badan Pusat Statistik, 2013; Wiharto et al., 2008).

Field data were collected from two purposively selected[4] sample villages, Sukaluyu and Tamansari, located in the northern valley of Gunung Salak, where the total population is approximately 8,200, living in 1200 households. The villages have poor infrastructure facilities, and household incomes are mainly based on agricultural and forest products, sold in local and district markets, in addition to wage labour and retailing (Badan Pusat Statistik, 2013). Agriculture is a major component of local livelihoods and carried out by small-scale farmers.

With the equatorial climate, many types of cultivated cereals, including hill rice, paddy rice and maize, and a diversity of vegetables and fruit are mainly harvested all year round from agricultural fields. Fruit, vegetables, bamboo, rattan and firewood are also collected from nearby forests.

[3] In the study site rainfall occurs throughout the year, but based on its intensity seasons are divided into two, where heavy rainfall occurs in the rainy season.
[4] Villages were selected based on their watershed location, i.e. middle (Sukaluyu) and upper (Tamansari); and having the largest sample size of farm households, i.e. agroforestry.

Land is managed in various ways, such as swidden cultivation (huma/ladang), rice fields (sawah), gardens (kebun), mixed gardens (kebun talun) and mixed forest (talun) (Kleden et al., 2009). Most of the land area is forest and owned by the state. Local people use this state land for traditional cultivation purposes (e.g. swidden) but they do not have permanent rights for this land. Private land is generally owned by smallholder famers and is mostly unregistered. This tenurial insecurity creates a feeling of insecurity among local people that discourages long-term investment in land, including fallow management (Rahman et al., 2012). Tenurial insecurity also limits access to the formal credit required for initial investments and for procuring the inputs needed to improve land use practices.

Data collection

Rapid rural appraisals (RRA) were used to collect basic socioeconomic and geographical information about the research site, including the types of local land use systems. Village mapping and key informant interview sessions were conducted in each village by involving the village head and three farmers, selected purposively based on their knowledge about the community and surrounding areas.

Two focus group discussion (FGD) sessions were conducted (one in each village[5]) to characterize the existing agroforestry systems and their products from farmers' perspectives. The village heads and local farmer representative groups (consisting of eight to twelve farmers[6]) were present in these sessions.

Field observation methods were used to identify the range of local agroforestry systems in the research site, and their structure, species, management and products. Observations were carried out in 25 locations which were decided based on the information gathered from the RRA and FGD. During the observation period, several pictures of local agroforestry systems were taken, and relevant information was noted with the help of an expert local informant[7].

A separate set of semi-structured questionnaires was used to carry out a survey with

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

[6] Farmers in each group were purposively selected based on their knowledge of local cultivation systems.

[7] One resident of the study site, who had considerable knowledge of local land use systems, products, markets and institutions, was employed as an expert local informant. This informant was present during the whole period of fieldwork, and helped check the validity of information obtained.

the farmers who are practicing agroforestry. Purposive sampling restricted to well-managed[8] agroforestry farms is used, which restricted the sample size to 20 farms. It was estimated that they represent about 30% of the total agroforestry farms in the study villages. The sample agroforestry farms are highly dispersed because monoculture agriculture is the most common practice dominating the landscape of the study area. A questionnaire targeting the socioeconomic and demographic characteristics of farm households including age, family size, education, land allocation, farm products and income, was developed for the semi-structured interviews, and pre-tested on two households. A number of questions were refined with the help of the expert local informant and during the FGD sessions to make sure that they elicited the information required. The product value of crops has been calculated based on the amount produced in one production year (the most recent year).

Data analysis

Descriptive statistics were used to analyze household and farming characteristics of the 20 sampled households who carry out agroforestry (i.e. age, education, family size, farm size, yearly income, and location of household in distance from village center and nearest forest). The total land area per household and the proportion of their land used for the two farming systems (i.e. agroforestry, non-agroforestry) were calculated, and the yearly income derived from each of these two systems of farming were compared. The narrative analysis technique was used to describe the basic structure of the existing agroforestry systems. Each agroforestry product was categorized based on its market value (high, medium, low) and types of use (i.e. domestic consumption, sold at the market).

Results

Socioeconomic characteristics of agroforestry farmers

The average total landholding per agroforestry farming family is 0.98 ha, with 0.85 ha allocated to agroforestry (Table 1). Besides agroforestry, some have land (average 0.11 ha) allocated permanently to cultivation of crops such as hill rice, cassava,

[8] Some farmers started agroforestry farming but after a few years gave up planting the understory, for various reasons (e.g. lack of management interest or capital). Thus many agroforestry farms were converted to simple tree orchards, and these are excluded from the sample.

maize, beans and a range of vegetables. The annual household income from all sources averaged IDR 20.15 million (US$ 2015). Products from farming accounted for an average 24% of household income. They comprised agroforestry products which contributed IDR 3.25 million/year per household and other agricultural products which contributed IDR 1.66 million/year. Therefore, the income per area of land is four times lower for the agroforestry land than the land used for cultivation of other agricultural crops. Off-farm sources (76% of total household income) include casual and skilled labour, shopkeeping, home industries and services. The expert local informant reported that engaging in off-farm income-generating activities limits the household labour available for agriculture, and this makes agroforestry appropriate for these households because it requires comparatively less labour input. However, the private and government banking sectors were both reluctant to provide loans for the establishment of new farming systems such as agroforestry by most of the surveyed smallholder farmers, being unwilling to take the risk of accepting the farmers' land or standing trees as collateral.

Table 1: Household and farming characteristics of agroforestry farmers in Gunung Salak Valley, West Java, Indonesia (n= 20).

Household and farming characteristics	Mean	Minimum	Maximum
Distance to the village center (minutes of walking)	23.45	10	30
Distance to the edge of nearest forest (minutes of walking)	10.60	2	30
Age of farmer	53.50	30	73
Education of farmer (year of schooling)	5	0	12
Members per household	6.7	2	10
Total land area (ha)	0.98	0.11	4.00
Total agroforestry area (ha)	0.85	0.05	4.00
Total cropland (other than agroforestry) (ha)	0.11	0.00	1.00
Total homestead area (ha)	0.02	0.00	0.08
Total annual income from all sources (million IDR)	20.15	10	76.80
Total annual income from agroforestry land (million IDR)	3.25	0.15	12.07
Total annual income from cropland (million IDR)	1.66	0.00	14.50

Types and characteristics of agroforestry in the study site

The informants from FGD sessions stated that homegardens are the traditional and most common land use system of smallholder farmers in the area. The other forms of agroforestry system are also used mainly to provide products to support the households livelihoods. These systems are based on traditional knowledge which has mainly developed from farmers' own trials. The two villages' farmed areas are bordered by forests. The agroforestry systems that have been found in the study area, can be classified into five types and all conform to the *hortus* model described above.

1) Homegardens

The growing of trees in or adjacent to the homestead or home compound is a long-standing traditional practice. It was observed that homegardens consisted of an assemblage of plants which includes trees, shrubs and herbaceous plants (Figure 1). Contrary to a superficial appearance of a random assemblage, the gardens were usually carefully structured and purposefully managed. The ground layer is usually partitioned into two, with the lower-most (less than 1 m height) dominated by a range of vegetable and medicinal plants, and the second layer (1-3 m height) composed of food plants such as banana, papaya and yam (Table 2). Various fruit trees, including water apples, rambutan and star gooseberry, some of which would continue to grow taller, dominate the intermediate layer of 3-10 m height. The upper tree layer consisted of timber and fruit trees, e.g. sengon, durian and coconut, with 35%-70% of tree cover being 10-20 m in height and the remainder being taller upper canopy and emergent tree crowns. Both men and women are involved in managing homegardens and harvesting crops.

Figure 1: Homegardens in the research site. Photo © Syed Rahman.

2) Fruit tree system

It was observed that the fruit-based agroforests developed by some farmers in the study site. These have been established on former swidden and other agriculture fields, through the planting of a diversity of fruit trees and understory crops such as cassava (Table 2). This is generally a permanent system, as the fruit trees, including durians and mangoes, are productive for a long period of time. Respondents stated that individual fruit trees are established and maintained as integrated components of the system continuously over time with over-mature trees being individually replaced whenever needed. It was observed that this maintains a high, closed canopy of domesticated trees with dense undergrowth and high levels of agro-biodiversity. In the FGD sessions, farmers reported that these systems have been established mainly for subsistence. While some of them have been converted into mixed tree gardens (producing fruit and timber), a focus on fruit production has resulted from the recent increase in demand from fruit markets in Bogor and Jakarta that has given new value to species such as durian and mango. It was observed that fruit trees represent the main permanent structure of the system, comprising 25%-60% of the canopy cover which is more than 15 m in height. Men are responsible for managing this system, but depending on the distance of the plot from the home, women are also responsible for harvesting fruit and understory crops.

3) Timber tree system

Timber production has high financial value for the farmers in the research site. It is a rotational system, based on planting of a selected timber species, e.g. teak, jabon or sengon, that makes up 30-70% of the canopy tree cover, above various types of understory crop, e.g. yams, maize, beans. Respondents stated that this system is also generally established on former swidden and other agriculture fields. In principle, stands of timber trees are harvested at a time when their diameter reaches a size to yield useful timber, after which they are either immediately replaced through natural regeneration or planting, or the land use is reverted to seasonal crops for a few years before being planted to trees again. Timber trees, together with perinnial planted crop species in agroforestry systems, are an important household asset (natural capital). In the FGDs, farmers reported that trees serve as a 'living savings account' as some trees are also harvested when significant cash needs arose, such as for weddings, school fees, large medical expenses, periodic social commitments, or emergencies. Normally men are responsible for managing this system, whereas women are also involved in harvesting understory crops depending on the distance of the plot from the home.

Figure 2: Timber trees of jabon (*Anthocephalus cadamba*) with understory crops in the research site. Photo © Syed Rahman.

4) Mixed fruit-timber system

In the mixed fruit-timber system the trees are interplanted with understory crops, e.g. cassava. Respondents stated that generally this system is practiced on land where the farmers previously planted seasonal cash crops, including swidden cultivation fields. It is observed that it is characterized by high species diversity and usually three to four vertical canopy strata of intimately mixed plant species leading to a total tree canopy cover of 35-70%. Respondents reported that the selection of crops for cultivation in the understory is based on their shade tolerance and these crops are established while tree species grow up over the years with gradual canopy coverage. After harvesting of the timber trees, they are usually not replaced by planting new timber trees. In contrast fruit trees are maintained to continue fruit production for a longer period of time. Men are responsible for managing this system, but depending on the distance of the plot from the home, women are responsible for harvesting fruit and understory crops.

5) Forest understory system

On a limited scale, primarily only for household consumption, farmers reported that they cultivate cassava, banana, yam, and pineapple in the forest area bordering their homesteads and farm land with only a small management input, little disturbance to the forest and no appreciable deforestation. After harvesting the crops are replanted. Men are responsible for managing this system. This is an example of forest farming.

Table 2: Harvested agroforestry products observed in the study site and reported by farmers during FGDs.

Local or English name	Scientific name	System in which cultivated [a]	Income category[b]	Uses [c]
Vegetables				
Bean	*Dolichos lablab*	H, F, T	B	1, 2
Cassava	*Manihot utilissima*	H, F, T,M, U	B	1, 2
Chilli	*Capsicum annuum*	H, F, T	B	1, 2
Cincau	*Cylea barbata*	H, F, T	A	1, 2
Cowpea	*Vigna sinensis*	F, T,	B	1, 2

Cucumber	*Cucumis sativus*	H, F, T,	B	1, 2
Eggplant	*Solanum melongena*	H, T	B	1, 2
Melinjo	*Gnetum gnemon*	H	C	1, 2
Okra	*Abelmoschus esculentus*	H	B	1, 2
Pumpkin	*Cucurbita pepo*	F, T	B	1, 2
Spinach	*Spinacia oleracea*	H	B	1, 2
Sweet potato	*Ipomoea batatas*	H, F,T	B	1, 2
Taro	*Colocasia esculenta*	H, F, T	C	1,2
Tomato	*Lycopersicon esculentum*	F, T	B	1, 2
Yam	*Dioscorea* spp.	H, F,T, M, U	B	1,2
Cereals/oil seed crops				
Maize	*Zea mays*	F, T	A	1, 2
Hill rice	*Oryza javanica*	F, T	A	1, 2
Sunflower	*Helianthus annuus*	F, T	A	2
Peanut	*Arachis hypogaea*	F,T	B	1,2
Spices				
Ginger	*Zingiber officinale*	H, F, M	A	1, 2
Lemongrass	*Cymbopogon citratus*	H, T	A	1,2
Glangal	*Alpinia galanga*	H	B	1,2
Nutmeg	*Myristica fragrans*	H, F	A	1, 2
Fruits and Nuts				
Avocado	*Persea americana*	H	A	1, 2
Banana	*Musa* spp.	H, T, U	A	1, 2
Betel nut	*Areca catechu*	H	A	1,2
Coconut	*Cocos nucifera*	H	A	1, 2
Durian	*Durio zibethinus*	H, F	A	1, 2

Guava	*Psidium guajava*	H	A	1, 2
Jackfruit	*Artocarpus heterophyllus*	H	A	1, 2
Lemon	*Citrus limonum*	H	A	1, 2
Mango	*Mangifera indica*	H, F	A	1, 2
Menteng	*Baccaurea racemosa*	H	A	1, 2
Papaya	*Carica papaya*	H	A	1, 2
Pineapple	*Ananas comosus*	H, U	A	1, 2
Rambutan	*Nephelium lappaceum*	H	A	1, 2
Star gooseberry	*Phyllanthus acidus*	H	A	1, 2
Water apples	*Eugenia* spp.	H	A	1, 2
Timber				
Teak	*Tectona grandis*	H, T, M	A	2
Jabon	*Anthocephalus cadamba*	H, T, M	A	2
Litsea	*Litsea* spp.	H, T, M	A	2
Sengon	*Albizia falcataria*	H, T, M	A	2

[a] The cultivation system: H = Homegardens, F = Fruit tree system, T = Timber tree system, M = Mixed fruit-timber system, U = Forest understory. [b]The income categories high (A), medium (B) and low (C) are based on the market value of the total amount harvested per hectare. [c] Uses: 1 = Domestic consumption, 2 = Sold at the market.

Discussion

In the research site in the Gunung Salak Valley, farmers have a range of agroforestry practices that can be classified into five systems, namely homegardens, fruit tree system, timber tree system, mixed fruit-timber system, and cropping in the forest understory. All of these systems are belong to the *hortus* model based on the diversity of plant species cultivated, and structural as well as functional diversity. Homegardens are the most traditional and common practice in the study site reflecting their recognition as the oldest land use activity next to shifting cultivation (Kumar, 2006; Kumar and Nair, 2004), with the earliest evidence of garden cultivation dating back to 7000-3000 BC (Soemarwoto, 1987) or even to 13,000-

9000 BC in the case of fishing communities in Southeast Asia (Wiersum, 2006). The fruit tree and mixed fruit-timber systems that observed are analogous to those observed in a Dudukuhan tree farming systems in the neighbouring area (Nanggung, West Java) by Manurung et al. (2008).

In the research site, there is a continuity of cropping in the forest understory system. In addition, farmers reported that the fruit tree system and mixed fruit-timber system are permanent and not transformed back to the annual cropping system. In contrast, the timber system tends to be rotational. Thus, the observed agroforestry systems in the research site can be categorized into two main types: i) integral, rotational timber system; ii) integral, permanent homegarden, fruit tree, mixed fruit-timber and forest understory systems. All of these systems are characterized by the establishment or maintenance of a high, closed tree canopy with dense undergrowth and high levels of agro-biodiversity. In all systems except the forest understory these are trees of species that can be considered domesticated. For all of these observed systems there is a close ‘integration’ of trees with local crops, and utilization of the principle of ‘multifunctionality’ in their management. Although these systems are designed for production, they are all characterized by high ecological diversity in terms of structural and species composition and economically in terms of their range of products and patterns of utilization.

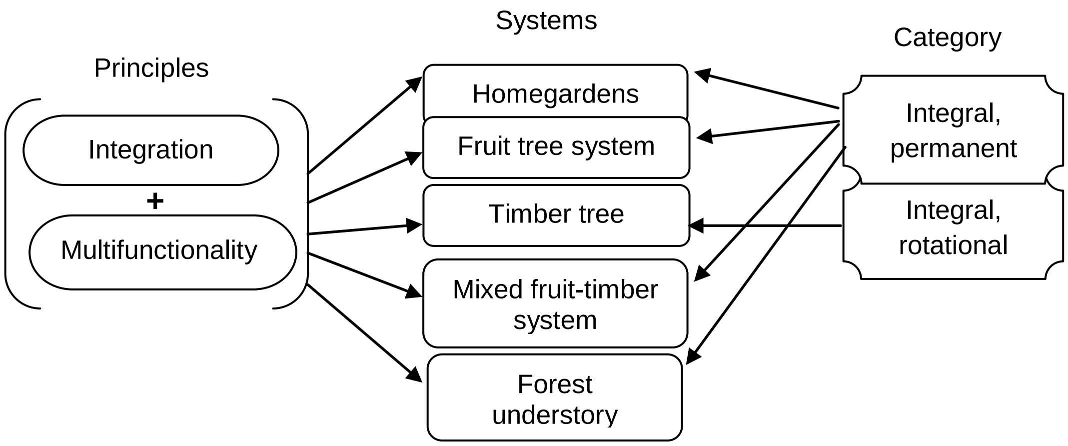

Figure 3: Types of agroforestry system at the study site.

In common with other countries in Southeast Asia, tree culture is widespread in Indonesia. Trees are managed by farmers in various patterns and models (Michon, 2005). The typology (homegardens, fruit tree system, timber tree system, mixed fruit-timber system, cropping in the forest understory) used in our research to classify agroforestry systems is site specific. However, our observation of the applicability of this typology in the two study villages corresponds sufficiently well to that observed in studies of systems practiced in other parts of West Java (Roshetko et al., 2013; Manurung et al., 2008; Snelder and Lasco, 2008) that we can be confident of its generality in this region. We do not recommended extrapolating this five-class topology more widely, however we believe that a two-class split between rotational and permanent systems can be applied to the multitude of systems that exist throughout Indonesia and more widely across tropical Asia. For example, the agroforestry systems based on teak in Central Java, and jabon in South Kalimantan are rotational (Roshetko et al., 2013; Krisnawati et al., 2011), and the jungle rubber and durian systems in Sumatra are permanent (Michon, 2005).

Agroforestry land with cultivated trees is usually established outside the boundaries of natural forests and should be treated as a distinct category from both primary and secondary forests because its primary economic land use is food production through agricultural and horticultural practices (Michon, 2005). In the research site, the canopy cover of integrated trees on agroforestry land ranged between 30% and 70%. However, this land still lies outside the FAO (2000) definition of forest. While it does have a tree canopy cover > 10% and often exists in patches > 0.5 ha, it does not meet the criterion of being “not primarily under agricultural or urban land use”. The FAO definition of forest specifically excludes stands of trees established primarily for agricultural production, for example fruit tree plantations (which is the dominant use of trees in the agroforests of the study area). However, the FAO definition of forest is not a matter of function as both forests and agroforestry systems provide tree products and services. Rather it is an arbitrary distinction of perception. Therefore, Roshetko et al. (2008) have argued for the recognition of agroforestry systems that surpass the minimum thresholds of tree canopy cover and area as “forests”.

From the point of view of farmers, defining agroforestry land as “forest” may give them more protection from commercial or local politically powerful actors who are seeking to displace them from their current land, e.g. for conversion to timber or oil palm plantations (Oxfam, 2011). If the agroforestry land is classified as forest, it may be harder for the powerful actors to obtain the legal right from government to manage the land for such conversion. Furthermore, where there are payment for ecosystem services (PES) schemes, either a privately managed or communal scheme, or some form of government subsidy, classification of land as forest may give farmers better access to payments from these schemes, e.g. they could be paid for maintaining tree cover on the land above the 10% minimum threshold and so avoiding "deforestation". Although good mechanisms for PES do not yet exist in Indonesia, if farmers are willing to maintain a much higher tree cover or biomass or biodiversity that will surpass this minimum 10% of tree cover on the land, they may get additional payments for avoided "forest degradation" (Fauzi and Anna, 2013; Lipper et al., 2009).

Defining agroforestry land as "forest", however, will include it in the national policies (and international agreements) linked to "forests". Even if farmers are still allowed to harvest timber and NTFPs from the system, their flexibility to convert the land back to (non-tree) crop production may be restricted if this would be classified as deforestation. Considering agroforestry as forest may also have a negative effect on farmers' control over the land[9], e.g. they may be required to get additional permits/pay additional taxes or bribes to be allowed to harvest the trees and sell them as timber (see also Laurance, 2004; Smith et al., 2003).

In reality such agroforestry systems share many properties with both 'agricultural' and 'forest' systems (Roshetko et al., 2008; Michon, 2005), and since both 'forest' and 'agroforestry' systems provide tree products and services, they have many dimensions that overlap with each other. Therefore, any binary classification will inevitably simplify this multivariate distribution of systems. Instead of a simple classification of the systems, a more quantitative and qualitative approach, such as one based on ordination, could be used depending on the purpose of the analysis. For example, if the classification is primarily for the purpose of analyzing the benefit to people's livelihoods, then all systems whose economic benefit remains dominated by crops might be placed in the same 'agriculture' class. In contrast, if the analysis is focused more on environmental characteristics (e.g. the regulating ecosystem

[9] For example, Indonesian Law No. 41/1999 on Forestry (paragraph 1) authorizes the government to arrange and manage everything related to forests, forest areas, and forest products (Presiden Republik Indonesia, 1999).

services provided by trees), then all systems that include more than a certain threshold cover of trees might be placed in the same 'forest' class. Therefore, it might be best to adopt a more complex classification approach incorporating different economic, social and environmental dimensions.

The agroforestry systems documented in this study are not only a form of forest like 'cultivated trees', but also of 'anthropogenic vegetation'. Growing trees is a traditional practice in the research site which has been derived from agricultural antecedents, e.g. swidden[10], through farmers' long experience of trials of new practices and has mainly been used to produce livelihood necessities.

Agroforestry farmers in the research site own small areas of land (on average 0.98 ha) but allocate a high proportion to agroforestry (0.85 ha), similar to those in communities in other parts of West Java (Wijaya et al., 2012). It was therefore surprising that the farmers reported annual income from their agroforestry to be much lower per land area (IDR 3.25 million/0.85 ha) than their income from cropping of their remaining agricultural land (IDR 1.66 million/0.11 ha). Two possible explanations for this mismatch between farmers' reporting of incomes and their decisions over land use are the time scale of income and the importance of other benefits and costs of each system. The level of annual income from products harvested from both systems was based on farmers' reports of their income during the one most recent production year. However, for most of the farmers the timber trees in their agroforests had yet to reach harvestable maturity and in some cases fruit trees had yet to grow to maturity and achieve maximum fruit yield[11]. Since tree species have a longer juvenile (non-productive) period compared with agricultural crops such as rice or maize that mature within a few months, income from agroforestry systems will be much lower during the years of their establishment phase, but farmers expect their income from later harvests from trees to more than compensate for the opportunity costs of not using the land intensively for agricultural crops in the meantime (Rahman et al., 2008; Elevitch and Wilkinson, 2000).

[10] By planting damar trees in the swidden areas at Jambi, Indonesia, farmers have managed to re-create a new forest landscape (Michon, 2005).

[11] Moreover, it is also important to consider that farmers' ability to recall the income received from sale of multiple agroforestry products spread over the 12 month period may be less accurate than their ability to recall the one-off income from the sale of their main agricultural crop.

While the landholdings per farming family in the research site were small (ca. 1 ha), in this productive environment with equatorial climate and fertile volcanic-derived soils, high yields of agricultural crops can be obtained per area of land provided that there is sufficient input of labour. Given the importance of off-farm income in the livelihoods of the studied households (equating to 76% of their total income) available labour, rather than available area of farmland, is the most economically limiting resource for most of the households. Most do not have the available labour to intensively cultivate agricultural crops in all arable lands that they occupy. Therefore, practicing more permanent sustainable agroforestry systems is appropriate for them. These systems require less labour input, while still increasing (or maintaining) their natural capital value. They yield a diversity of products, which meet a wider range of household nutritional and health needs, while giving access to a wider range of market opportunities. These factors are all likely to contribute to the spontaneous tree product diversification through agroforestry by smallholders that has been observed elsewhere in Indonesia and tropical Asia (CGIAR, 2011; Snelder and Lasco, 2008; Mercer, 2004; Penot, 2004; Steppler and Nair, 1987; Arnold, 1983) and the recognition of smallholder tree cultivation as a viable livelihood strategy in various agroforestry and community forestry programs (FAO, 2006a; Sales et al., 2005; ICRAF, 2003).

Research on smallholder tree cultivation systems is neglected compared with the much larger research programmes into large-scale forestry and agricultural (tree) crop plantations in tropical Asia. Although research on smallholder systems has recently increased (Leakey et al., 2012), not enough is known about the dynamics of trees on farmland and their corresponding contribution to the production of wood and other products and services (FAO, 2006a). Similarly there is a lack of information on the actual amount of land occupied by smallholder tree growing systems partly because of the multitude of systems that do exist (Snelder and Lasco, 2008) and their lack of fit to the land cover/land use classifications used by FAO and other institutions. In order to understand current and potential contributions of farmer's tree cultivation to rural development and ecosystem services more usually associated with forests, extensive research and good statistical data are required, which is absent from most official statistics (FAO, 2006b). Furthermore, there are a wide range of factors that can influence farmers' choice of farming practices (Meijer et al., 2015; Cecilia et al., 2009; Snelder and Lasco, 2008). There is therefore a need for new research to assess which individual factors motivate[12] farmers to adopt agroforestry practices specifically. Building on the approach of the present paper, the most appropriate research method will be a systematic comparison between farmers who have and have not adopted agroforestry practices within the same case study communities and landscapes.

Conclusions

The agroforestry systems in Gunung Salak Valley share the properties of forests in that they have a high tree canopy cover, yet economically and culturally they are an important component of people's farming systems. They fulfill a wide range of roles as reflected in the diversity of agroforestry systems adopted, which range from homegardens to different combinations of fruit and timber tree systems, to crop production in the understory of existing forests. The systems are based on a culturally important mixture of maintained traditional practices and new innovations introduced through trials by current farmers. This combination is maintaining a notable diversity in terms of both species composition and utilization. Most agroforestry products are for domestic consumtion, but they also provide important opportunities to sell in the market. Some products have high market value, e.g. cincau, nutmeg, durian, mango, pineapple, rambutan, teak, and may represent a valuable opportunity for future increases in income.

In areas where the tradition of agroforestry is less well established the introduction of tree culture into subsistence monocropping cycles can represent a viable strategy for agricultural diversification, which can serve both farmers' interest in terms of increasing product diversity and economic sustainability. At the same time agroforestry can limiting the labour inputs required for intensive agricultural cropping and help to meet the environmental concerns of external, and in some cases local, stakeholders. Such a strategy needs to be informed by the local context of productive activities, especially existing farming systems and household livelihood strategies. Of particular importance for government agencies is to remove policy disincentives that inhibit such innovations such as farmers' lack of land tenure, and to improve the dissemination of information about successful management practices

[12] Motivational factors are discussed in the later chapters of this thesis (i.e. chapter 3, 4 and 5).

and the availability of any necessary materials not currently available to farmers, such as loans. Given the properties that such agroforestry systems share with both agricultural and forest systems, their classification will always be problematic if a binary system is applied. Therefore a more sophisticated approach should be adopted that incorporates the economic, social and environmental characteristics of a wider range of systems.

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Chapter Three

Finding Alternatives to Swidden Agriculture: Does Agroforestry Improve Livelihood Options and Reduce Pressure on Existing Forest?

This chapter is based on: **Rahman S.A.**, Jacobsen J. B., Healey J. R., Roshetko J. M., Sunderland T., (2017). 'Finding Alternatives to Swidden Agriculture: Does Agroforestry Improve Livelihood Options and Reduce Pressure on Existing Forest?' *Agroforestry Systems*, 91: 185-199. DOI 10.1007/s10457-016-9912-4.

Abstract

Swidden cultivation often causes deforestation and land degradation, which can result in a number of serious environmental problems. This paper examines the economic and social potential of agroforestry systems and the barriers to their widespread adoption, as a land use alternative to swidden cultivation, which may potentially help protect local forest. The Gunung Salak valley in West Java, Indonesia is presented as a case study. Based on farmers' and experts' assessment, costs and benefits have been estimated, which show that the two investigated agroforestry systems have higher net present value (NPV) and benefit-cost ratio (B/C) than the two swidden cultivation systems. Tree ownership also creates more permanent rights to farmland and is prestigious in the community. Agroforestry products (fruit, vegetables etc.) have high monetary value and help strengthen social cohesion when shared with neighbors. However, farmers are reluctant to implement agroforestry. Stated reasons are related to both culture and capacity. Farmers practicing agroforestry are less involved in forest clearing and forest products collection than swidden farmers indicating that it may contribute positively to conservation of local forests. Increasing the adoption of agroforestry farming in the study area will require support to overcome capacity constraints.

Keywords: agroforestry adoption, income, social potential, forest protection, policy support

Introduction

Swidden agriculture, also known as slash-and-burn farming is a widespread subsistence practice in the tropics (Peng et al., 2014; Schuck et al., 2002). Swidden is mainly practiced in the mountainous and hilly parts of Latin America, Central Africa and Southeast Asia by smallholder farmers (Munthali, 2013; Van et al., 2012), and often drives deforestation as well as forest degradation (Rahman et al., 2012; Styger et al., 2006).

Multiple terms are used to refer to swidden cultivation and related systems in the scientific literature: swidden agriculture, shifting cultivation, slash-and-burn farming, as well as regional terms *jhum* in South Asia or *ladang* in Indonesia (Van et al., 2012; Mertz et al., 2009; Imang et al., 2008). 'Swidden' was first proposed as a term by the Swedish anthropologist K.G. Izikovitz in 1951 in the sense of burning woody vegetation to clear land for agriculture (Peng, et al., 2014; Russell, 1988). 'Shifting cultivation' is often used more broadly to refer to agricultural activities where fields are cultivated for crop production for a number of years and then left fallow for a number of years (Vongvisouk, 2014; Therik, 1999). However, others define it more narrowly to refer to systems in which the whole livelihoods of farmers are shifted with the cultivation within the forest landscape (Aweto, 2013; Inoue, 2000; Adimihardja, 1992). Our focus is on swidden which does not necessarily refer to shifting fields but only to land cleared by burning (Peng, et al., 2014; Marten, 1986), as is the case in our research site in Gunung Salak.

In Gunung Salak valley, West Java, Indonesia swidden cultivation practices are deeply rooted in communities' culture and provide various subsistence products mostly to local poor farmers (Galudra et al., 2008). However, this system can have serious negative environmental consequences by contributing to deforestation and land degradation (Li et al., 2014; Rahman et al., 2012; Barraclough and Ghimire, 1995; Gupta, 1993). The most severe environmental impacts occur in two ways, firstly, when the swidden cultivators clear forests to prepare land for cultivation and, secondly, from the forest clearing process fire can escape and burn uncontrolled in adjacent forest areas (Rahman et al., 2012; Mai, 1999). Loss of forest cover and degradation of remaining forest can greatly increase the incidence of soil erosion in areas on steep slopes (Shoaib et al., 1998; Sfeir-Younis and Dragun, 1993). Soil erosion and landslides have negative effects on a range of ecosystem services including food provisioning from agriculture in both uplands and lowlands, and can negatively affect farm families' standards of living (Rahman et al., 2012).

In order to overcome the negative consequences of swidden, farmers would need to adopt new practices that serve multiple purposes including conserving forest resources as well as producing food and supporting sustainable development (Leakey, 2010; Roshetko et al., 2008; Sunderland et al., 1999). Agroforestry, and specifically the practice of growing trees on farmland alongside crops, has well-established research evidence of its potential to reduce deforestation and forest degradation at a landscape scale (Rahman et al., 2014; Idol et al., 2011; Garrity, 2004). One definition of agroforestry is 'a dynamic, ecologically-based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels' (Mead, 2004). In response to both environmental concerns and the need to ensure the sustenance of livelihoods, there are many examples where agroforestry is advocated as a potential solution to the need to develop a more sustainable form of land use that improves farm productivity while, at same time, improving the welfare of the community (Roshetko et al., 2013; Leakey et al., 2012; Ahmed and Rahman, 2000). Agroforestry can be more financially profitable to local farmers than traditional monoculture systems, and support the transition to permanent cultivation (Rahman et al., 2014; Franzel and Scherr, 2002; Predo, 2002; Mai, 1999). Agroforestry is not only financially, but also environmentally, promising compared with simpler systems, by ameliorating the agroclimate and increasing biodiversity (Jessica et al., 2014; Swallow et al., 2006; Huxley, 1993), protecting soil organic matter and increasing nutrient cycling (Elevitch and Wilkinson, 1998; Wu, 1996; Sae-Lee et al., 1992).

If agroforestry is really as beneficial as scientific studies suggest, the logical prediction would then be that this system would be adopted by a high proportion of farmers. However, this is not the case in large areas of the tropics (Meijer et al., 2015; Jepma, 2013; Dahlquist et al., 2007; Kiptot et al., 2007; Craswell et al., 1998). The research reported in this paper addresses this issue by analyzing the value of existing agroforestry systems, investigating their economic and social potential relative to swidden farming. We also seek to identify what factors are barriers to widespread agroforestry adoption. This information would be valuable for the development of appropriate strategies to encourage more farmers to adopt agroforestry and to improve management of existing agroforestry systems (Fisher and Bunch, 1996; Saxena and Ballabh, 1995; Nair and Dagar, 1991). We also assess the evidence that agroforestry may better conserve forest, by comparing forest products' extraction and land clearing between agroforestry and swidden farmers.

Materials and methods

Study site

The study area 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, and is located in the Gunung Salak valley, Bogor District, west Java, Indonesia. The reason for selecting this site is that both agroforestry and swidden cultivation are practiced by farmers in the same communities and environments, thus their economic and social potential can be compared and the barriers to agroforestry adoption can be investigated with precision. The sustainability of livelihoods in the study area, like much of Indonesia, is threatened by overall poverty with low income and poor infrastructure development (Badan Pusat Statistik, 2013), and the expansion of subsistence agriculture (especially swidden) due to rapid population growth is a major contributing factor to forest loss and environmental degradation (EST, 2015; Galudra et al., 2008). Moreover, restrictions on the harvest of some products (e.g. timber) from natural forest provide an economic incentive for smallholders to integrate trees into their farming systems. All of these characteristics of the study area are representative of a large proportion of Indonesian and tropical Asian agricultural landscapes.

The climate in this region is equatorial with two distinct seasons[1], i.e. dry (April-October) and rainy (November-March). The region is more humid and rainy than most parts of west Java, the average relative humidity and annual precipitation are 70% and 1700 mm respectively. The average temperature is 25.9 °C, and the diurnal range is 9-10 °C, rather high for Indonesia (Badan Pusat Statistik, 2013; Wiharto et al., 2008). The soils are highly fertile and dominated by volcanic sedimentary rocks. Given the proximity of large active volcanoes, the area is considered highly seismic.

[1] In the study site rainfall occurs throughout the year, but based on its intensity, two seasons are recognised, where heavy rainfall occurs in the "rainy" season.

Field data were collected during January-August, 2013 from two purposively selected[2] sample villages, i.e. Sukaluyu and Tamansari located in the northern valley of Gunung Salak, where the total population is approximately 8,200, living in 1200 households. The study site has poor infrastructural facilities, and the local economy is mainly based on agricultural and forest products (Badan Pusat Statistik, 2013). Our survey showed that in the two villages most community members have small land holdings (<1 ha) and carry out subsistence agriculture. Upland rice, irrigated rice, maize, and varieties of vegetables and fruits are the main agricultural crops. Land is used in various ways, such as rice fields (sawah), gardens (kebun), mixed gardens (kebun talun), mixed forests (talun) and swidden cultivation fields (huma/ladang) (Kleden et al., 2009). Private land use rights are granted by the government but farmers have no formal rights to state forest land. In the agroforestry farms, people cultivate various fruits, e.g. durian (*Durio zibethinus*), mango (*Mangifera indica*), rambutan (*Nephelium lappaceum*) and menteng (*Baccaurea racemosa*), and timber trees, e.g. teak (*Tectona grandis*), sengon (*Albizia falcataria*) and Jabon (*Anthocephalus chinensis*), with various understory crops, e.g. cassava (*Manihot esculenta*), maize (*Zea mays*), pineapple (*Ananas comosus*) and cincau (*Cylea barbata*). In the swidden fields, people commonly cultivate upland rice (*Oryza javanica)*, maize (*Zea mays*), yam (*Dioscorea* spp.), beans (*Dolichos lablab*) and cassava (*Manihot utilissima*). Fruits, vegetables, bamboo, rattan and firewood are also collected from nearby forests. Agricultural and forest products are sold in the local and district markets, and are an important source of household income, besides wage labor, and retailing.

Data collection

Primary data were collected by rapid rural appraisal (RRA) for the basic socio-economic and geographical information of the research site using village mapping and key informant interviews (FAO, 2015; Angelsen et al., 2011). These sessions were conducted by involving village heads in the purposive selection of farmers based on their knowledge about the village and surrounding areas.

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[2] Villages were selected to represent two contrasting watershed locations, i.e. mid-stream (Sukaluyu) and up-stream (Tamansari); and having the largest sample size of farm households, i.e. agroforestry and swidden.

Two focus group discussion (FGD) sessions (one in each village[3]) and field observation methods were used to identify the types of local cultivation systems and their contribution to local livelihoods. The village heads and local farmer representative groups (consisting of eight to twelve farmers[4]) were present in the FGD sessions. Field observations were carried out in 25 locations which were decided based on the information gathered from RRA and FGD. During the observation period, several pictures of local cultivation systems were taken, and relevant information was noted with the help of an expert local informant[5].

In-depth interviews of farmers were conducted to obtain the data needed for cost-benefit analysis of agroforestry and swidden. Two agroforestry farms of contrasting types, (i) durian and cassava (agroforestry 1) and (ii) teak, yam and maize (agroforestry 2); and two swidden farms of contrasting types, (i) upland rice (swidden 1) and (ii) maize (swidden 2), were selected. Based on the output of FGDs and field observations, these four farm types were purposefully selected by the first author as being popular (commonly adopted at a wider range) and providing the highest incomes among the farm populations in the agroforestry and swidden farming categories. During the interviews, the farmers were asked several questions about the actual and envisaged costs and benefits of each cultivation system, i.e. establishment cost, total yields, total labor requirement, cost of irrigation, pesticides, and fertilizer. The data collected from the four cultivation systems were checked with a local government agriculture officer to verify that the absolute values were in the expected range based on his experience of farming systems in the study area.

Twenty agroforestry and 20 swidden farmers were selected for semi-structured questionnaire interviews to collect information about their land holding area, income, farming benefits to their livelihood, forest products (FPs) collection, the area of forest that they cleared[6], and the barriers to agroforestry adoption that they faced. Due to

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

[4] Farmers in each group were purposively selected based on their knowledge of local cultivation systems.

[5] One resident of the study site, who had considerable knowledge of local land use systems, products, markets and institutions, was employed as an expert local informant. This informant was present during the whole period of fieldwork, and helped check the validity of information obtained.

[6] Households were asked whether or not in the last five years they had cleared any forest, and if yes, we also asked how much, and for what purpose it was cleared. We have used FAO's forest definition

the range of land use practices and the unequal distribution of farms in the study area, purposive sampling was used to select farms that adequately represented the full development of the system type into which they were classified within the range of local land use practices[7]. We estimate that they represent about 30% and 40% of the farmer populations who are practicing agroforestry and swidden respectively. A number of questions were refined with the help of the expert local informant and during FGD sessions to make sure that they elicited the information required. The product value of crops was calculated with the key informant farmers during the interview based on the amount harvested in one production year (the most recent year).

Other data were gathered from the local government forestry office, the Southeast Asian regional office of ICRAF and CIFOR headquarters located in Bogor, west Java, to corroborate the primary data that were collected from the research site, and for background information and qualitative inputs for the study.

Data analysis

Qualitative analysis was carried out using the narrative analysis technique, particularly to investigate the social potential of existing agroforestry systems. For cost benefit analysis, the *net present value (*NPV), *benefit-cost ratio* (B/C) and *payback period* were calculated and compared following Stocking et al. (1990). The NPV determines the present value of net benefits by discounting the streams of benefits and costs back to the beginning of the base year (Disney et al., 2013; Stocking et al., 1990). The NPV is calculated by the following formula:

(FAO, 2000), which defined forest as lands of more than 0.5 hectares, with a tree canopy cover of more than 10%, where the trees should be able to reach a minimum height of 5 meters *in situ*, and which are not primarily under agricultural land use.

[7] For example, some farmers started agroforestry farming but after a few years gave up planting the understory, for various reasons (e.g. lack of management interest or capital). Thus many agroforestry farms were converted to simple tree orchards, and we have excluded them from our sample. In fact very few farmers had developed the system type in full, and this was the only basis for the selection of farms who met that criterion.

$$NPV = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t} \qquad (1.1)$$

where

B_t - the benefits of production by a cultivation practice

C_t - the costs of production by a cultivation practice

t - time, running until the end of the investment at T.

r - the discount rate.

The B/C compares the discounted benefits with discounted costs. A B/C of greater than 1 means the cultivation is profitable, whilst a B/C of less than 1 means that it generates losses. The B/C is calculated as follows:

$$\frac{B}{C} = \frac{\sum_{t=0}^{n} \frac{B}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} \qquad (1.2)$$

The *payback period* measures the number of years it will take for the undiscounted net benefits to repay the investment (Stocking et al., 1990).

Assumptions

Land and establishment cost:

The market for agricultural land is underdeveloped in the study area, therefore the price of land is difficult to identify. However, as mentioned by MacDicken (1990), there is no need to value the land separately if farmers want to change the use of their existing land to agroforestry. Thus, in our analysis the land value is omitted from the calculation. Establishment costs include: i) labor cost for land preparation, and ii) the price of seeds, seedlings and fertilizer which are required to start a project.

Yields:

Crop components included in calculations for the selected cultivation systems are summarized in Table 1. The values of yields were calculated on an annual basis. Yields of durian (from grafted seedlings) are calculated under three categories, i) low yields during the fourth to sixth year, ii) medium yields during the seventh to eighth year, iii) high yields from the ninth year onwards. The market value of timber for the teak, yam and maize agroforestry system is calculated in ten-year rotation periods, after which it is assumed that teak is replanted.

Table 1: Brief description of selected cultivation systems for analysis.

Cultivation system	Component	Cultivation type
Agroforestry 1	Durian, cassava	Permanent
Agroforestry 2	Teak, yam, maize	Rotational @ 10 year
Swidden 1	Upland rice	Semi-permanent
Swidden 2	Maize	Semi-permanent

Labor:

Farmers often use family labor for farm work, but hired labor is also important in the study area. Family labor is not a cash expenditure from the farmer's perspective, and it is complicated to identify the amount of family labor contributed to each cultivation system, as farmers have different household size and labor availability. Therefore, all calculations were conducted based on the total amount of labor $^{-day}$ required for each cultivation system.

Pesticides, fertilizer, irrigation:

Even though pesticides and fertilizers are minimally used in swidden and for understory crops in agroforestry, the costs are calculated based on the amount used in one production year as reported during the interviews. The cost of irrigation is ignored as high intensity rainfall occurs throughout the year, thus irrigation is not a cash expenditure for farmers.

Time horizon for analysis:

Once forest trees are included in the agroforestry system the lifespan of this project can be considered indefinite. However, for simplicity, in our analysis the project life is considered to be 30 years as this may be a realistic lifetime for one rotation of durian trees in agroforestry system 1, which has the longest cycle. The consequence is that trees planted for timber in agroforestry system 2 can have three rotations (harvest cycles) and other crops have 30 annual cultivation cycles during the project lifespan.

A similar time horizon is used in other comparable studies (e.g. Rahman et al., 2014; Rahman et al., 2008).

Results

The cash flow of the four different cultivation systems, and the calculations of NPV and especially B/C, show that both agroforestry systems are more profitable than the two swidden systems (Table 2). Whereas profitability measured by NPV is similar in three of the systems, for agroforestry system 2 (with teak) it is almost three times higher. This is driven by the high output prices of the teak timber production from this system. Even though teak-based agroforestry requires some additional costs during rotations, these are offset by the return from selling timber. Furthermore, the value of intensively managed diversified understory crop yields in the teak-based system is higher than for both swidden systems, thus agroforestry system 2 is the superior land use option in the study site.

Risk factors should be accounted for in the financial analysis, as agricultural projects may face a wide variety of risks[8]. Furthermore, it is important to consider the assumptions in the calculations. Therefore, sensitivity analysis was conducted on changes in discount rate[9] (Table 3), and variation in yields (Table 4). Regardless of the discount rate used, agroforestry 2 remains the most profitable system, whereas agroforestry 1 provides a lower NPV than the two swidden systems for discount rates of 20% and above. In the case of decrease in yields, the NPV of both agroforestry systems are always positive and higher than swidden cultivation (Table 4).

No difference in payback period was found between the four systems (Table 2). A one year payback period for the agroforestry systems indicates that within a year the undiscounted net benefit is high enough to repay the comparatively higher investment in establishing this system.

[8] Many natural risk factors are site specific (e.g. landslides, lava flows) whereas others are more widespread (e.g. storms). Some threats are induced by humans, such as fire, pest introductions and price fluctuation (e.g. if supply is increased due to increases in output due to expansion of farm production).

[9] One method to include risk into analysis is to use an increased discount rate, which reflects the added yearly risk of a project (see Elevitch and Wilkinson, 2000).

Table 2: Annual cost and revenue of selected cultivation systems in Indonesian Rupiah (IDR) per hectare.

Type of operation	Year	Agroforestry 1	Agroforestry 2	Swidden 1	Swidden 2
Site preparation	0	375,000	500,000	180,000	180,000
Operational cost, i.e. labor, seeds, seedlings, fertilizer, pesticide	1	2,161,667	5,130,150		
	2-3	1,461,667			
	4-6	1,581,667*			
	7-8	1,641,667*			
	9-30	1,701,667*			
	2-9, 12-19, 22-29		2,630,150		
	10, 20, 30		3,750,000*		
	11, 21		5,730,150*©		
	1-30			2,171,000	2,861,000
Annual crop yields	1-3	9,025,000			
	4-6	11,225,000**			
	7,8	13,125,000**			
	9-30	20,025,000**			
	1-30		19,348,333	15,000,000	15,000,000
Revenue from selling timber	10,20,30	n/a	300,000,000***		
NPV (r=10%)		122,077,993	330,154,427	120,937,885	114,433,314
B/C		10.36	16.19	6.91	5.24
Payback period		1 year	1 year	1 year	1 year

Note: Agroforestry 1 (durian and cassava) = no cost for cassava seeds/seedlings from years 2-30 as farmers produce it from the previous year; additional labor cost* for the durian harvesting** in the years 4-6 (trees first bearing fruit/low production), 7-8 (medium production) and 9-30 (full production).
Agroforestry 2 (teak, yam, maize) = additional labor cost* for timber harvesting*** in years 10, 20, 30, and land preparation (e.g. stump clearing) in years 11, 21; extra cost for seedlings© in years 11, 21.
Cost and revenue are estimated to be the same for years 1-30 for swidden 1 (upland rice) and swidden 2 (maize).

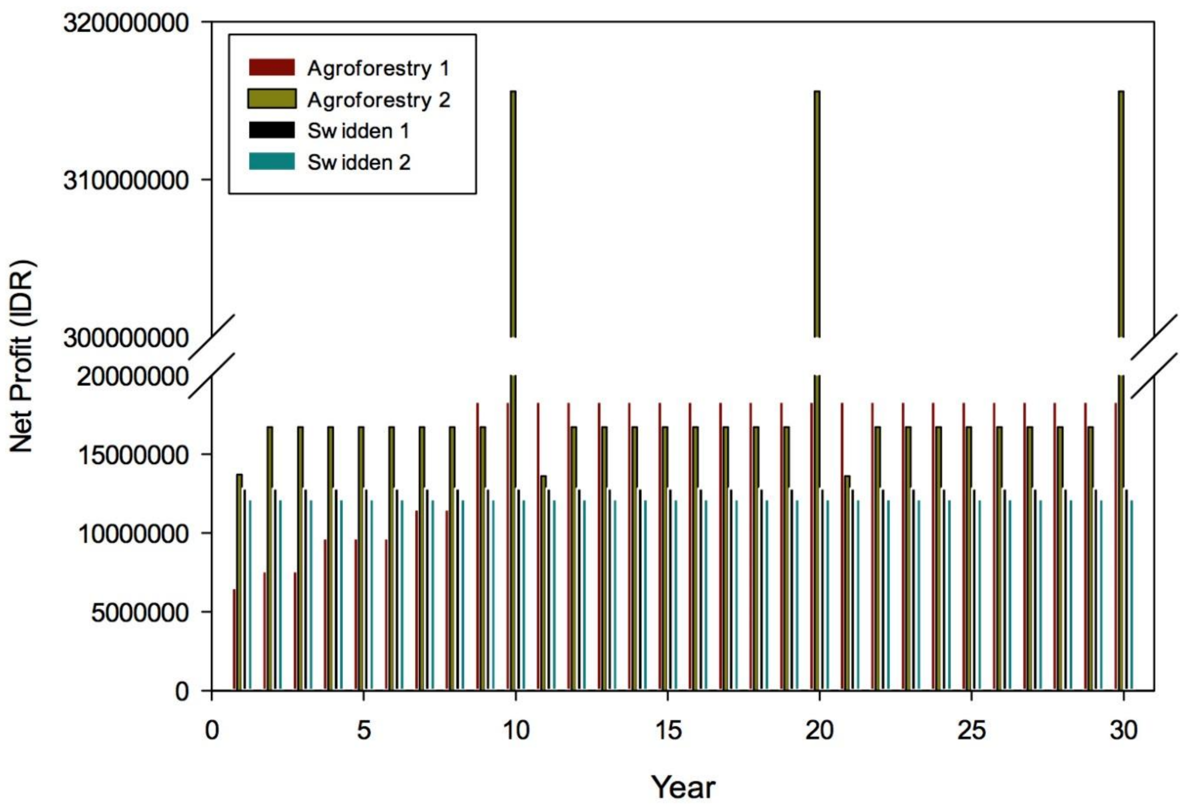

Figure 1: Annual cash flow (net profit) of different cultivation systems (IDR/ha).

Through the semi-structured questionnaire interviews and FGDs, it was identified that agroforestry not only creates production capacity, but also tree planting establishes more permanent land rights for farmers, with those rights transferring to future generations. In contrast, fallow or swidden systems may weaken tenure security. One of the respondents established his durian-based agroforestry farm in 2001, and he remembered that before practicing agroforestry 'I left my land abandoned and one of my neighbors used it to stack his logs to sell that he had harvested'. During FGDs, it was reported that cultivation categories defined as 'agroforestry' are prestigious in the community, owing to the high value of tree products (e.g. teak, durian) which have higher monetary value than do products from swidden agriculture. Additionally, agroforestry farmers share their fruit and vegetable products with neighbors, providing direct benefits to others and strengthening social cohesion. Agroforestry also creates various jobs, such as traders and regular or seasonal wage-laborers for harvesting, transporting, sorting etc. of fruit and timber, thus supporting the emergence of farm-related rural employment and specialization.

Table 3: Sensitivity of profitability (NPV) to change in discount rate of agroforestry and swidden cultivation systems.

Discount rate (r)	NPV			
	Agroforestry 1	Agroforestry 2	Swidden 1	Swidden 2
5%	221,438,725	616,502,476	197,213,174	186,606,183
10%	122,077,993	330,154,427	120,937,885	114,433,314
20%	53,588,283	137,580,080	63,874,775	60,439,308
30%	31,582,414	76,579,723	42,747,011	40,447,889
40%	21,803,255	50,274,014	32,071,174	30,346,246
50%	16,499,245	36,674,210	25,657,866	24,277,873
60%	13,228,225	28,714,082	21,381,650	20,231,651
70%	11,026,191	23,599,254	18,327,140	17,341,426
80%	9,447,968	20,065,665	16,036,249	15,173,749
90%	8,263,065	17,482,427	14,254,444	13,487,777

Table 4: Sensitivity of profitability (NPV) to varying the yields of agroforestry and swidden cultivation systems.

Decrease of production	NPV (r = 10%)			
	Agroforestry 1	Agroforestry 2	Swidden 1	Swidden 2
0%	122,077,993	330,154,427	120,937,885	114,433,314
5%	115,974,093	313,646,706	114,890,991	108,711,648
10%	109,870,193	297,138,984	108,844,097	102,989,983
20%	97,662,394	264,123,542	96,750,308	91,546,651
30%	85,454,595	231,108,099	84,656,519	80,103,320
40%	73,246,795	198,092,656	72,562,731	68,659,988
50%	61,038,996	165,077,213	60,468,942	57,216,657
60%	48,831,197	132,061,771	48,375,154	45,773,325
70%	36,623,397	99,046,328	36,281,365	34,329,994
80%	24,415,598	66,030,885	24,187,577	22,886,662
90%	12,207,799	33,015,442	12,093,788	11,443,331

Despite agroforestry systems being more profitable, more prestigious and better for securing land use rights, some farmers in the study area still persist with the less profitable swidden cultivation. The semi-structured questionnaire interviews with 20 key informant swidden farmers revealed some of the factors underlying non-adoption of agroforestry (Table 5). Adoption is hampered by capacity (2, 3, 4) and motivational (1) factors. Capacity constraints were mentioned 27 times by the farmers, while motivational factors were mentioned 18 times. ‘No interest’ in agroforestry practice is deeply rooted in their tradition, whereas swidden practice has been practiced by generations. ‘Lack of capital’ is also a serious constraint on initial investment in agroforestry. This is particularly true for swidden farmers as their cultivation practices are largely subsistence-oriented and yield insufficient capital to invest in agroforestry, i.e. it requires about half of their annual household income to invest in agroforestry (Tables 2 and 6). Lack of technical assistance is another major constraint as government programs to promote agroforestry do not exist in the study site. There is no agroforestry extension, no technical or market information, no price guarantees and no supply of high quality seedlings.

Table 5: Constraints on the adoption of agroforestry, as mentioned by 20 swidden farmers. The motivational factor is marked with M and factors related to capacity are marked with C.

Reasons	Number of farmers	Per cent
(1) No interest (M)	18	90
(2) Lack of sufficient knowledge (C)	7	35
(3) Lack of capital (C)	16	80
(4) Lack of technical assistance (C)	4	20

The interviews with the 40 key informant farmers revealed that most of the swidden lands in the study site are semi-permanent with cultivation interspersed with either short or long fallow periods, whereas other agricultural land is cultivated continuously without fallow periods. Swidden farmers occupy less land than agroforestry farmers because (i) low household income restricts them from investing in new land and (ii) limited labor is available for agriculture as a high proportion of household labor is required for off-farm work which accounts for a high proportion of their income[10] (Table 6). Eight-five per cent of swidden farmers were involved in forest clearing whereas only 30% of agroforestry farmers were involved in this activity. As a result, on average a swidden farming household cleared a larger area (0.29 ha) of forest than an agroforestry farming household (0.09 ha). Among swidden farmers, 45% of them cleared forest for the establishment (by slash-and-burn) of swidden farming, whereas a relatively low number of agroforestry farmers (15%) cleared forest for agroforestry purposes.

Table 6: Farm size, income, forest clearing activity and collecting of forest products by swidden farmers and agroforestry farmers.

Description	Swidden farmers (n=20)	Agroforestry farmers (n=20)
Total swidden land (ha)	0.46	-
Total agroforestry land (ha)	-	0.85
Total other cropland (ha)	0.29	0.11
Total homestead land (ha)	0.02	0.02
Total land area (ha)	0.77	0.98
Total annual income from all sources (million IDR)	12.07	20.15
Total annual income from swidden/agroforestry (million IDR)	1.04	3.25
Total annual income from other cropland (million IDR)	2.52	1.66
Forest area cleared per household (last 5 years) (ha)	0.29	0.09
Reason for clearing	Swidden: 45% Permanent monoculture: 35% Plantation: 0.5% Not cleared: 15%	Agroforestry: 15% Permanent monoculture: 15% Not cleared: 70%
Distance to the edge of nearest forest (minutes of	24.0	10.6

[10] Annual household off-farm income is calculated to be 8.5 and 15.2 million IDR, i.e. 70% and 75% of total household income for swidden and agroforestry farmers respectively, and much greater than the total farm income. During FGDs it was reported that households allocate a high proportion of their labor to this off-farm work.

walking)		
Firewood collected from forest per household (kg $month^{-1}$)	33	5.60
Fodder collected from forest per household (kg $month^{-1}$)	1.65	3.15
Forest food [a] collected per household (kg $month^{-1}$)	4.85	1.70

[a] Forest food mainly constitutes bamboo shoots, mushrooms, tubers and other leafy vegetables, nuts and fruit including rambutan, menteng and wild bananas.

Swidden farmers collect, on average, more firewood from forests than do agroforestry farmers (Table 6). In interviews, the respondents said that this difference is because there is a big stock of firewood available in the agroforestry farms, especially from tree pruning and thinning. Also, their relatively higher farm income enables agroforestry farmers to buy gas cylinders, thereby reducing their need for firewood. Cattle rearing is not common in the research site, thus the rate of fodder collection from forest is low. Swidden farmers collect more forest food than agroforestry farmers. This was due to the diversity of crop species in agroforestry systems providing various types of food, and at the same time the higher farm income of agroforestry farmers enabled their households to buy food from local markets. There are a total of 4 timber, 15 fruit and nut, and 23 other understory crop species cultivated in the agroforestry systems.

Discussion

As an alternative to swidden farming, in the Gunung Salak study site agroforestry systems were found to be financially profitable and have good potential to secure sustainable livelihoods through diversified food sources and strengthened land tenure. Durian- and teak-based agroforestry systems are the most popular in the study site. The B/C indicated that total monetary gain is much higher in both of these systems than the total costs required to undertake the project, and much higher than for swidden systems. In addition, the payback period showed that there was no notable problem of delayed cash returns for those farmers adopting either agroforestry system; it was equal to the one year period of the swidden systems. However, NPV showed only one agroforestry system (the teak-based one) to be notably more profitable than both the swidden systems. Both sensitivity analyses confirmed that it is the teak-based agroforestry system that is more profitable over a range of conditions than are the durian-based agroforestry or swidden cultivation systems.

Smallholder teak production in Java is an important source of cash income for rural families (Roshetko et al., 2013) and has become part of many farmers' culture (Perdana et al., 2012), whereas swidden has retained this cultural status in the study area. There are 1.5 million smallholder farmers in Java managing 444,000 ha of tree-based agroforestry systems, where teak is the dominant tree crop. In other parts of Indonesia, there is an additional 800,000 ha of smallholder agroforestry, where teak is one component of multispecies, tree-based systems, favored because of its high market price (Departemen Kehutanan, 2005). In Central and East Java, smallholder farmers see tree farming systems as a 'living savings account' that diversifies production, reduces risk, and builds assets to enhance family incomes and security (van Noordwijk et al., 2008). De Foresta et al. (2004) found that the average annual income from mature fruit and timber agroforestry systems in Krui, Lampung were IDR 2,410,000 ha^{-1} yr^{-1}. Tree farming systems in the Philippines provided a range of annual incomes equivalent to IDR 2,374,802 - 163,553,043 $ha^{-1}yr^{-1}$, which greatly exceed incomes provided by annual crop systems, and the imperata grassland shifting cultivation system (Predo, 2002). Tree-based production systems are also promoted in government policies because of their perceived biological, economic and social resilience in the context of anthropogenic climate change and other production challenges (Alfaro et al., 2014; Thorlakson and Neufeldt, 2012; Steffan-Dewenter et al., 2007).

In our research site, through active tree planting, agroforestry creates permanent rights to farm land that transfer to future generations. Practicing this permanent form of cultivation is also prestigious in the community, because the tree products have high monetary and social values. From a social and institutional point of view, agroforestry is an important element in smallholder farmers' land security strategies in Indonesia (Michon and de Foresta, 1999), giving farmers the opportunity to secure tenure, as the recognized tree planter, with the property being legally transferred to descendants as patrimony (Michon, 2005).

Furthermore, swidden farmers have capacity constraints on agricultural cultivation of a large land area, thus they are only able to use less land than agroforestry farmers. Low household income limits the capacity to invest in cultivating new land, due to the importance of off-farm income in the livelihoods of the studied households. Available labor to cultivate agricultural crops is the most limiting resource for them. On the other hand, more permanent sustainable agroforestry practices require less labor input. Thus, smallholder tree cultivation is recognized as a viable livelihood strategy in various agroforestry and community forestry programs (e.g. FAO, 2006a; Sales et al., 2005; ICRAF, 2003).

The debates on the underlying causes of tropical deforestation and the drivers of agents' behaviour are complex, and the relationships between forest clearing and household and contextual variables vary depending on the setting (VanWey et al., 2005). Even with a limited land holding capacity, swidden farming households at our study site cleared a larger area of forest than did agroforestry farming households. Even though the average distance of swidden farm household to the nearest forest is relatively far, they collected more firewood from forests than did agroforestry households. This is because agroforestry farms have a good supply of firewood, and relatively higher farm income allowing a larger proportion of agroforestry farmers to buy gas cylinders. Recent studies in different locations around the tropics indicate that one important reason for deforestation is crop growing (Babigumira et al., 2014), and swidden farming is often held to be the principle driving force for that (Fox et al., 2000; Angelsen, 1995; Myers, 1992). However, Heltberg et al. (2000) reported that one of the main drivers of forest degradation in rural India is unsustainable firewood collection. A study in the buffer zone of the Kerinci Seblat National Park, Indonesia highlighted the relationship between farm diversification and reliance on adjacent national park resources (Murniati et al., 2001). Factors associated with a higher tendency to extract forest products from protected areas were low farm income and low supply of on-farm tree-based products. A study by Garrity et al. (2002) around the Mount Kitanglad Range National Park in Mindañao, the Philippines provides support for a link between adoption of agroforestry and reduction in pressure on forest.

Even though agroforestry systems have major economic benefits for farmers, several factors constrain agroforestry adoption. The major one in the study area is lack of investment capital and the higher traditional cultural value of swidden farming, which has been practiced by many generations, within the local communities. There is an absence of government assistance which could help to overcome these barriers to adoption of agroforestry. Several other studies have also found that tradition and customs are still a decisive factor influencing farmers' choice to practice swidden cultivation (Padoch et al., 2014; Peng et al., 2014; Predo, 2002) and that lack of capital and government backing[11] are crucial constraints on agroforestry adoption (Rahman et al., 2012; Van et al., 2012; Mai, 1999). Institutional innovation theory pioneered by economists (Hayami and Ruttan, 1971; Schultz, 1964) argues that physical constraints can be compensated by knowledge and institutional influence. Empirical evidence from Sumatra, Indonesia illustrated that with a supportive local institutional influence, tree culture has extended greatly into the landscape of swidden cultivation fields where young trees are cultivated with crops (Michon, 2005). Swidden cultivation eventually disappeared when the agroforestry silvicultural system had sufficiently matured and started to function as a productive and profitable tree-based system. When agroforestry systems fit local biophysical and socioeconomic conditions, they can rapidly become part of local culture (Perdana et al., 2012). There is potential for this intensification to be achieved in our study area through a smooth adaptation of tree-based farming practices with necessary government backup, thus the association of 'agro' and 'forest' components will occur at the level of the farming system itself, and if adopted at a sufficient scale it will significantly contribute to increasing tree cover in agricultural landscapes (see also Michon, 2005).

Conclusions

Communities in Gunung Salak have created a cultivated landscape which their livelihoods depend on. Their traditional swidden cultivation practices provide various subsistence products, but they can have serious negative environmental consequences by contributing to deforestation and land degradation. Agroforestry is an alternative cultivation strategy that has been adopted by some farmers within the communities. It does increase average farm income, making it more resilient to

[11] Other studies conducted in West Java, Sumatra, and Sulawesi also indicate that technical assistance is an important factor for agroforestry farm intensification and farmer motivation (Martini et al., 2012; Manurung et al., 2008; Roshetko et al., 2007).

changes in market and economic conditions, and reduce pressure on adjacent forest for conversion to agriculture and as a source of firewood, fruits, vegetables and other products. These agroforestry systems also enable farmers to secure permanent land tenure and can improve social cohesive in communities. Adoption of agroforestry by farmers in the Salak valley can be increased by the implementation of supportive policies and measures (including capital support and technical assistance) by government and non-government organizations. These measures are most likely to be effective if they are sensitive to the strong local tradition of swidden cultivation and underlying systems of local knowledge. Effective policies should be propagated not by temporary projects but by permanent, government-backed institutions that are focused on agroforestry practices and the needs for their adaptation to meet new opportunities and constraints (see also Rahman et al., 2008). The successful adoption of durian-and teak-based agroforestry by many farmers in the study area indicates the high potential for success of such a programme.

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Chapter Four

Towards Productive Landscapes: Trade-offs in Tree-cover and Income across a Matrix of Smallholder Agricultural Land-use Systems

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Abstract

One of the main causes of tropical forest loss is conversion to agriculture, which is constantly increasing as a dominant land cover in the tropics. The loss of forests greatly affects biodiversity and ecosystem services. This paper assesses the economic return from increasing tree cover in agricultural landscapes in two tropical locations, West Java, Indonesia and eastern Bangladesh. Agroforestry systems are compared with subsistence seasonal food-crop-based agricultural systems. Data were collected through rapid rural appraisal, field observation, focus groups and semi-structured interviews of farm households. The inclusion of agroforestry tree crops in seasonal agriculture improved the systems' overall economic performance (net present value), even when it reduced understorey crop production. However, seasonal agriculture has higher income per unit of land area used for crop cultivation compared with the tree establishment and development phase of agroforestry farms. Thus, there is a trade-off between short-term loss of agricultural income and longer-term economic gain from planting trees in farmland. For resource-poor farmers to implement this change, institutional support is needed to improve their knowledge and skills with this unfamiliar form of land management, sufficient capital for the initial investment, and an increase in the security of land tenure.

Keywords: deforestation, crop production, tree planting, income, ecosystem services

Introduction

Throughout the past century, tropical forests have declined mainly due to land conversion (Laurance, 2007; Lambin et al., 2003), and continue to be lost at alarming rates (Davidar et al., 2010). Although recent conservation efforts may have slowed down the speed of deforestation, every year the area of tropical forest decreases by an estimated 12.3 million ha (FAO, 2010)[1]. With an estimated two billion extra people expected on the planet in the next 25 years, primarily in tropical areas, forests and their biodiversity face an increasingly uncertain future (Beenhouwer et al., 2013). Although the underlying causes and the drivers of agents' forest clearing behaviour are complex (Babigumira et al., 2014), it is widely found that one of the main immediate causes of forest conversion in the tropics is to provide land for subsistence or commercial agriculture (Babigumira et al., 2014; Hosonuma et al., 2012; Hersperger et al., 2010; Angelsen and Kaimowitz, 1999). Furthermore, with the scale and impact of agriculture constantly rising, and emerging as a dominant land cover in the tropics, forest biodiversity and ecosystem services will be increasingly affected by the agricultural landscape matrix (Perfecto and Vandermeer, 2008; Scherr and McNeely, 2008).

Food production and biodiversity conservation are not necessarily mutually exclusive, and there is no simple relationship between the biodiversity and crop yield of an area of farmed land (Beenhouwer et al., 2013). Rural land use challenges in the tropics also include environmental degradation on fragile agricultural lands (Rahman and Rahman, 2011), including a decrease in soil fertility experienced by farmers (Snelder and Lasco, 2008). Evidence from a number of studies indicates declining growth of yields under intensive cropping even on some of the better lands, e.g. the Indo-Gangetic plains (Vira et al., 2015; FAO, 2011; ILEIA, 2000). In response, tropical agroforestry systems have been proposed as a mechanism for sustaining both biodiversity and its associated ecosystem services in food production areas (Steffan-Dewenter et al., 2007; Schroth et al., 2004), by increasing tree cover, while maintaining food production. The importance of agroforestry systems in generating ecosystem services such as enhanced food production, carbon

[1] In Asia a recent net increase in forest cover has been reported at the regional level due to large-scale successful afforestation efforts in China, India, Viet Nam, and Thailand. However, these 'planted forests' are inferior for providing the full range of ecosystem services (Roshetko, 2013; Xu, 2011).

sequestration, watershed functions (stabilization of stream flow, minimization of sediment load) and soil protection is being increasingly recognized (Lasco et al., 2014; Idol et al. 2011; Jose, 2009; Roshetko et al., 2007a; Alavalapati et al., 2004; Schaik and van Noordwijk, 2002). Tree components also produce important products, e.g. wood, fruits, latex, resins etc., that provide extra income to farmers and help alleviate poverty (Tscharntke et al., 2011; Snelder and Lasco, 2008; McNeely and Schroth, 2006). The economic return, especially net present value (NPV), internal rate of return (IRR), benefit-cost ratio (B/C), return-to-land and return-to-labor of agroforestry has been found to be much higher than from seasonal agricultural systems in many locations (Roshetko et al., 2013; Rahman et al., 2008; Rahman et al., 2007; Rasul and Thapa, 2006; Alavalapati and Mercer, 2004; Elevitch and Wilkinson, 2000). This is especially so for marginal farmlands where agricultural crop production is no longer biophysically or economically viable (Roshetko et al., 2008), and may become incompatible with the sustainable development concept with its major focus on ‘people-centered’ development (Snelder and Lasco, 2008).

Many ecological and economic studies have been conducted on the effect of land-use change, and management at the landscape scale, on ecosystem services (e.g. Grossman, 2015; Labriere et al., 2015; Ango et al., 2014; Baral et al., 2014; Vaast and Somarriba, 2014; Jose, 2009; Steffan-Dewenter, 2007). However, only a few (Wood et al., 2016; Sinare and Gordon, 2015; Tremblay et al., 2015) have focused on the simultaneous delivery of different agro-ecosystem services (including especially the maintenance of food provisioning) under scenarios of increasing tree planting in smallholder land use systems, and none of these carried out their research in Asia (see also Snelder and Lasco, 2008). Thus, this study seeks to fill this gap by assessing the trade-offs between income and tree cover when incorporating trees into food-crop-based agricultural systems in two tropical Asian locations, West Java, Indonesia and eastern Bangladesh. Our analysis compares provisioning ecosystem services provided by agroforestry with seasonal food crop farming, practiced in either swidden or permanent systems. Expansion of these subsistence systems is a major contributing factor to forest loss and environmental degradation in West Java (EST, 2015; Galudra et al., 2008). Similarly, upland slash-and-burn swidden agriculture, which is the dominant economic land use (Rahman et al., 2014), is a leading cause of deforestation in eastern Bangladesh. Hence, the two locations represent a complementary pair of examples for our analysis targeting the effect of increasing tree cultivation, and thus tree cover, in the dominant[2] type of Asian tropical agricultural landscapes.

This study will provide new information on the contribution that can be made to the income of seasonal food crop farmers by adopting agroforestry practices, specifically through production of a wider range of food and timber provisioning ecosystem services. It will meet the need for more detailed research resulting in quantitative data from different locations on a range of agroforestry systems compared with alternative farming practices, which is crucial evidence to better inform land use and farming policy and development practice (Snelder and Lasco, 2008; FAO 2006).

Materials and methods

Study site

This research was conducted in Gunung Salak valley, Bogor District, West Java, Indonesia and Khagrachhari district, eastern Bangladesh.

The research site in Indonesia lies between 6º 32' 11.31" S and 6º 40' 08.94" S latitudes and between 106º 46' 12.04" E and 106º 47' 27.42" E longitudes. The climate is equatorial with two distinct seasons[3], i.e. relatively dry (April-October) and rainy (November-March). The region is more humid and rainy than most parts of West Java. Given the proximity of large active volcanoes, the area is considered highly seismic (Badan Pusat Statistik, 2013; Wiharto et al., 2008) leading to highly fertile volcanic soils (Table 1). Field data were collected from three purposively selected[4] sample villages: Kp. Cangkrang, Sukaluyu and Tamansari, which are located in the northern Gunung Salak valley. The latter two villages contain a mixture of households practicing each of the two land use systems that form the major comparison of this study: subsistence seasonal swidden farming and agroforestry. The first village is located in a different part of the watershed, most of its studied

[2] In the tropical rural Asian landscapes, agriculture is the dominant type of economic land use (Babigumira et al., 2014).

[3] In the Indonesian study site rainfall occurs throughout the year, but based on its intensity two seasons are recognized, with heavy rainfall demarcating the rainy season.

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

households carry out a different farming system (permanent monoculture farming) and it is included in this study as an outgroup comparison. The total population in this area is approximately 10,200 people spread across 1600 households. Villages have poor infrastructure, and 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).

The research site in Bangladesh is part of the Chittangong Hill Tracts, the only extensive forested hilly area in Bangladesh, which lies in the eastern part of the country 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 area has three distinct seasons, i.e. hot and humid summer (March–June), cool and rainy monsoon (June-October) and cool and dry winter (October-March) (BBS, 2014). Mean annual rainfall is higher than the Indonesian study site, and soils were also highly fertile (Table 1). Field data were collected from two purposively selected sample villages[5], Mai Twi Para and Chondro Keron Karbari Para, with a total population of approximately 750, in 135 households. These two villages have poor infrastructure, and household incomes are mainly based on the sale of agricultural and forest products in local and district markets, with wage labor providing additional household income. They both include a mixture of households practicing each of the two land use systems that form the major comparison of this study: subsistence seasonal swidden farming and agroforestry.

In both research sites, agriculture is mainly a subsistence practice, conducted by small-scale farmers and deeply rooted in their culture. The main agricultural crops (upland rice, paddy rice, and a diversity of vegetables and fruit) are mainly cultivated in agricultural fields year-round. In all the studied villages, forest products (FPs) are collected from nearby forests. Farmers practicing swidden prepare new areas of land using the traditional slash-and-burn method to cultivate predominantly the food crops upland rice, maize and vegetables. They rotate crop cultivation between fields to maintain soil fertility by leaving land fallow for 2-4 years. Farmers practicing permanent monoculture agriculture in the Indonesian site grow single seasonal crops (predominantly upland rice, paddy rice, maize, vegetables or spices). Some farmers have replaced such traditional crops with high-value cash crops, e.g. taro, banana

[5] The area consists of hills, and the two villages were selected as those with the largest sample size of farm households that practice the farming systems being compared in this study, i.e. swidden and agroforestry.

and papaya. In both research sites, some farmers have adopted a range of agroforestry systems (e.g. fruit tree, timber tree or mixed fruit-timber), where trees are grown together with seasonal and perennial crops.

Table 1: Basic characteristics of the research sites.

Characteristics	**Indonesia**	**Bangladesh**
Average precipitation (mm/year)	1700	2540
Average relative humidity (%)	70	66
Average temperature (°C)	26	24
Soil	Highly fertile derived from volcanic and sedimentary rocks	Highly fertile of variable depth above broken shale or sandstone as well as mottled sand
Main economic activities	Agricultural and forest products, wage labor and retailing	Agricultural and forest products, wage labor
Main source of forest products	Natural forest	Natural and secondary forest
Forest products collected	Firewood, rattan, bamboo, fruits, vegetables	Firewood, timber, bamboo, rattan, wild fruits, vegetables
Agricultural markets	Village and district	Village and district
Local land use	Household dwelling units, home gardens, agricultural fields and forests	Household dwelling units, home gardens, agricultural fields and forests
Land tenure	State *de jure* owner. Private and community *de facto* user[6].	State *de jure* owner. Private and community *de facto* user[7].

Data source: BBS, 2014; BBS, 2013; Badan Pusat Statistik, 2013; Wiharto et al., 2008; Local Agricultural Office; RRA and village survey in this study.

[6] In the Indonesian study site, the national government is the owner of the land. Individuals and communities have land use and transfer rights. Individuals and communities have no formal rights to state forest land but, with government agreement, people can collect NTFP.

[7] In the Bangladesh study site, the national government is the owner of the land. Individuals and communities have the right to use the land, but no transfer rights. Individuals and communities have no formal rights to state forest land but, with government agreement, people can collect NTFP.

Data collection

Primary data of the basic socioeconomic and geographical state of the research sites were collected by rapid rural appraisals (RRA) using village mapping and key informant interviews (FAO, 2015; Angelsen et al., 2011). Key informant interviews and village mapping sessions were conducted (one in each village) by involving the village head and three farmers, selected purposively based on their knowledge about the village and surrounding areas.

Five focus group discussion (FGD) sessions (one in each village[8]) and field observations were used to identify the types of local cultivation systems and their products. The village heads and local farmer representative groups (consisting of eight to twelve farmers[9]) were present in the FGD sessions. Field observations were carried out in fifty-five farm locations identified during the RRAs and FGDs. Several pictures of local cultivation systems were taken[10], and relevant information was noted with the assistance of expert local informants[11].

Semi-structured interviews were conducted to collect information on farm products and their values, land area and allocation, and other basic characteristics of the farm household, i.e. family and labor force size, age and education of the family members, income, expenditure, savings and interest in tree-based farming. In Indonesia 20 permanent monoculture[12], 20 swidden and 20 agroforestry farmers were interviewed; and in Bangladesh[13] 40 swidden and 21 agroforestry farmers were interviewed. 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-

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

[9] Farmers in each group were purposively selected based on their knowledge of local cultivation systems.

[10] Pictures were taken as visual supporting evidence to aid data analysis and interpretation by characterising the structure of each specific cultivation system.

[11] 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.

[12] In this research, permanent monoculture refers to growing a single crop at given times of the year in a rotational system in the same area without abandoning the land.

[13] In the Bangladesh research site permanent monoculture is rarely practiced, with insufficient farmers in the studied villages to provide an adequate sample, thus it was not included in the study.

managed[14] form of each of the contrasted farming systems[15]. We estimate that in the Indonesian study villages they represent 20%, 40% and 30% of the permanent monoculture, swidden and agroforestry farming populations respectively. In the Bangladesh study villages they represent about 50% and 60% of the swidden and agroforestry farming populations respectively. The questionnaire that guided the interviews was refined and finalized with the help of the expert local informants and during FGD sessions to make sure that the questions elicited the information required. The product value of crops was calculated with the key informant farmers during the interview based on the total production in the most recent season/year.

The primary data (i.e. local farm production and its market value) collected from the research sites were cross-checked with data gathered from local state agriculture and forestry offices, and the ICRAF Southeast Asian Regional office and CIFOR headquarters (both located in Bogor, Indonesia).

Data analysis

Descriptive statistics were used to compare characteristics (age, education, family size, farm size, yearly income and expenditure) of the different farmer groups[16]. The size of farms and proportion of land used for different categories of land use were compared amongst the farmer groups. To compare two farmer groups, a two-sample un-paired Student's t-test (t) was calculated, with the assumption of unequal variance, and the Welch (or Satterthwaite) approximation to the degrees of freedom (df) was used to determine the p-value. ANOVA was used to test differences amongst three farmer groups, with F-statistics reported as F (*a*, *b*), where *a* and *b* are between and within group degrees of freedom respectively. All analyses were performed in the R environment for statistical computing (version R 2.15.0) (R Core Team 2015) in a Windows platform.

[14] For example, some farmers started agroforestry farming but after a few years gave up planting the understorey, for various reasons (e.g. lack of management interest or capital). Thus, many agroforestry farms were converted to simple tree orchards, and we have excluded these from our sample.

[15] Each of these farmer groups as a whole cultivates plots of land under different forms of farming (agroforestry, swidden, permanent monoculture). Therefore, each group was selected on the basis of their dominant form of farming practice.

[16] Descriptive statistics are abbreviated: M = mean, SD = standard deviation and N = sample size.

Net present value (NPV) was calculated to assess the overall economic performance of crop production under mixed tree crops *versus* the non-agroforestry farming systems (swidden and permanent monoculture) on the basis of a 30-year time period (Rahman et al., 2007; 2014; Arun 2013) and a 10% discount rate as it is an appropriate rate to match the banking system local to the research site (Rahman et al., 2007; 2014)[17]. Sensitivity analysis was also conducted on variation in yields, as the combination of tree species may affect understorey crop production. Means are compared (independent sample t-test using SPSS V 22) to assess the different factors that may affect the decisions of non-agroforestry (swidden and permanent monoculture) farmers to choose to adopt agroforestry tree-based farming, by determining the conditional probability that a farmer will adopt given a set of independent influencing factors, i.e. land area, family size, income, age, education, and credit availability (Rahman et al., 2012). Our hypothesis is that, with less land available for permanent cultivation, farmers are more inclined to practice seasonal cultivation, e.g. swidden. Farmers with larger family size, lower family income, who are older, and less-educated are also more closely aligned to seasonal cultivation. Available credit helps to enable the adoption of agroforestry. The dependent variable in our case is binary which takes the value ‘1’ if a non-agroforestry farmer wants to practice agroforestry and ‘0’ if otherwise. The definition and expected signs of the explanatory variables and the results are described in Table 7.

Results

In both study sites, agroforestry farmers are younger than swidden farmers (Table 2). In addition, in the Indonesian case, the farmers in the lower watershed village practicing permanent monoculture were of comparable age to the swidden farmers in the two villages higher in the watershed. All the Indonesian farmer groups have roughly the same educational qualifications, whereas in Bangladesh the agroforestry farmers have higher levels of education than the swidden farmers. In both areas all respondents and household heads were male. The average household labor force size is 1.2, 1.4 and 1.5 for agroforestry, swidden and permanent monoculture farmers in Indonesia, and 1.6 for both the agroforestry and swidden farmers in

[17] Further details of the NPV calculation are given in Appendix 1, including the yearly cash flow results for selected cultivation systems in the research sites in Appendix 1, Table 1.

Bangladesh. Agroforestry farmers have higher annual income than swidden farmers in both areas. In Indonesia, the permanent monoculture farmers have higher income than the others. The savings of Indonesian farmers are lower than Bangladeshi farmers. They do not differ much amongst the farming groups in Indonesia, however agroforestry farmers in Bangladesh have double the amount of savings (US$ 481.14) of swidden farmers (US$ 240.69).

Table 2: Basic characteristics of the farm households.

Characteristics	**Indonesia**			**Bangladesh**	
	AF (n=20)	SW (n=20)	PM (n=20)	AF (n=21)	SW (n=40)
Age of household head	53	60	59	42	45
Education of household head (year of schooling)	5.0	5.1	4.8	6.0	3.7
Sex of household head	Male (100%)	Male (100%)	Male (100%)	Male (100%)	Male (100%)
Family size	6.7	4.7	4.9	4.7	4.8
Labour force (age 15-59)	1.2	1.4	1.5	1.6	1.6
Distance to the village center (minutes of walking)	23.5	12.8	12.9	5.7	8.2
Distance to the edge of nearest forest (minutes of walking)	10.6	24.0	9.2	21.3	16.9
Total land area (ha)	0.98	0.77	0.26	3.72	2.22
Total annual income (US$)	2015	1207	2497	1380	1076
Total annual expenditure (US$)	1454	1114	2109	1397	1069
Total savings in a bank/ credit association (US$)	126	172	168	481	241
Total outstanding debit (US$)	8.50	7.50	9.50	177.01	182.56

Note: AF = Agroforestry farmer, SW = Swidden farmer, PM = Permanent monoculture farmer. US$ 1 = 10,000 Indonesian Rupiah (IDR) or 78 Bangladeshi Taka (BDT).

Each of the farmer groups as a whole cultivates plots of land under different forms of farming (Figure 2). The total farm size of agroforestry farmers is significantly larger (M = 3.7 ha, SD = 2.8, N = 21) than that of swidden farmers (M = 2.2 ha, SD = 2.2, N = 40) in Bangladesh (t = 2.28, df = 24.59, p-value = 0.03) (Figure 1). In Indonesia, farm size also differs between the groups [F (2.57) = 6.4, p = 0.003], with swidden and agroforestry farms in the middle and upper watershed villages being significantly larger than the permanent monoculture farms in the lower watershed village. However, there was no significant difference in farm size between the swidden and agroforestry farmers (t = 0.8, df = 20.6, p-value = 0.38).

The proportion of the total land area of the interviewed agroforestry farmers that they use for agroforestry systems (M = 61%, SD = 32%, N=41) is significantly higher than that the swidden farmers use for swidden systems (M = 47%, SD = 21%, N = 60) (t = 2.37, df = 63.1, p-value = 0.02). The allocation of land to ‘other land uses’ follows a similar pattern for the two groups of farmers (Figure 2).

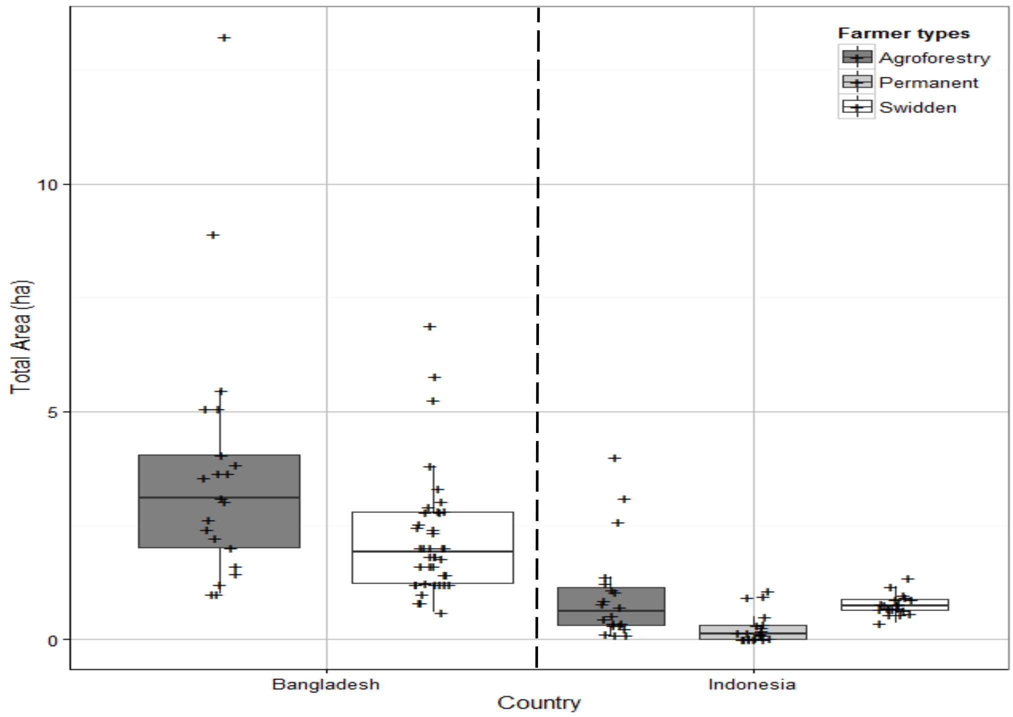

Figure 1: Boxplot showing total farm size (ha) amongst the different farmer groups. For each box the horizontal center line shows the median of the distribution, the top and bottom edges of the box show the 75% (Q3) and 25% (Q1) quartiles respectively, and the top and bottom ends of the whiskers are defined as the first data point within the limits defined by Q3+(1.5*IQR) and Q1-(1.5*IQR) respectively, where IQR is the inter-quartile range (the box height).

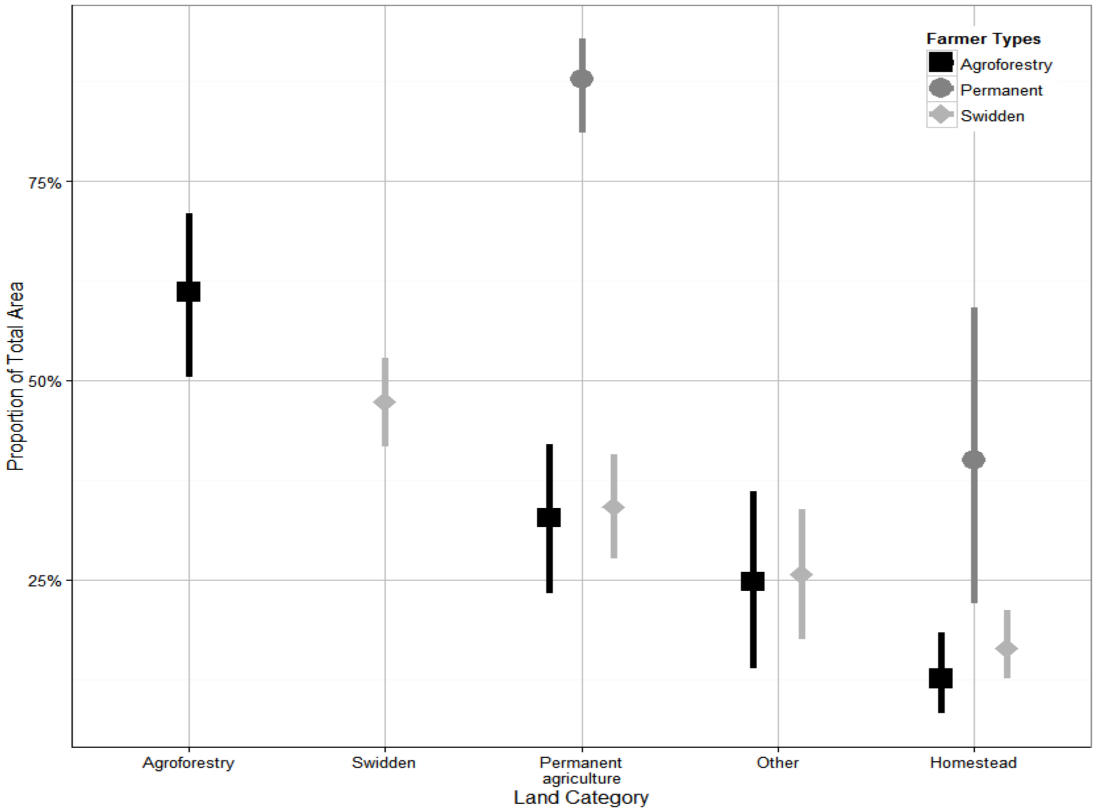

Figure 2: The proportion of their total land area used for various forms of farming amongst the different farmer groups[18]. The square, diamond and circle symbols show the mean values and the ends of the vertical lines show +/- 1 standard deviation.

The agroforestry farmers tend to cultivate a single plot of land. In Indonesia, on average the agroforestry farmers allocate 88% of their land to the single largest plot, whereas in Bangladesh it is only 58% of their land (Figure 3). This indicates that the land of the Bangladeshi agroforestry farmers tends to be divided into more plots with a greater diversity of plot sizes. In contrast, for the swidden farmers there is less difference between the two countries in the division of their land between plots of different sizes; in both cases the proportion of their land that is allocated to their largest plot varies widely amongst farmers. This is because there is a tendency to spread the farming risk[19] across many smaller plots. In contrast, the vast majority of

[18] The ‘other’ land use type includes fallows, wetlands and ponds. ‘Homestead’ refers to a farmhouse surrounded by carefully managed, planted and naturally grown plants, e.g. fruits, vegetables and ornamentals.

[19] During the FGDs farmers reported that in the swidden system there is a farming risk, which is associated with crop failure, landslides, and land grabbing by more powerful actors.

permanent monoculture farmers allocated a very high proportion of their land to their single largest plot (on average 91%).

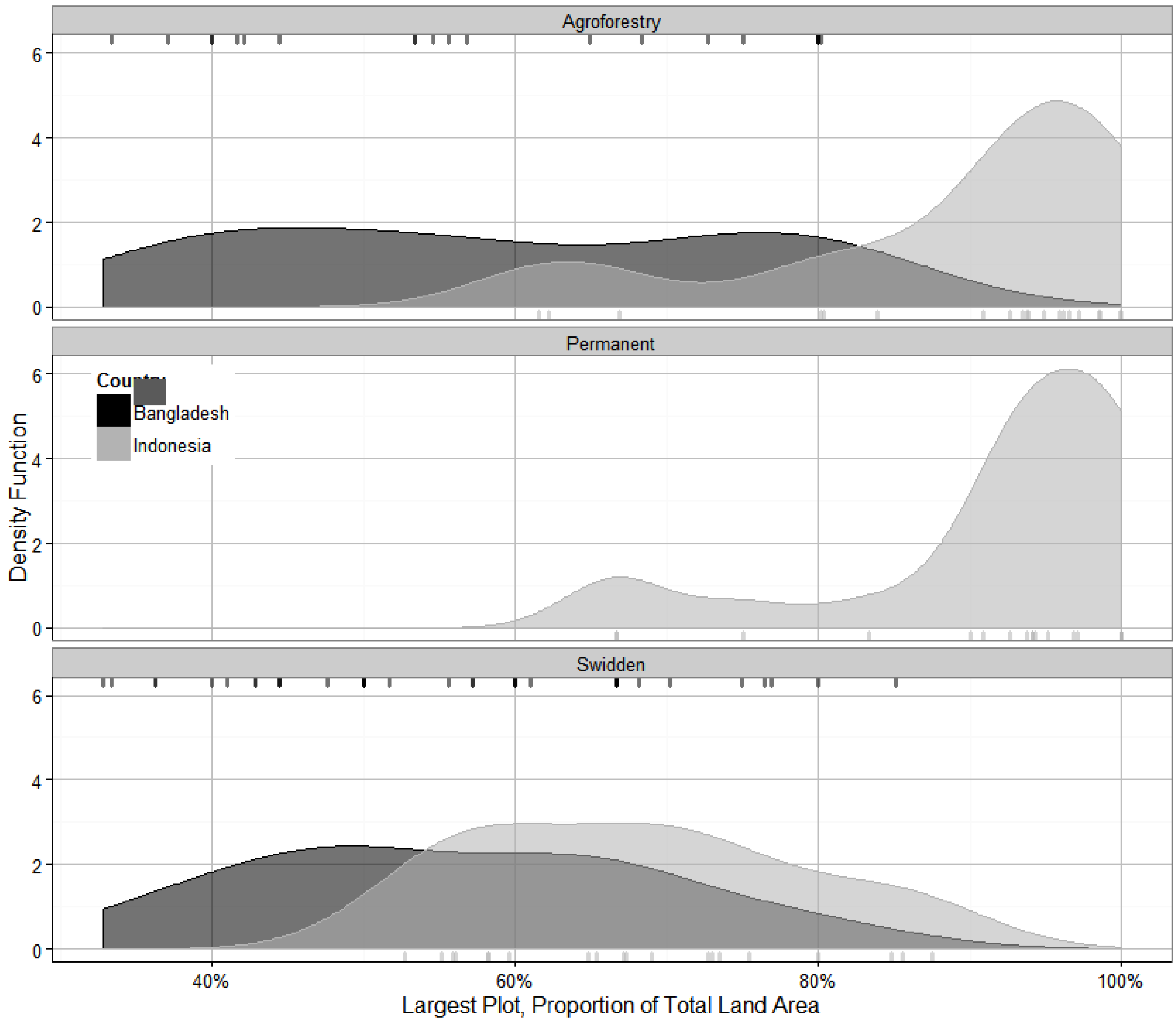

Figure 3: Comparison amongst farmer groups in the probability of their largest plot occupying different proportions of their land area. Kernel density plots showing the concentration of observations as a density function against the percentage of their land area occupied by their largest plot for the farmers in each group (agroforestry, swidden and permanent monoculture). The kernel density estimation model used to generate each curve fixes its integral as 1 across the modelled range from 33% to 100% of land area. The probability between two x-values is the area under the curve between those two points. The Kernel density analysis was carried out using R, version R 2.15.0.

In the Indonesia study site, the agroforestry farmers earn an average income of US$382 per hectare of land that they allocate to agroforestry (Table 3). This is 1.7 times higher than the income of swidden farmers per hectare of land allocated to swidden (US$226). However, the average income of the permanent monoculture farmers located lower in the watershed, who allocated 100% of their mean 0.20 ha of land to this use, was much higher (US$2990 ha^{-1}). In contrast, in Bangladesh the swidden farmers had a higher income per area of land used for swidden (US$610 ha^{-1}) than the agroforestry farmers had per area of agroforestry land (US$441 ha^{-1}). In Bangladesh the two groups of farmers allocated a similar proportion of their land (ca. 30%) to their dominant land use (agroforestry and swidden respectively), whereas in Indonesia agroforestry farmers allocated 87% of their land to this use, but swidden farmers allocated a lower proportion (60%) of their land to swidden.

Table 3: Farm households' allocation of their land area (ha) to different farming systems and the annual income (US$) from total production on each[20].

			Indonesia			Bangladesh	
			Agroforestry farmer	Swidden farmer	Permanent monoculture farmer	Agroforestry farmer	Swidden farmer
Land area and income share	Agroforestry land	Area (ha) and proportion of total land (%, in brackets)	0.85 (86.73)	0.00	0.00	1.07 (28.76)	0.00
		Income (US$) and share of total farm income (%, in brackets)	324.55 (66.11)	n/a	n/a	472.20 (45.13)	n/a
	Swidden land	Area (ha) and proportion of total land (%, in brackets)	0.00	0.46 (59.74)	0.00	0.00	0.71 (31.98)
		Income (US$) and share of total farm income (%, in brackets)	n/a	104.00 (29.21)	n/a	n/a	433.34 (67.32)
	Permanent monoculture land	Area (ha) and proportion of total land (%, in brackets)	0.11 (11.22)	0.29 (37.66)	0.20 (76.92)	0.92 (24.73)	0.51 (22.97)
		Income (US$) and share of total farm income (%, in brackets)	166.35 (33.89)	252.00 (70.79)	598.08 (100)	574.12 (54.87)	210.38 (32.68)
Total farm income (US$) and share of total household income (%, in brackets)			490.90 (24.36)	356.00 (29.49)	598.08 (23.95)	1046.32 (75.80)	643.72 (59.81)

[20] The level of annual income from products harvested from different farming systems was based on farmers' reports of their income during the single most recent production year. However, for most of the agroforestry farmers this underestimated their potential future income as the timber trees in their agroforests had yet to reach harvestable maturity and in some cases fruit trees had yet to grow to maturity and achieve maximum fruit yield. Since tree species have a longer juvenile period compared with other agricultural crops such as rice and maize that mature within a few months, income from agroforestry systems will be much lower during the years of their establishment phase.

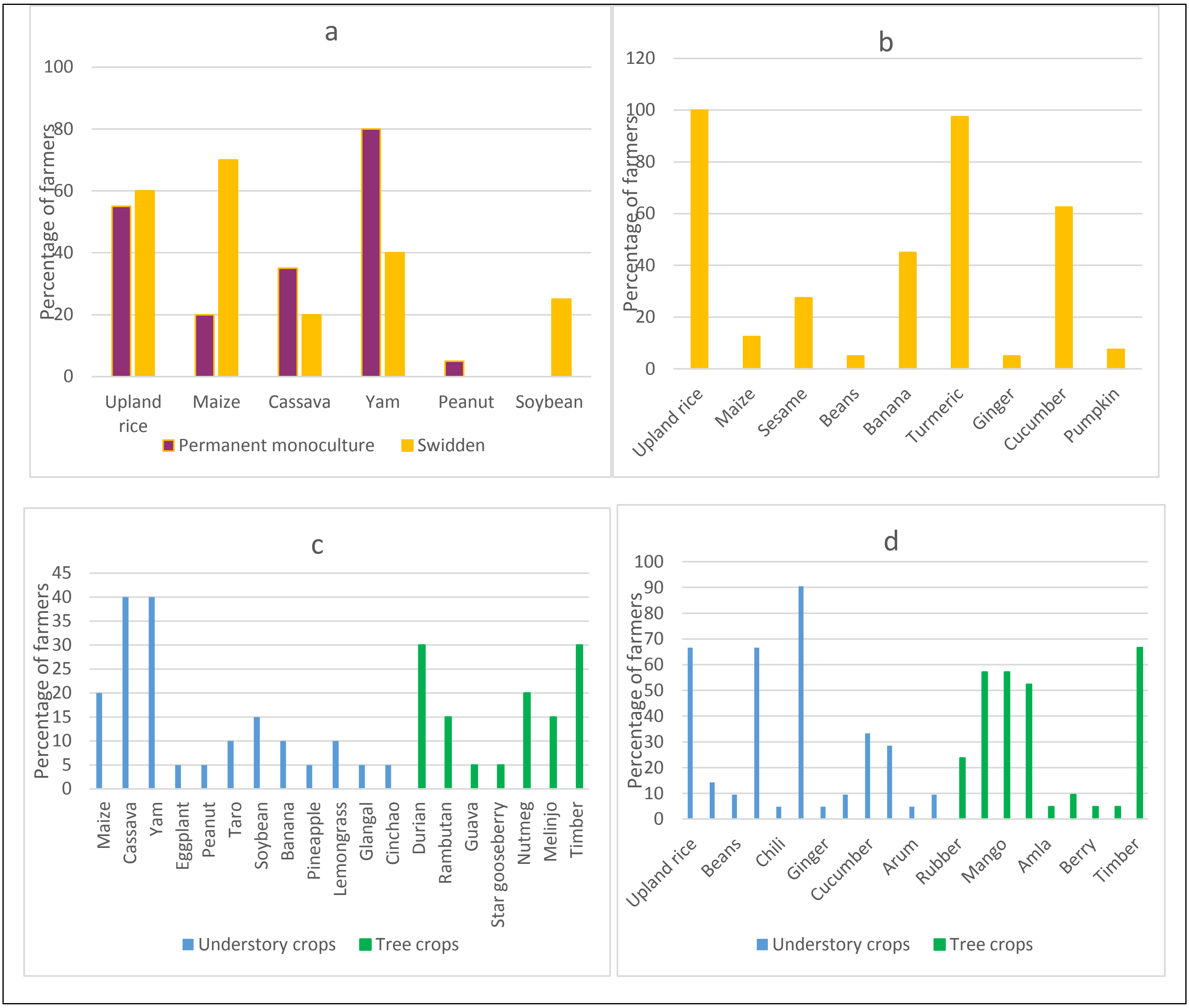

Figure 4: The percentage of farmers cultivating each type of subsistence crop (a, Indonesia swidden and permanent monoculture; b, Bangladesh swidden; c, Indonesia agroforestry; d, Bangladesh agroforestry).

Farmers in our study sites spread their production over a wide diversity of crops (Figure 4). In Indonesia, yam is the most common permanent monoculture crop, being cultivated by 80% of farmers. Among swidden farmers, maize and upland rice are most popular. On agroforestry farms, the most common crops are the annuals cassava and yam, followed by the fruit trees durian and nutmeg and the timber trees teak and white jabon. In Bangladesh, turmeric, rice and banana are the most widely cultivated field crops, mangium the dominant timber tree, and mango, jackfruit and lychee the dominant fruit trees for agroforestry farmers. The surveyed agroforestry farmers in Indonesia do not grow rice in their agroforestry fields, but in separate non-agroforestry fields. The average income and net present value (NPV, on the basis of a 30-year time period and 10% discount rate) of the main agricultural crops grown in the swidden and permanent monoculture systems is presented in Table 4. Among the crops, yam generated the highest income (mean income during its cultivation period was US$1,531.40 ha^{-1}, NPV= US$14,436.38 ha^{-1}) in Indonesia followed by upland rice, maize and peanut. In Bangladesh farmers earn the highest income from banana (mean income US$6,175.00 ha^{-1}, NPV= US$58,211.00 ha^{-1}) followed by turmeric, cucumber, maize and upland rice.

To test the difference in overall economic performance (NPV) of farm production under agroforestry, with a mixture of tree crops, to that of non-agroforestry farming systems (swidden and permanent monoculture), the most popular locally cultivated trees were selected: durian, nutmeg and teak in Indonesia; mango, jackfruit, lychee and mangium in Bangladesh. Risk factors, such as the effect that the tree species combination may have on productivity of the understorey crops are important in assessing economic performance. This effect depends on various factors, e.g. intensity of shade and spread of tree canopy, sunlight, rainfall, soil conditions and fertilizer inputs. Therefore, sensitivity analysis was conducted testing the effect of variation in crop yield reduction in 10% intervals from 0% to 60% on the NPV (Table 5 and 6). With durian as the overstorey tree crop, all of the understorey crops, except yam, are profitable up to yield reductions of 40% compared with other cropping systems (Table 5, Table 4) in Indonesia. Nutmeg as a tree crop provides a low return (NPV) and the nutmeg system is not profitable at any level of crop loss. In contrast, teak has high value so the teak-based agroforestry system remains profitable regardless of the understorey crop yield reduction it may cause. Similarly, in Bangladesh mango- and lychee-based agroforestry systems are profitable regardless of the yield reduction with any selected crops except banana, which is profitable up to 30% loss (Table 6, Table 4). The jackfruit-based system is profitable up to 50% loss of most crops, but there is a big variability in the mangium system as rice, maize, sesame, turmeric and cucumber are profitable up to 30%, 20%, 40%, 10% and 10% of crop yield reduction respectively. In contrast banana is never profitable with mangium.

Table 4: Income from main agricultural crops (US$ ha^{-1}), when grown in open fields[21].

Crop and cultivation period	Indonesia		Bangladesh	
	Mean	NPV	Mean	NPV
Upland rice (3 months)	1,282.90	12,093.79	1,140.00	10,747.00
Maize (4 months)	1,213.90	11,443.33	1520.00	14,329.00
Yam (4 months)	1,531.40	14,436.38	n/a	n/a
Cassava (8 months)	1,134.40	10,693.89	n/a	n/a
Peanut (4.5 months)	1,191.40	11,231.23	n/a	n/a
Soybean (3 months)	300.00	2,828.07	n/a	n/a
Sesame (3 months)	n/a	n/a	902.50	8,508.00
Turmeric (10 months)	n/a	n/a	2,422.50	22,837.00
Cucumber (4 months)	n/a	n/a	2,066.25	19,478.00
Banana (10 months)	n/a	n/a	6,175.00	58,211.00

Data sources: focus group discussion, farm level semi-structure questionnaire interview, Local Agricultural Office, ICRAF, CIFOR.

[21] The calculation of NPV is based on a 30-year time horizon, a 10% discount rate, and one harvest per crop per year regardless of its cultivation period, as farmer decision-making about whether to combine crops in the same year is too complex to model.

Table 5: Sensitivity of overall profitability (NPV in US$ ha^{-1}) to decreases in production of six understorey crops resulting from competition with three different overstorey tree species[22] in agroforestry systems in Indonesia [23].

Decrease of production	Durian tree (NPV 4,849.42) + the understorey crops					
	Upland rice	Maize	Yam	Cassava	Peanut	Soybean
0%	16,943.21	16,292.75	19,285.80	15,543.31	16,080.65	7,677.49
10%	15,733.83	15,148.42	17,842.16	14,473.92	14,957.52	7,394.69
20%	14,524.45	14,004.09	16,398.52	13,404.53	13,834.40	7,111.88
30%	13,315.54	12,859.75	14,954.88	12,335.14	12,711.28	6,829.07
40%	12,105.69	11,715.42	13,511.25	11,265.76	11,588.16	6,546.27
50%	10,896.31	10,571.09	12,067.61	10,196.37	10,465.03	6,263.46
60%	9,686.94	9,426.75	10,623.97	9,126.98	9,341.91	5,980.65
	Nutmeg tree (NPV 516.15) + the understorey crops					
	Upland rice	Maize	Yam	Cassava	Peanut	Soybean
0%	12,609.94	11,959.48	14,952.52	11,210.04	11,747.37	3,344.22
10%	11,400.56	10,815.15	13,508.89	10,140.65	10,624.25	3,061.41
20%	10,191.18	9,670.81	12,065.25	9,071.26	9,501.13	2,778.61
30%	8,981.80	8,526.48	10,621.61	8,001.87	8,378.01	2,495.80
40%	7,772.42	7,382.15	9,177.97	6,932.48	7,254.88	2,212.99

[22] Fruit trees (durian, nutmeg) and timber tree (teak).

[23] NPV is calculated based on a 30-year time horizon with a 10% discount rate. Once trees are included in the cultivation system the lifespan of the project can be considered indefinite. However, for simplicity, in our analysis the project life is still considered to be 30 years as this may be a realistic lifetime for one productive rotation of fruit trees (durian and nutmeg), and for three rotations (harvest cycles) of the timber tree (teak). Yields of durian and nutmeg (from grafted seedlings) are calculated in three periods: durian has low yields during the fourth to sixth years, medium yields during the seventh to eighth years, and high yields from the ninth year onwards; nutmeg has low yields during the seventh to ninth years, medium yields during the tenth to twelfth years, and high yields from the thirteenth year onwards. The calculation for each understorey crop is based on 30 annual productions assuming constant income cycles, i.e. one production per year regardless of its cultivation period, as farmer decision-making about whether to combine crops in the same year is too complex to model.

50%	6,563.04	6,237.81	7,734.34	5,863.09	6,131.76	1,930.18
60%	5,353.66	5,093.48	6,290.70	4,791.82	5,008.64	1,647.38
	Teak tree (NPV 17,116.38) + the understorey crops					
	Upland rice	Maize	Yam	Cassava	Peanut	Soybean
0%	29,210.17	28,559.71	31,552.76	27,810.27	28,347.61	19,944.45
10%	28,000.79	27,415.38	30,109.12	26,740.88	27,224.48	19,661.64
20%	26,791.41	26,271.04	28,665.48	25,671.49	26,101.36	19,378.84
30%	25,582.03	25,126.71	27,221.84	24,602.10	24,978.24	19,096.03
40%	24,372.65	23,982.38	25,778.20	23,532.71	23,855.11	18,813.22
50%	23,163.27	22,838.04	24,334.57	22,463.32	22,731.99	18,530.41
60%	21,953.89	21,693.71	22,890.93	21,393.93	21,608.87	18,247.61

Table 6: Sensitivity of overall profitability (NPV in US$ ha^{-1}) to decreases in production of six understorey crops resulting from competition with four different overstorey tree species[24] in agroforestry systems in Bangladesh[25].

Decrease of production	Mango tree (NPV 20,768) + the understorey crops					
	Upland rice	Maize	Sesame	Turmeric	Cucumber	Banana
0%	31,515.02	35,097.24	29,276.12	43,605.03	40,246.70	78,979.53
10%	30,440.35	33,664.35	28,414.32	41,321.36	38,298.81	73,158.41
20%	29,365.68	32,231.46	27,570.79	39,037.69	36,351.02	67,337.29
30%	28,291.01	30,798.57	26,720.49	36,754.02	34,403.14	61,516.17

[24] Fruit trees (mango, jackfruit, lychee) and timber tree (mangium).

[25] NPV is calculated based on a 30-year time horizon with a 10% discount rate. Yields of mango, lychee and jackfruit (from grafted seedlings) are calculated in three periods: mango and lychee have low yields during the sixth to eighth years, medium yields during the ninth to eleventh years, and high yields from the twelfth year onwards; jackfruit has low yields during the sixth to seventh years, medium yields during the eighth to ninth years, and high yields from the tenth year onwards. The market value of timber from mangium is calculated in ten-year rotation periods, after which it is assumed that it is replanted. The calculation for each understorey crop is based on 30 annual productions assuming constant income cycles, i.e. one production per year regardless of its cultivation period, as farmer decision-making about whether to combine crops in the same year is too complex to model.

40%	27,216.34	29,365.68	25,870.18	34,470.35	32,455.35	55,695.05
50%	26,141.67	27,932.79	25,019.87	32,186.68	30,507.47	49,873.93
60%	25,067.01	26,499.90	24,169.56	29,903.01	28,559.68	44,052.81
	Jackfruit tree (NPV 11,386) + the understorey crops					
	Upland rice	Maize	Sesame	Turmeric	Cucumber	Banana
0%	22,133.05	25,715.27	19,894.15	34,223.06	30,864.73	69,597.56
10%	21,058.38	24,282.38	19,032.35	31,939.39	28,916.84	63,776.44
20%	19,983.71	22,849.49	18,188.83	29,655.72	26,969.05	57,955.32
30%	18,909.04	21,416.60	17,338.52	27,372.05	25,021.17	52,134.20
40%	17,834.37	19,983.71	16,488.21	25,088.38	23,073.38	46,313.08
50%	16,759.71	18,550.82	15,637.90	22,804.71	21,125.50	40,491.96
60%	15,685.04	17,117.93	14,787.60	20,521.04	19,177.71	34,670.84
	Lychee tree (NPV 19,006) + the understorey crops					
	Upland rice	Maize	Sesame	Turmeric	Cucumber	Banana
0%	29,752.28	33,334.51	27,513.39	41,842.30	38,483.96	77,216.80
10%	28,677.61	31,901.62	26,651.58	39,558.63	36,536.08	71,395.68
20%	27,602.95	30,468.73	25,808.06	37,274.96	34,588.29	65,574.56
30%	26,528.28	29,035.84	24,957.75	34,991.29	32,640.41	59,753.44
40%	25,453.61	27,602.95	24,107.45	32,707.62	30,692.62	53,932.32
50%	24,378.94	26,170.05	23,257.14	30,423.95	28,744.73	48,111.20
60%	23,304.27	24,737.16	22,406.83	28,140.28	26,796.94	42,290.08
	Mangium tree (NPV 3,570) + the understorey crops					
	Upland rice	Maize	Sesame	Turmeric	Cucumber	Banana
0%	14,317.08	17,899.31	12,078.19	26,407.10	23,048.76	61,781.60
10%	13,242.41	16,466.42	11,216.38	24,123.43	21,100.88	55,960.48
20%	12,167.74	15,033.53	10,372.86	21,839.76	19,153.09	50,139.36
30%	11,093.08	13,600.64	9,522.55	19,556.09	17,205.21	44,318.24
40%	10,018.41	12,167.74	8,672.24	17,272.42	15,257.42	38,497.12
50%	8,943.74	10,734.85	7,821.94	14,988.75	13,309.53	32,676.00
60%	7,869.07	9,301.96	6,971.63	12,705.08	11,361.74	26,854.88

From the information gathered during our semi-structured interviews of the non-agroforestry famer groups (swidden and permanent monoculture), a comparison of means is used to investigate the conditional probability that a farmer may adopt tree-based farming given a set of influential factors. The mean values of different influential factors, i.e. farmer age, education, land area, family size, income and credit availability, revealed no significant differences between those who have a (potential) interest in agroforestry and those who have not, in either country, except that interest in adopting agroforestry was very significantly associated with educational level for swidden (but not permanent monoculture) farmers in Indonesia (Table 7). Therefore, with this exception, there is no evidence that these factors have a significant influence on farmer choice of tree-based farming in our study areas, which is corroborated by the qualitative information obtained from FGD sessions that swidden and permanent monoculture are retained because they are deeply rooted in local traditions extending back over many generations.

Table 7: Farmers' interest in adopting agroforestry.

Variable	Definition	Expected sign	Indonesia		Bangladesh
			Swidden	Permanent monoculture	Swidden
			p-value	p-value	p-value
Age	Decision maker's age in years	+	0.966	0.710	0.713
Education	Decision maker's educational qualification (total years of schooling)	+	**< 0.001**	0.923	0.339
Land	Household total land area (ha)	+	0.477	0.057	0.222
Household size	Total number of people in the household (persons)	+	0.907	0.210	0.559
Income	Household total income (US$)	+	0.408	0.977	0.251
Credit	= 1 if the farmer got credit from any sources, and 0 otherwise	+	0.331	0.498	0.160

Note: Significant value at $p < 0.05$ is indicated in bold

Discussion

Profitability measured by NPV over a 30-year time period shows that farmers will achieve a positive economic performance by mixing trees and seasonal crops in agroforestry systems compared with seasonal agriculture in both countries. This finding holds across a wide range of percentage reductions in understorey crop production when trees become mature and their canopies close. Teak-based agroforestry systems, followed by durian, showed the best economic performance at the Indonesian site, both considerably outperforming seasonal crop-based farming systems. Agroforestry systems with two fruit tree species, mango and lychee, also showed a good economic performance in Bangladesh. In the short term, however, before tree crops have reached maturity, permanent monoculture and swidden farms provide higher income, as seasonal crop farms generate quicker returns than do agroforestry farms. Furthermore, when adopting tree crops, farmers have to accept reduced yields of understorey seasonal crops before receiving the increase in income from harvesting these tree crops (Oladele and Popoola, 2013; Singh et al., 2012; Tiwari et al., 2012). Farmers may also face other interacting risks, such as crop failures, fluctuating market demand and prices, pests and diseases, and climate change. Changing successfully to tree-dominated systems will require farmers to develop access to high quality tree germplasm, tree management expertise, which may be lacking in government extension services, and market channels for tree products, which are generally different from those for annual crops. Nonetheless, a more ecologically diverse farming system yielding a wider range of products is more likely to be buffered against such risks over the 30-year time period assessed in this paper (Elevitch and Wilkinson, 2000). This change in farming system to agroforestry may, however, have serious subsistence and cultural costs as the cultivation of seasonal crops is primarily for household subsistence consumption and is deeply rooted in their culture. The retention of seasonal crop farming by many farmers, despite the medium-/long-term economic advantage of adopting agroforestry demonstrated by the results of the present study, is likely to be explained by culture- and tradition-linked factors retaining a decisive influence on farmer preferences. This is also indicated by their retention of comparatively small plots of seasonal crops, despite this restricting the efficiency of the productive assets (Rahman et al., 2012).

Farmers are concerned about the loss of understorey crop production in agroforestry systems, however our results provide strong evidence that these will be compensated by the generation of cash income from tree products in the medium-term. Provided that farmers can afford to bear the losses up to the time that their trees have grown to harvestable maturity, they are likely to gain a net benefit by achieving a level of income from tree products that enables them to purchase essential needs including food. However, farmers may lack confidence in this shift in the basis of their livelihoods. Even if it is likely to increase their net income, they may feel more exposed to risks of market failure of their tree crops and regret the loss of cultural identity associated with the cultivation of specific traditional crops (Mwase et al., 2015; UEA, 2015; Gyau et al., 2014; Pannell, 2009). Thus, smallholder farmers' decision-making about whether to shift their food production system to agroforestry in place of subsistence crop production is based on cultural considerations as well as the trade-off between short-term and a longer-term benefits.

Living costs are predicted to increase in both the studied countries, however as food security largely depends on income security, even in remote places (van Noordwijk et al., 2014), our economic analyses demonstrate that the higher income from tree-based farming has the potential to enhance food security. Incorporation of tree species selected for the local value of their products (fruit, timber) into food-crop-based subsistence agricultural systems can also enhance household well-being by consumption of a more diverse diet of higher nutritional quality, both from the harvested fruit and from foodstuffs that can be purchased with the income generated. In this sense, farming families may increase their food sovereignty through improved access to healthy and culturally appropriate food (Vira et al., 2015; Edelman et al., 2014).

The higher establishment costs of agroforestry systems than traditional agricultural alternatives indicated by the present study can be attributed to their distinction from established routines of seasonal farming (Rahman et al., 2008). All of the farmers in our study site are poor[26] (Table 2), therefore initial capital support could be helpful to facilitate local adoption of agroforestry. Furthermore, the farmers do not have full

[26] As indicated by their daily income being less than US$1.25 per person. The US$1.25 level at 2005 purchasing power parity is essentially set the same way by the World Bank as the original US$1 per day poverty line (World Bank, 2015).

tenure rights to the land as it is owned by the state (Table 1). Therefore, swidden farmers tend to establish many small swidden plots across the landscape to spread risk[19] (Figure 3), and this practice is viewed as a major cause of tropical deforestation (Peng et al., 2014; Rahman et al., 2012). In contrast, agroforestry tends to be established in larger plots, reflecting the greater investment by households in this longer-term (more permanent) farming practice (Rahman et al., 2014; Michon, 2005). Tenure security is an important factor influencing land use decisions (Rahman et al., 2007; Feder et al., 1988). To adopt agroforestry instead of traditional seasonal cultivation, farmers need to invest substantial amounts of financial and labor resources. Insecure land tenure constrains such investments and has induced farmers to continue their traditional land use practices (Rasul and Thapa, 2003).

To adopt tree-based agroforestry systems, farmers may also need to develop a different set of skills, knowledge and technologies (Schultz, 1964), and the present study did find evidence of a strong positive association between education level and interest in adopting agroforestry within one group of farmers (those practicing swidden in Indonesia). Others (Roshetko et al, 2007b; Lipton, 1989; Binswanger, 1987) argue that smallholder farmers cannot use improved technology when structural constraints are imposed by institutions. Institutions not only govern the processes by which scientific and technical knowledge is created, but also facilitate the introduction and use of new technology in agricultural production. The equally important role of infrastructure, including transportation facilities and access to market centres, in facilitating land use change has been emphasised by Reardon et al. (2001), Turkelboom et al. (1996) and Allan (1986) as they increase the potential income from new crops and technologies. In Lampung, Indonesia a team of socioeconomic, forestry, horticulture and livestock specialists determined that smallholder agroforestry systems and the productivity of those systems are limited by a lack of technical information, resources and consultation (Gintings et al., 1996). Experience from across Indonesia shows that farmers' previous agricultural knowledge, quality of land resources, proximity to markets and level of support received (both technical and through policy) all play important roles in determining the technology adopted and subsequent success (Roshetko et al., 2007b; Potter and Lee, 1998; Gintings et al., 1996). Therefore, the motivation of self-interest – the desire to profit from their investment of time and resources – is invaluable for farmers' success, once skills, knowledge, and institutional support have been secured (Roshetko et al., 2008; Rasul and Thapa, 2007). If these institutional and policy requirements can be met, then agroforestry systems have great potential as a 'land sharing' option in the marginal farmlands that efficiently combines provision of local food security and environmental services of benefit to a wider population, instead of the 'land sparing' separation of agriculture and forests (Lasco et al., 2014; van Noordwijk et al., 2014).

Conclusions

The economic assessment of tree-based faming in our research shows higher net present value than that of seasonal agricultural systems in both West Java and eastern Bangladesh. Trees also help diversify farm products, which can potentially improve household nutrition and welfare. In both locations, agroforestry is a practice that has already been adopted by some households and this establishes the set of tree species that are popular in each location to incorporate into food-crop-based agricultural systems. This represents diversification of farming based on a combination of locally favoured tree and agricultural crops. Nonetheless, the cultural value of retaining the practice of seasonal agriculture with a narrow set of traditional subsistence food crops still has the potential to inhibit farm diversification through agroforestry. This resistance to changing farming practice is likely to be reinforced by the inability of many households to cope with the short-term loss of food crop productivity during the tree crop establishment phase, before tree products can be harvested resulting in longer-term net benefits. Insecurity of land tenure compounds this risk. Therefore, to implement such an initiative on the ground, a strong and long-term institutional framework is needed to provide more secure land tenure, and short-term technical and financial support (initial capital provided by NGO and Government agencies) during the tree establishment phase. The success of this framework will be greatly facilitated by the development and implementation of government policy involving a broad cross-section of local people to incorporate their aspirations, and sensitivity to their cultural values, in the planning and decision-making processes. This will also require provision of technical extension based on expert knowledge of tree planting and management, which is likely to benefit from further research. Participatory research may play a particularly valuable role in the areas of plant breeding to match local needs and the ecological functioning of agroforestry systems (Witcombe et al., 1996). This could result in agricultural sovereignty and self-sufficiency being operationalized spontaneously by the farmers in a smallholder tree-based farming environment that could lead to increases in tree cover in the agricultural landscape.

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Appendix 1

Assumptions for the calculation of Net Present Value:

The market for agricultural land is underdeveloped in the study areas, therefore the price of land is unstable and difficult to identify. However, as mentioned by MacDicken and Vergara (1990)[27], there is no need to value the land separately if farmers want to change their existing cultivation system to another. Thus, in our cash flow analysis the land value is omitted from the calculation (Table 1).

Farmers often use family labor for farm work, but hired labor is also important in the study area. Family labor is not a cash expenditure from the farmer's perspective, and it is complicated to identify the amount of family labor contributed to each cultivation system, as farmers have different household size and labor availability. Therefore, all calculations were conducted based on the total amount of labor per day required for each cultivation system. The costs of seeds, saplings, irrigation, pesticides and fertilizers are calculated based on the amount used for each cultivation system.

Table 1: Yearly cash flow of selected cultivation systems in the research sites (US$/ha). The value for 'Year' refers to the range of years, or individual years, in the calculation of cash flow between 0 and 30 that apply for each individual cost and revenue.

	Type of crop	Year	Cost	Revenue	Profit
Indonesia	Upland rice	1-30	217.10	1,500.00	1,282.90
	Maize	1-30	286.10	1,500.00	1,213.90
	Yam	1-30	268.60	1,800.00	1,531.40
	Cassava	1-30	365.60	1,500.00	1,134.40
	Peanut	1-30	308.60	1,500.00	1,191.40
	Soybean	1-30	145.00	445.00	300.00
	Durian	1	113.67	0.00	-113.67
		2-3	26.17	0.00	-26.17
		4-6	38.17*	220.00*	181.83
		7-8	44.17*	410.00**	365.83

[27] Macdicken K. G., Vergara N.T., (1990). *Agroforestry: Classification and Management.* John Wiley & Sons, New York.

		9-30	50.17*	1,100.00***	1,049.83
	Nutmeg	1	214.17	0.00	-214.17
		2-6	131.67	0.00	-131.67
		7-9	143.67*	200.00*	56.33
		10-12	173.67*	320.00**	146.33
		13-30	203.67*	560.00***	356.33
	Teak	1	360.00**	0.00	-360.00
		2-9, 12-19, 22-29	12.00	0.00	-12.00
		10, 20, 30	111.98*	30,000.00	29,888.02
		11, 21	300.00**	0.00	-300.00
Bangladesh	Upland rice	1-30	170.00	1,310.00	1,140.00
	Maize	1-30	195.00	1,715.00	1,520.00
	Sesame	1-30	160.00	1,062.50	902.50
	Turmeric	1-30	635.00	3,057.50	2,422.50
	Cucumber	1-30	261.00	2,327.25	2,066.25
	Banana	1-30	792.00	6,967.00	6,175.00
	Mango	1	150.00	0.00	-150.00
		2-5	17.31	0.00	-17.31
		6-8	30.00*	1,360.00*	1,330.00
		9-11	70.00*	3,157.52**	3,087.52
		12-30	95.00*	5,320.00***	5,225.00
	Jackfruit	1	130.00	0.00	-130.00
		2-5	16.50	0.00	-16.50
		6-7	25.00*	858.33*	833.33
		8-9	50.00*	1,716.67**	1,666.67
		10-30	70.00*	2,570.00***	2,500.00
	Lychee	1	140.00	0.00	-140.00
		2-5	16.50	0.00	-16.50
		6-8	35.00*	1,188.84*	1,153.84
		9-11	90.00*	3,423.33**	3,333.33
		12-30	115.00*	4,730.38***	4,615.38
	Mangium	1	130.00**	0.00	-130.00
		2-9, 12-19, 22-29	12.50	0.00	-12.50
		10, 20, 30	100.00*	6,600.00	6,500.00
		11, 21	130.00**	0.00	-130.00

* Additional labor cost for fruit/timber harvesting; ** additional cost for saplings.
* Low production; ** medium production; *** high production.

Chapter Five

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,

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[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).

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 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.

[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.

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 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.

[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.

[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.

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.

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.

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[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.

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 (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.

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.

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

[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 Appendix 1.

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.

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

[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).

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 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

[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).

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

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[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).

valuable source of funding for initial investments and the subsequent inputs needed to improve land use practices, as land without secure tenure does not qualify as collateral (see also Rahman et al., 2012).

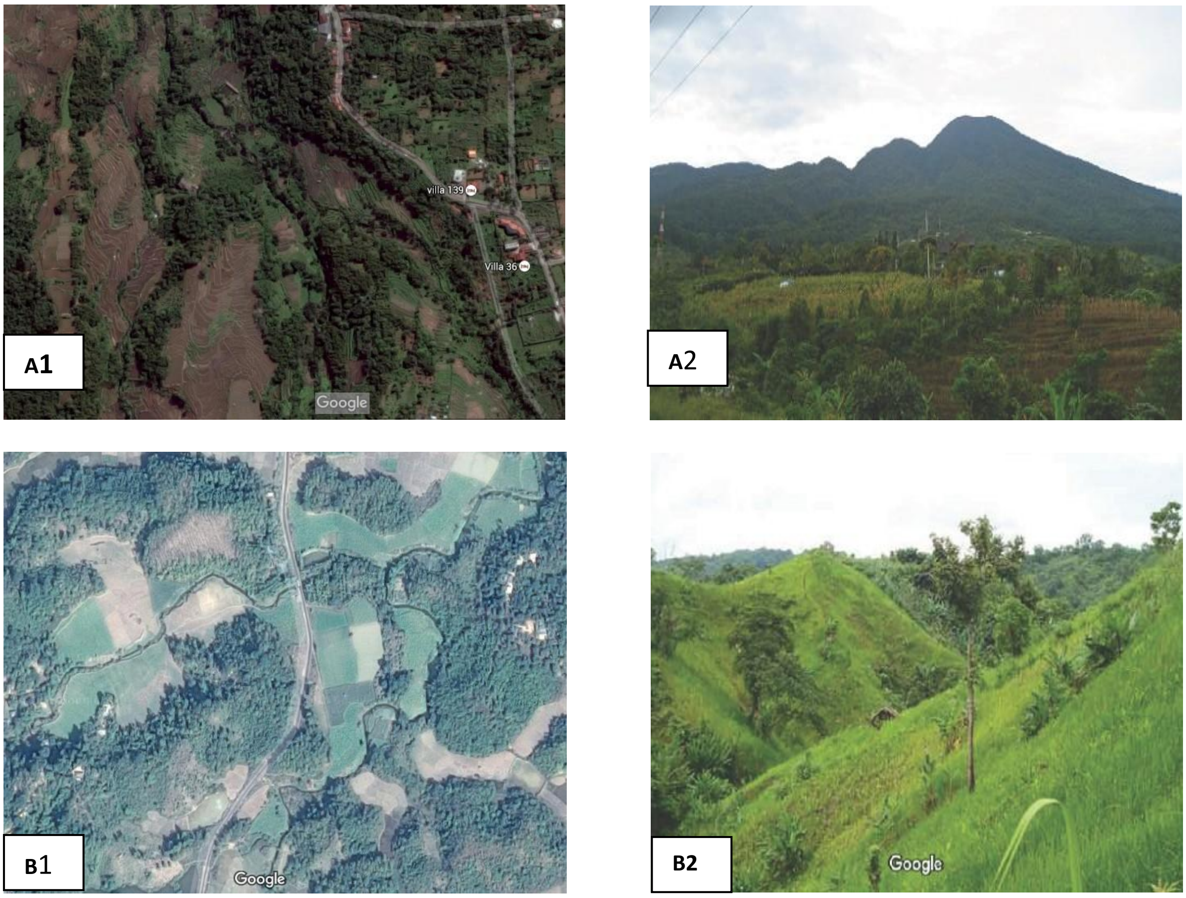


Figure 1. Degraded forest land in the study sites (A, Indonesia; B, Bangladesh), A1 and B1 satellite images, A2 and B2 photos of the studied landscapes. © Google Earth (2015).

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,

[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.

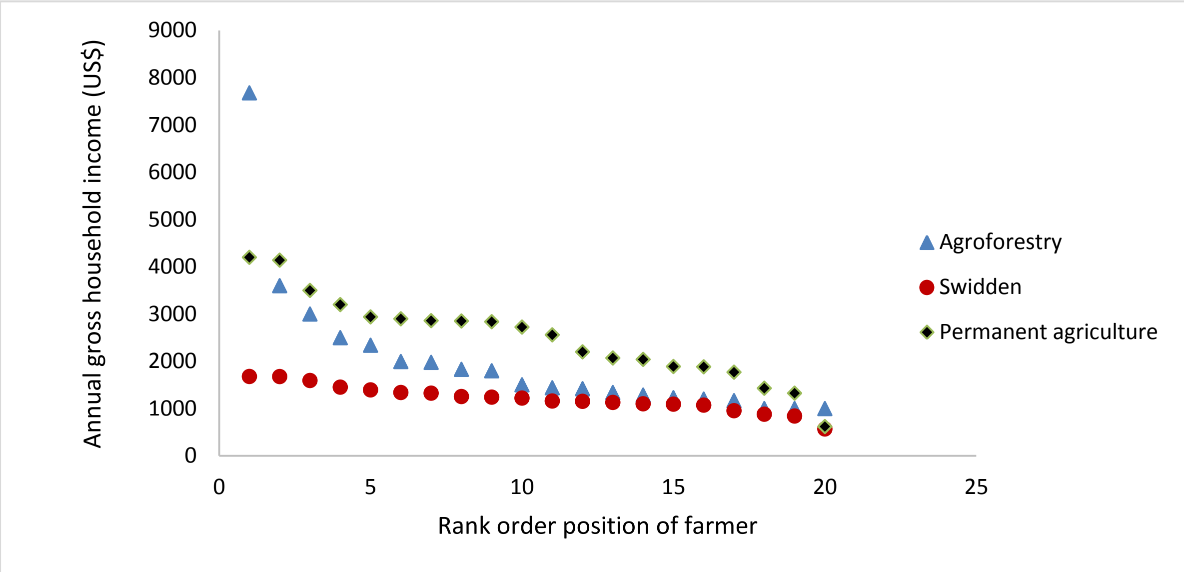
2015) (Table 2). Low income and poverty continues to be a national problem, with 31.5% and 11.3% of people living below the poverty line in Bangladesh and Indonesia respectively (ADB, 2016a). Government subsidies, e.g. pension allowances, and disabled and vulnerability schemes, are rare and no interviewed 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 2. Mean (and standard error of the mean) value of family size, farm size, income, expenditure, savings and debt 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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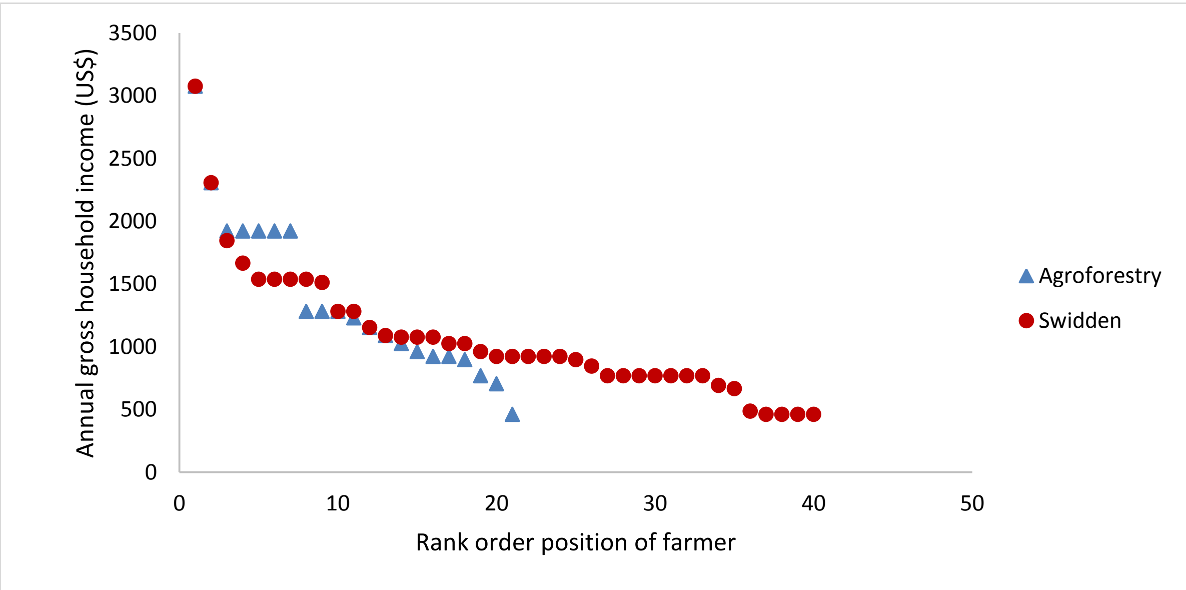

Figure 2. Annual gross household income (US$) of surveyed farmers by group: a) agroforestry, swidden and permanent agriculture in Indonesia; b) agroforestry and swidden in Bangladesh. Within each group the farmers are arranged in rank order from the highest to the lowest income.

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 management, 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.

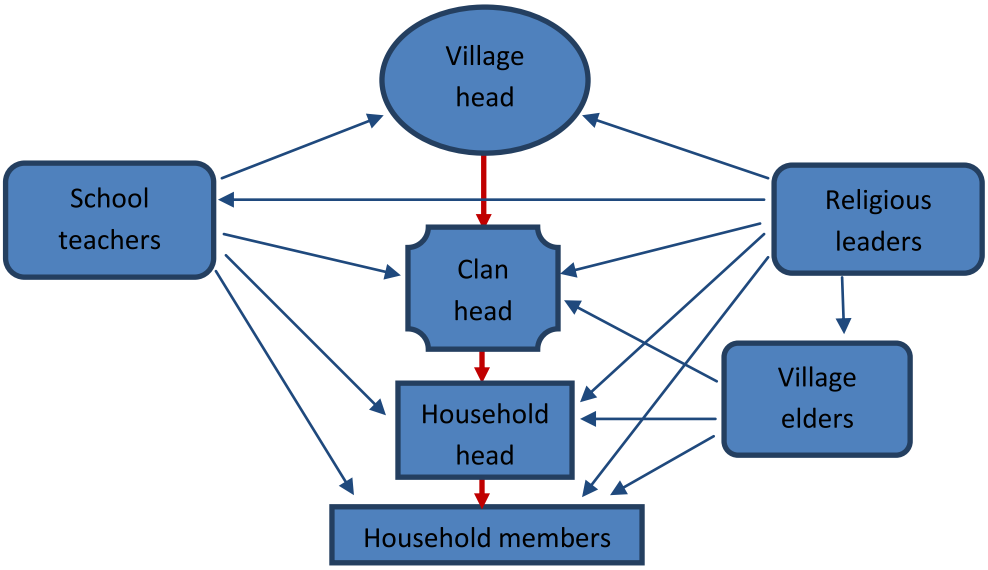

Figure 3. Customary community power structure of all three villages in the Indonesia study site and both villages in the Bangladesh study site as revealed in the focus group discussions. Within the hierarchy of positions of the principal actors the bold red arrows show the actor who has power over those lower down in the diagram. The thinner arrows illustrate the influence of different actor groups (i.e. school teachers, religious leaders, village elders) that was 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 3). 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 2), 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

[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.

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 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 3). In both sites the most 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%). In Bangladesh, however, 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 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 for 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 2). 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

[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 are often stolen by other people because of the poor state of law enforcement in the area.

that there has been a general lack of interaction of extension workers with the study villages and a specific lack of agroforestry extension.

Table 3. 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

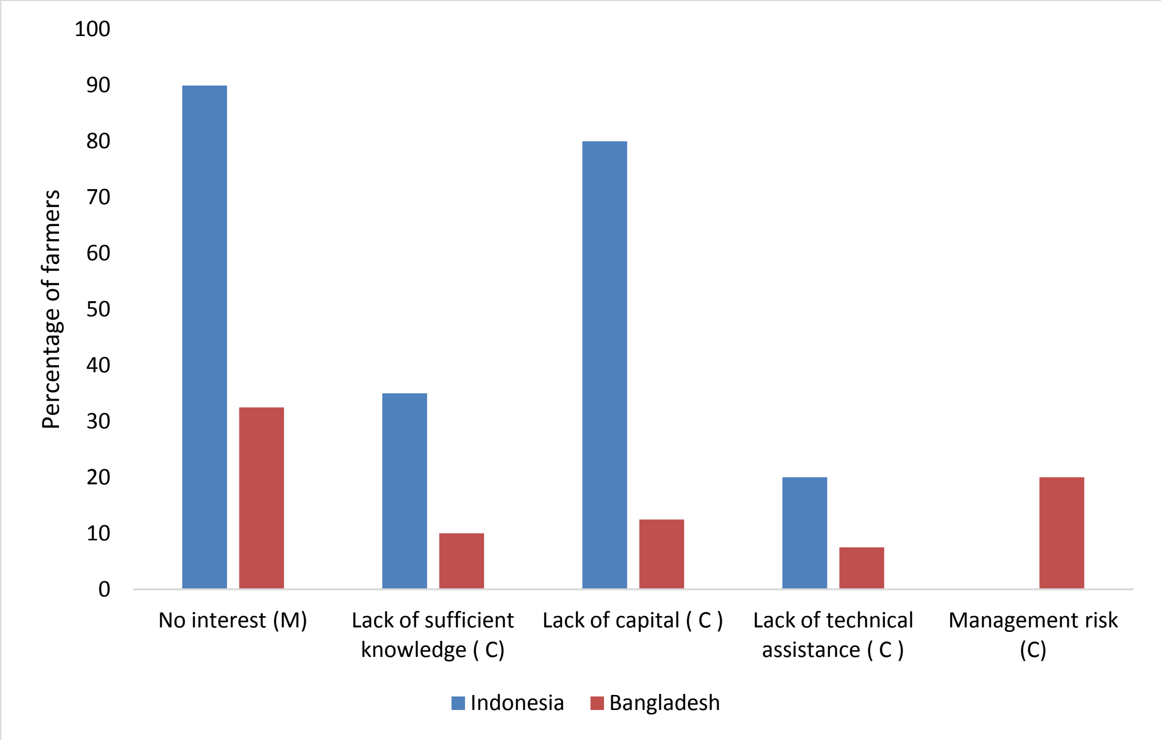

Figure 4. Constraints on the adoption of agroforestry mentioned by 20 and 40 key informant swidden farmers in Indonesia and Bangladesh respectively during semi-structured questionnaire interviews. The motivational factor is marked with M and factors related to capacity are marked with C.

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 3), 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 3). 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

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

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 4.). 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.
- 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 4) 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 4), 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 4. 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 yielding 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 a 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, and 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 4) (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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Appendix 1

Table 1: 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*

Chapter Six

Synthesis and Conclusions

Agroforestry: classification and terminology

Agroforestry science has a knowledge gap to document the multitude of agroforestry systems that are practiced in different environmental, climatic, economic and socio-cultural conditions (Mbow et al., 2013; Snelder and Lasco, 2008; FAO, 2006). This documentation is crucial for the development of policy frameworks (Snelder and Lasco, 2008; Sinclair, 1999). Therefore, our result (Chapter 2) is a valuable contribution of information on the documentation of the agroforestry systems being practiced in the Gunung Salak Valley, Indonesia. The documentation was made according to the structure, components involved and management practices of the systems. The systems were found to be locally derived from antecedent agricultural systems that have long provided livelihood necessities, in particular swidden farming, through farmers' long experience of trialing new practices. All of the systems are characterized by dense undergrowth, high and closed tree canopy, and high levels of agro-biodiversity. These characteristics of the systems were found to correspond to many of those observed by studies in other parts of West Java, throughout Indonesia and more widely across tropical Asia (Roshetko et al., 2013; Krisnawati et al., 2011; Manurung et al., 2008; Snelder and Lasco, 2008; Michon, 2005).

The canopy cover of trees in the agroforestry farms of the Gunung Salak site ranged between 30% and 70%, and often occur in patches > 0.5 ha, and would easily be confused with either primary or secondary forests in a superficial survey, e.g. using remote sensing. However, these agroforests would not be included in the definition of 'forest' used by FAO in its global forest resource assessment, which specifically excludes stands of trees that are primarily established for the purpose of agricultural production, for example fruit tree plantations (FAO, 2015). Given that these agroforests provided many of the products and ecosystem services associated with forests, e.g. timber, fuel, non-timber forest products, a carbon sink (Beenhouwer et al., 2013; Roshetko, 2013; Gardner et al., 2009), the concept of 'forest' defined by FAO is not fit for the purpose of providing reliable evidence to inform land-use policy. Therefore, the operational classification of land-use systems should be more fine-tuned, such as using ordination, to incorporate the economic, social and environmental characteristics of the wider range of existing systems. For example, if the purpose of classification is to analyze food production, then all systems that can provide food might be placed in the same ‘agriculture’ class. If the analysis is focused more on environmental benefits provided by trees, then all systems that will surpass a certain threshold of tree cover might be placed in the same ‘forest’ class.

Alternatives to slash-and-burn: benefits of agroforestry, and its link to the protection of local forests

Agricultural encroachment by smallholder farmers using slash-and-burn is considered to be a major cause of tropical deforestation (Li et al., 2014; Rahman et al., 2012; Angelsen, 1995). This land use change has many negative consequences for ecosystem services including enhanced greenhouse gas emissions from the use of fire, as documented in Indonesia by CIFOR (2015) and GFED (2015). Smallholder farmers are often driven by economic imperatives and, for them to consider changing to a different land use system, this new system must be more profitable than the existing system (Predo and Francisco, 2008).

Agroforestry systems that smallholder farmers develop with limited resources (land, capital) to meet their livelihood needs can be a viable alternative to slash-and-burn (Roshetko, 2013; Rahman et al., 2012). However, across landscapes there are often a wide range of different agroforestry systems for which there is a shortage of reliable empirical data on economic profitability (Vira et al., 2015; FAO, 2005; Hosier, 1989).

Based on the empirical data collected in this study, the economic analysis (CBA) of the agroforestry systems practiced by the communities in Gunung Salak valley, West Java, showed a higher net present value (NPV) and benefit-cost ratio (B/C) than the swidden cultivation systems (Chapter 3). Our CBA modeling on the inclusion of tree crops in seasonal agriculture farms (both in swidden and permanent systems) also showed how this improved economic performance (NPV) in both our research sites in West Java and eastern Bangladesh (Chapter 4). As the agroforestry farmers grow varieties of crops for their own consumption and/or for sale, cost-benefit analysis (CBA) is an important method for analysis of the economic performance of such systems in a specific area (Atangana et al., 2014; Rahman et al., 2008; Elevitch and Wilkinson, 2000).

This study also demonstrated farmers' experience as agroforestry systems increased livelihood security as a 'safety-net' function, by supporting farmers during periods of vulnerability, such as crop failure and illness (Chapter 5). As trees also help diversify farm products, they can potentially improve household nutrition and welfare. Tree ownership is perceived to be prestigious in the community, creates more permanent rights to farmland, and helps strengthen social cohesion (Chapter 3). Tree cultivation is also important for cultural ecosystem services. For instance, mango and banana are considered to have high cultural significance in the study sites, and their leaves are used in religious and social ceremonies.

The agroforestry deforestation hypothesis' suggests that increased adoption of agroforestry reduces local rates of deforestation and forest degradation, e.g. by providing an alternative source of forest products like timber, firewood and fodder (Atangana et al., 2014). This research does provide support for this hypothesis with evidence of a lower rate of forest exploitation by agroforestry than swidden farmers in the Gunung Salak study site (Chapter 3).

These results corroborate the studies conducted in West Sumatra, Indonesia, Mindañao, the Philippines, Kavrepalanchok, Nepal and elsewhere, which also found that agroforestry systems have potential to reduce pressure on local forests (Pandit et al., 2014; Scherr and McNeely, 2008; Strandby-Andersen et al., 2008; Garrity et al., 2002; Murniati et al., 2001). Therefore, they do justify Roshetko's (2013) emphasis of the potential of smallholder tree-based farming to expand regional forest resources thus expanding the productive base for forest products and services, as well as representing a major contribution to local livelihoods.

However, the studies' results do still leave open the possibility that under some circumstances, because of its profitability, agroforestry may incentivize farmers to convert more forest area into agroforestry farms (Angelsen and Kaimowitz, 2001). Nevertheless, this is not the issue that has been found from the case of this study.

Barriers to adoption of agroforestry by smallholder farmers

Across landscapes, smallholders' adoption of agroforestry by planting trees on their farm land is often associated with various objectives and usages and differs from larger-scale tree plantations in the motives for tree species selection, attitudes towards livelihood risk management, and approaches to tree management and marketing (Snelder and Lasco, 2008; Arnold and Dewees, 1999; Scherr, 1995). However, this study found strong evidence that the adoption and economic success of agroforestry practices depends on farmers' ability to overcome a number of barriers (Chapter 3, 4 and 5).

Despite high income prospect and positive social value (Chapter 3 and 4), the barriers to adoption of agroforestry by smallholders in the Indonesia and Bangladesh study sites are related to the local cultures that influence farmers' decisions to continue traditional farming practices, lack of sufficient capital to invest in agroforestry, lack of sufficient knowledge, lack of technical assistance, insecure land tenure, and management risk as discussed in chapters 3, 4 and 5. Lack of capital is a serious constraint on initial investment in agroforestry. This is particularly true for swidden farmers as their cultivation practices are largely subsistence-oriented and their yields are not sufficient to form the initial capital to invest in agroforestry.

Farmers' decisions may over-ride the constraints of cultural adherence to traditional farming practice if the positive economic and social value of agroforestry is strong enough. This may occur due to the high monetary value of tree products, the value of tree planting for establishing land rights, prestige, and strengthening social cohesion by sharing fruit and vegetable products with neighbours (Chapter 3 and 4). Overcoming other barriers (as described above), farmers' adoption of agroforestry can be increased by the implementation of supportive policies and measures, such as capital support, establishment of tailored market system, secured land tenure, and technical assistance by government and non-government organizations (Chapter 3, 4 and 5). Effective policies should be propagated not by temporary projects but by long-term, government-backed institutions that are focused on agroforestry practices that may need adaptation to meet new opportunities and constraints. Moreover, to strengthen such supportive institutions it should consider both the internal relevance to institutions (i.e. rules, norms and codes that define the formal and informal rights, privilege and obligations of various groups involved) and organizations (i.e. the physical manifestation of institutions) as well as factors of external relevance (i.e. external setting defined by social, economic, environmental, and institutional features) (Roshetko et al., 2008; Kant and Berry, 2005). This is because, even though farmers grow trees under a range of different environmental conditions and stages of land-use intensification throughout the tropics (van Noordwijk et al., 1997; Arnold and Dewees, 1995), in many locations farmers' decisions to adopt agroforestry are highly dependent on a combination of favorable conditions (Rahman et al., 2008; van Noordwijk et al., 2008).

Landscape approaches: land-use decision making in West Java and eastern Bangladesh

'Landscape approaches' are increasingly seen as an imperative to expand food production while also protecting ecosystems, and at the same time reducing poverty and coping with climate change through integrated planning and decision-making (Sayer and Buck, 2015; Sayer et al., 2013). Therefore, to make landscape approaches effective at various landscape scales, there is a need for careful landscape design to counter local land-use challenges. This needs to be highly participatory to ensure that it is informed and supported by coherent local communities, as well as competent government policies (Watts and Colfer, 2011; Lawrence, 2010; Sayer, 2009; Laven et al., 2005).

Local land use challenges in Guning Salak, West Java, and eastern Bangladesh are associated with internal and external factors, such as population pressure, deforestation, poverty, lack of community control, weak tenure, and poor government services (Chapter 5). To cope with these challenges, a mixed land management approach is required, which needs to include elements of both segregation and integration of land uses, supported by competent government policies and local communities having sufficiently high social capital.

This is because, in reality, considering just a single approach, such as 'segregation' inherent in the 'land sparing' landscape model is not sufficient to achieve conservation goals alone (van Noordwijk et al., 2001). Therefore, in the research sites in West Java and eastern Bangladesh, to protect remaining forest from further human disturbance, a carefully designed 'segregation' approach will require the boundary of protected forest to be drawn. However, in the agricultural land areas 'integration' through agroforestry can be used to enhance farm production, income and environmental conservation. The sustainability of agroforestry will enable it to achieve medium- and long-term goals in the provision of valued goods and services (see van Noordwijk et al., 2001). Even the efficiency of close integration for various functions from a single land-use system (e.g. swidden) is often questioned (Michon, 2005), smallholder agroforestry can provide such functions from its single system (Chapter 2, 3, 4 and 5).

Smallholder agroforestry systems practiced by some farmers in the study sites are generally successful from their own perspective. This is because, farmers' familiarity with the sites that they select for tree planting, and the care with which they plant and tend trees results in high rates of tree survival. Their management practices are targeted at their specific objectives which are generally to maximize yield of valued products. However, in local challenging land use conditions, various changes are needed to overcome existing barriers to agroforestry adoption in order to enable the widespread expansion of the 'integrated' land-use approach as discussed in chapter 5 (i.e. securing land tenure and provide flexible credit, tailored market system, integrating trees into traditional food crop systems, strengthening community capacity, involving local people in decision-making processes, useful government extension services, security of farm management, up to date agroforestry research to identify and address critical knowledge gaps).

A decline in the availability of local forest resources (due to deforestation and forest degradation) can potentially provide an incentive for smallholders to plant trees on their farmland. The net result of these decisions would be that an expansion of agroforestry practice would offset the loss of forest resources at a landscape level, and could contribute to an increase in these resources, and the supply of goods and services that they produce. This could increase net income of farming households in the landscape (unless this resulted in market saturation for forest products), and potentially every farmer who has the land and capacity to adopt agroforestry could benefit. However, the distribution of the remaining constraints to adoption amongst farming households would be important in determining the net effect of increased agroforestry on equity.

Limitations of the research and future research needs

To obtain high quality data of farm income, it would be best to collect it on at least a quarterly basis over at least a full year. Less frequent sampling reduces the accuracy due to a longer recall period for respondents, especially if they have to report irregular farm income sources. This may be a particular issue for agroforestry farms for which the timing of income (e.g. from fruits) may be very irregular. However, due to the time limitation of the fieldwork for this research (i.e. six months), it was not possible to collect data on a quarterly basis covering a full year. Therefore, data on the selected farming systems had to be collected based on a relatively long recall period for the farmers, i.e. the most recent whole production year. In addition, at the time of data collection, for most of the sampled agroforestry farms, their timber trees had yet to reach a harvestable size and in some cases fruit trees had yet to grow to maturity and achieve maximum fruit yield. Therefore, agroforestry farmers are likely to have had to use a greater degree of estimation of their income from tree crops, compared with the other farmer types. Even for agroforestry farmers with mature trees, where income from tree products is highly variable amongst years (e.g. for timber) a longer duration of total sampling period would be valuable to increase accuracy.

Many products from forests, e.g. firewood, food and fodder, are harvested illegally. This makes respondents nervous about revealing their involvement in this harvesting, and what exact volume of product is harvested (Duffy et al., 2016; St John et al., 2012). This same issue applies to farm involvement in deforestation to convert land to farming. Moreover, smallholder agricultural systems are under-represented in land use research (Roshetko, 2013; Snelder and Lasco 2008) and so there is a deficit of well developed and tested research methods that are suited to smallholder farmers. Overcoming these restrictions in research methodology to substantially improve the evidence base of smallholder farmer decision making will be particularly important for testing the 'agroforestry-deforestation' hypothesis across a range of socioeconomic and biophysical conditions (e.g. varying in the availability of surplus labour and capital resources), which is a major gap in the agroforestry literature. This will be important to determine under what conditions farmers who adopt agroforestry appear to reduce their rate of exploitation of forest resources (as was found to be the case in my study) or under what conditions agroforestry farmers subsequently expand their land managed under this system into forest areas (or their success attracts other farmers to clear forest in order to take up this practice).

Given the diversity of agroforestry practices (and system components) amongst farmers and locations, there is a lack of clear evidence about the variation in contributions by agroforestry to the delivery of different ecosystem services. Improving this knowledge base (e.g. through modeling) will be facilitated by research that produces a more sophisticated approach to system classification incorporating the systems' economic, social and environmental characteristics. Better characterizing the fit of these systems into landscapes will be crucial to model individual ecosystem services across the range of scales that they are delivered.

With a focus on small-holders for whom their farming is largely for subsistence, and so crucial for food security, the potential for successful adoption of agroforestry (that increases their welfare) will be strongly dependent on the effects of tree planting on their food crop production. My research used evidence that this effect can vary greatly dependent on the interaction of individual tree and crop species. Yet there is a lack of reliable research evidence about these effects to inform extension advice to smallholders about their choice of tree species, tree management methods and potential adjustments they should make to their crop selection (Tscharntke et al., 2011). It is important to recognize the potential importance of trees on the water balance of crops, which may be of growing importance in those areas of the tropics where future climate change reduces rainfall, or increases the duration of dry seasons. During my fieldwork I observed that many agroforestry farmers have given up planting understorey crops after a few years of adopting agroforestry. Future research should determine the reasons behind this, e.g. whether it is because they cannot achieve sufficient yields, or it is not the most profitable use of their labour compared with off-farm employment opportunities, or constraints of marketing the produce.

While my research has informed conclusions about the importance of enhancing farm income through the integration of markets and collaboration in marketing amongst producers, empirical evidence to validate these recommendations for agroforestry farmers in the two study sites is lacking (and is very sparse elsewhere). Research to address this gap should consider the local nature of supply-and-demand, market competition and farmers' options to address such competition. Research across all of these areas (from crop ecophysiology to market mechanisms) will be required to obtain a comprehensive understanding of the most important factors motivating or constraining farmers from adopting agroforestry and then persisting with this system.

For agroforestry to play a positive role in rural development it is important not just to know how it affects the welfare of those farmers who are able to adopt it, or even the net impact on welfare across communities. Instead it is also vitally important to know how increased adoption of this practice affects economic equity within and between communities, and specifically the livelihoods of most resource poor farmers, who might be the least able to adopt it. In other words, how efficient is it at alleviating the most extreme poverty. Livelihoods are not just about income or food provisioning, but may also be dependent on a range of other ecosystem services (which can be vital for the sustainability of people's livelihoods) and forests and agroforests may be particularly important for supplying this range of services in many landscapes. Therefore, research to assess the impact of agroforestry adoption on (long-term) equity needs to incorporate the whole range of relevant ecosystem services.

Many agroforestry landscapes are rich in biodiversity (e.g. cardamom agroforestry in the Eastern Himalaya) and some contribute to income from ecotourism due to their high aesthetic value (Sharma et al., 2008). While there is a growing body of literature on the contribution of agroforestry systems to biodiversity conservation (Clough et al., 2009; Steffan-Dewenter et al., 2007) there is a comparative lack of evidence about the impact of these effects on local livelihoods, which future research should address. This is important if the biodiversity conservation-motivated development of “land sharing” versus “land sparing” models for land use at a landscape scale, are going to be made compatible with sustainable development that does truly meet the livelihood needs of farming communities. Given the strong international interest in conservation of tropical forest biodiversity and other global ecosystem services delivered by tropical forests, such as climate regulation, research that provides robust evidence on the contribution of agroforestry systems to the delivery of these international objectives, while succeeding down through the scale of landscape to community and individual farming household, should be a high international priority.

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APPENDICES

(Questionnaires, and code list)

Farm household interview (HQ1): Agroforestry farmers

Control information

Task	Date(s)	By who?	Status OK? If not, give comments
Interview			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Identification

Identification and location of household

1. Household name and code	*(name)*	*(HID)*
2. Village name and code	*(name)*	*(VID)*
3. Name and PID (see B. below) of primary respondent	*(name)*	*(PID)*
4. Name and PID (see B. below) of secondary respondent	*(name)*	*(PID)*
5. Distance of the household from the centre of village (in *minutes of walking* and in *km*)	*1.* *min*	*2.* *km*
6. How far is the household from the edge of the nearest natural or managed forest?	1. … measured in terms of distance (straight line)?	*km*
	2. … measured in terms of time (in minutes of walking)?	*min*

B. Household composition

1. Who are the members of the household?

1. Personal Identification number (PID)	*** Name of household member**	**2. Relation to household head**	**3. Year born** *(yyyy)*	**4. Sex** *(0=male 1=female)*	**5. Education** *(number of years completed)*
1		Household head = code 0			
2					
3					
4					
5					
6					
7					
8					
9					
10					

Codes: *1=spouse (legally married or cohabiting); 2=son/daughter; 3=son/daughter in law; 4=grandchild; 5=mother/father; 6=mother/father in law; 7=brother or sister; 8=brother/sister in law; 9=uncle/aunt; 10=nephew/niece; 11=step/foster child; 12=other family; 13=not related (e.g., servant).*

2. Questions regarding the head of this household.

1.	What is the marital status of household head? *Codes: 1=married and living together; 2=married but spouse working away; 3=widow/widower; 4=divorced;; 5=never married; 9=other, specify:*	
2.	How long ago was this household formed	*years*
3.	Was the household head born in this village? *If 'yes', go to 5.*	*(1-0)*
4.	**If 'no':** how long has the household head lived in the village?	*years*
5.	Does the household head belong to the largest ethnic group/caste in the village?	*(1-0)*

C. Land

1. Amount of land (*ha*) that currently own and have rented in/out.

Category	**1. Area**	**2. Ownership** *(code tenure)*	**Main products collected in the past 12 months Max 3**		
			3. Rank1	**4. Rank2**	**5. Rank3**
1. Agroforestry					
2. Homestead					
Other land:					
3. Cropland (other than agroforestry)					
4. Pasture (natural or planted)					
5. Fallow					
6. Other vegetation types/land uses (forest, plantation, bush, grassland, wetland, etc.)					
7. Total land owned (1+2+3+…+6)					
8. Land rented out (**included** in 1-6)					
9. Land rented in (**not included** in 1-6)					

D. Assets and savings

1. Type of house.

1. Do you have your own house? 1)	
2. What is the type of material of (most of) the walls? 2)	
3. What is the type of material of (most of) the roof? 3)	
4. How many m^2 approx. is the house?	*m^2*

1) Codes: 0=no; 1=own the house on their own; 2=own the house together with other household(s); 3=renting the house alone; 4=renting the house with other household(s); 9=other, specify:
2) Codes: 1=mud/soil; 2=wooden (boards, trunks); 3= metal sheets; 4=bricks or concrete; 5=reeds/straw/grass/fibers; 9=other, specify:
3) Codes: 1=thatch; 2=wooden (boards); 3=iron or other metal sheets; 4=tiles; 9=other, specify:

2. Number and value of implements and other large household items that are owned by the household.

	1. No. of units owned	**2. Total value (current sales value of all units, not purchasing price)**
1. Car/truck		
2. Tractor		
3. Motorcycle		
4. Bicycle		
5. Handphone/phone		
6. TV		
7. Radio		
8. Cassette/CD/ VHS/VCD/DVD/ player		
9. Stove for cooking (gas or electric		

only)		
10. Refrigerator/freezer		
11. Fishing boat and boat engine		
12. Chainsaw		
13. Plough		
14. Scotch cart		
15. Shotgun/rifle		
16. Wooden cart or wheelbarrow		
17. Furniture		
18. Others (worth more than approx. 50 USD purchasing price)		

3. Savings and debt of the household.

1. How much does the household have in savings in banks, credit associations or savings clubs?	*Lc$*
2. How much does the household have in savings in non-productive assets such as gold and jewelry?	*Lc$*
3. How much does the household have in outstanding debt?	*Lc$*

4. Occupation, income and expenditure of the household

	1. Occupation 1	**2. Occupation 2**	**3. Occupation 3**
1. What is your occupation?			
2. What is your total yearly income?			
3. What is your yearly total expenditure?			

E. Income from agriculture – crops

1. Quantities and values of products that household has harvested from **agroforestry** in **the past season/year**.

1.Products: food (i.e., cereals, vegetables, fruits), **fibre, fuel, medicine,** other **raw materials**, and **ornamental** species. *(code-product)*	**2. Ownership** *(code-tenure)*	**3. Area of production** (*ha)*	**4. Total production (unit) (5+6)**	**5.Own use (unit) (incl. gifts)**	**6. Sold (unit)**	**7. Costs of total production** (*ha)*	**8. Price of total production** (*ha)*	**9.Total value (7-8)**

2. Quantities and values of products that household has harvested **(other than agroforestry)** in **the past season/year**.

1.Products: food (i.e., cereals, vegetables, fruits), **fibre, fuel, medicine,** other **raw materials**, and **ornamental** species. *(code-product)*	**2. Ownership** *(code-tenure)*	**3. Area of production** (*ha*)	**4. Total production (unit) (5+6)**	**5.Own use (unit) (incl. gifts)**	**6. Sold (unit) (incl. barter)**	**7. Costs of total production** (*ha*)	**8. Price of total production** (*ha*)	**9.Total value (7-8)**

F. Crisis and unexpected expenditures

1. Major income shortfalls or unexpectedly large expenditures during the past 12 months.

Event	**1. How severe?** 1)	**How did you cope with the income loss or costs?** *Rank max. 3*2)		
		2. Rank1	**3. Rank2**	**4. Rank3**
1. Serious crop failure				
2. Serious illness in family (productive age-group adult unable to work for more than one month during past 12 months, due to illness, or to taking care of ill person; or high medical costs)				
3. Death of productive age-group adult				
4. Land loss (expropriation, etc.)				
5. Major livestock loss (theft, drought, etc.)				
6. Other major asset loss (fire, theft, flood, etc.)				
7. Lost wage employment				
8. Wedding or other costly social events				
9. Other, specify:				

1) Codes severity: 0=no crisis; 1=yes, moderate crisis; 2=yes, severe crisis.

2) Codes coping:

1. *Harvest more forest products*
2. *Harvest more wild products not in the forest*
3. *Harvest more agricultural products*
4. *Spend cash savings*
5. *Sell assets (land, livestock, etc.)*
6. *Do extra casual labour work*
7. *Assistance from friends and relatives*
8. *Assistance from NGO, community org., religious org. or similar*
9. *Get loan from money lender, credit association, bank etc.*
10. *Tried to reduce household spending*
11. *Did nothing in particular*

19. *Other, specify:*

G. Forest clearing

1. Did the household clear any forest during the past 12 months? *If 'no', go to 9.*		*(1-0)*		
If YES:	2. How much forest was cleared?	*ha*		
	3. What was the cleared forest used for? *Codes: 1=permanent monoculture; 2=agroforestry;3=tree plantation; 4=pasture; 5=non-agric uses (Rank max 3)*	1.Rank1	2.Rank2	3.Rank3
	4. If used for crops (code '1' in question above), which principal crop was grown? *(code-product) Rank max 3*	1.Rank1	2.Rank2	3.Rank3
	5. What type of forest did you clear? *(code-forest)*			
	6. If secondary forest, what was the age of the forest?	*years*		
	7. What was the ownership status of the forest cleared? *(code tenure)*			
	8. How far from the house was the forest cleared located?	*km*		
9. Has the household over the last *5* years cleared forest? *If 'no', go to 11.*		*1-0*		
10. **If 'yes':** how much forest (approx.) has been cleared over the last 5 years? *Note: This should include the area reported in question 2.*		*ha*		
11. How much land used by the household has over the last 5 years been abandoned (left to convert to natural re-vegetation)?		*ha*		
12. IF ABANDONED, why?				
13. Did you collect any firewood from forest? if yes please specify		*Kg/month*		
14. Did you collect any fodder from forest? if yes please specify		*Kg/month*		
15. Did you collect any food (e.g. mushroom, fruits) from forest? if yes please specify		*Kg/month*		

H. Welfare perceptions and social capital

1. All things considered, how satisfied are you with your life over the past 12 months? *Codes: 1=very unsatisfied; 2=unsatisfied; 3=neither unsatisfied or satisfied; 4=satisfied; 5=very satisfied*		
2. Has the household's food production and income over the past 12 months been sufficient to cover the what you consider to be the needs of the household? *Codes: 1=no; 2=reasonable (just about sufficient); 3=yes*		
3. Compared with other households in the village (or community), how well-off is your household? *Codes: 1=worse-off; 2=about average; 3=better-off*		
4. How well-off is your household today compared with the situation **5 years ago?** *Codes: 1=less well-off now; 2=about the same; 3=better off now* *If 1 or 3, go to 5. If 2, go to 6.*		
5. **If worse-** ***or*** **better-off:** what is the main reason for the change? *Please rank the most important responses, max 3.*	**Reason: Change in …**	**Rank 1-3**
	1. off farm employment	
	2. land holding (e.g., bought/sold land)	
	3. forest resources	
	4. output prices (forest, agric,…)	
	5. outside support (govt., NGO,..)	
	6. remittances	
	7. cost of living (e.g., high inflation)	
	8. war, civil strife, unrest	
	9. conflicts in village (non-violent)	
	10. change in family situation (e.g. loss of family member/a major bread-winner)	
	11. illness	

	12. access (e.g. new road,…)	
	13.	
	14.	
	15. other, specify:	
6. Do you consider your village (community) to be a good place to live? *Codes: 1=no; 2=partly; 3=yes*		
7. Do you **in general** trust people in the village (community)? *Codes: 1=no; 2=partly, trust some and not others; 3=yes*		
8. Can you get help from other people in the village (community) if you are in need, for example, if you need extra money because someone in your family is sick? *Codes: 1=no; 2= can sometimes get help, but not always; 3=yes*		
9. Do you exchange any goods (e.g., serials, fruits, fuelwood, etc.) with neighbors?	1. If yes, what types?	
	2. In what reason?	

I. Forest services

1. Has the household over the past 12 months received any cash or in kind payments related to the following forest services?

Principal purpose	**1. Have received?** *(1-0)*	**2. If yes, amounts (values) received** *(Lc$)* *(if nothing, put '0')*
1. Tourism		
2. Carbon projects		
3. Water catchments projects		
4. Biodiversity conservation		
5. Other, specify:		

J. Other income sources

1. Other income that the household has received during **the past year**.

1. Type of income	**2. Total amount received past year**
1. Remittances	
2. Support from government, NGO, organization or similar	
3. Gifts/support from friends and relatives	
4. Pension	
5. Payment for forest services	
6. Payment for renting out land (if in kind, state the equivalent in cash)	
7. Compensation from logging or mining company (or similar)	
8. Other, specify:	

K. Agroforestry

1. Types of agroforestry practiced by the household

1. *(This one should be explain further in section 2 below)*	*main*
2.	
3.	

2. Yearly agroforestry income and expenditure (*main*)

	Items		Quantity (e.g., kg/ha/year)	Cost per unit (Lc$)
1. Types of expenditure	1. Irrigation			
	2. Fertilizer			
	3. Pesticide			
	4. Weeding			
	5. Pruning			
	6. Harvesting			
	7. Processing			
	8. Protection			
	9. Labor cost	Family labor		
		Hired labor		
	10. Other, specify:			
	Total			
2. Agroforestry establishment cost (land preparing, seeds, sapling etc.)				
3.Income earned from agroforestry			**Quantity (e.g., kg/ha/year)**	**Cost per unit (Lc$)**
	1. Cereal crops (paddy, wheat, etc.)			
	2. Vegetables			
	3. Spices (ginger, pulse, etc.)			
	4. Fruits			
	5. Medicine (herbal)			
	6. Honey			
	7. Fodder for livestock			
	8. Timber			
	9. Fuel wood			
	10. Other, specify:			
	Total			

3. Agroforestry practices

1. How long are you practicing agroforestry?		
2. What types of trees (tree species) have you in the farm? (local name)		
3. What types of crops have you in the farm? (local name)		
4. Do you have any contact with agriculturist?	1. Yes 2. No If yes, what types of contact?	
5. Reason for agroforestry practice/adoption	1. High income	
	2. Influence: *a. Influence by the peers (other farmers)* *b. Influence by the NGOs* *c. Influence by the GO officials* *d. Influence by the media*	
	3. Age old tradition	
	4. Erosion control and soil protection	

	5. Crop diversification and risk reduction	
	6. Presence of information and technical assistance	
	7. Intensive use of land and space	
	8. Other, specify:	
6. Do the market parties provide you necessary capital or any kind of help?	1. Banks	
	2. NGOs	
	3. Other, specify:	
7. Do you encounter problems related in practicing agroforestry?	1. Yes 2. No If yes, give details.	1. Natural disasters: Flood, Drought, Tornado, Diseases, Other (specify). 2. Human Influence: Species choice, Management, Decision, Other (specify). 3. Economic uncertainties: Wood quality, Products, Demand, Inflation, Other (specify). 4. Social: Land tenure, Harvest laws, Tax laws, Cultural values, Community pressures, Other (specify). 5. Other (specify):

4. Attitude towards Agroforestry

Please state whether you agree or disagree to the following statements	**Answer**	
	Agree	Disagree
1. Agroforestry practices can minimize land degradation		
2. Agroforestry increases the productivity of the farm.		
3. Practicing agroforestry can increase one's income		
4. Perennials (i.e. forest trees, fruit trees etc.) take a long time to mature hence farmers do not want to plant them.		
5. Agroforestry practices can minimize (land) conflict by more control over land.		
6. Agroforestry practices can ensure land patrimony by more control over land.		
7. Agroforestry practices can establish local identity through more income generation.		
8. Agroforestry practices can help empowering people (e.g., local decision making) by improving socio-economic status through income generation.		

Thank you

Farm household interview (HQ2): Swidden farmers

Control information

Task	Date(s)	By who?	Status OK? If not, give comments
Interview			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Identification

Identification and location of household

1. Household name and code	*(name)*	*(HID)*
2. Village name and code	*(name)*	*(VID)*
3. Name and PID (see B. below) of primary respondent	*(name)*	*(PID)*
4. Name and PID (see B. below) of secondary respondent	*(name)*	*(PID)*
5. Distance of the household from the centre of village (in *minutes of walking* and in *km*)	*1.* *min*	*2.* *km*
6. How far is the household from the edge of the nearest natural or managed forest?	1. … measured in terms of distance (straight line)?	*km*
	2. … measured in terms of time (in minutes of walking)?	*min*

B. Household composition

1. Who are the members of the household?

1. Personal Identification number (PID)	*** Name of household member**	**2. Relation to household head**	**3. Year born** *(yyyy)*	**4. Sex** *(0=male 1=female)*	**5. Education** *(number of years completed)*
1		Household head = code 0			
2					
3					
4					
5					
6					
7					
8					
9					
10					

Codes: *1=spouse (legally married or cohabiting); 2=son/daughter; 3=son/daughter in law; 4=grandchild; 5=mother/father; 6=mother/father in law; 7=brother or sister; 8=brother/sister in law; 9=uncle/aunt; 10=nephew/niece; 11=step/foster child; 12=other family; 13=not related (e.g., servant).*

2. Questions regarding the head of this household.

1. What is the marital status of household head? *Codes: 1=married and living together; 2=married but spouse working away; 3=widow/widower; 4=divorced;; 5=never married; 9=other, specify:*	
2. How long ago was this household formed	

	years
3. Was the household head born in this village? *If 'yes', go to 5.*	*(1-0)*
4. **If 'no':** how long has the household head lived in the village?	*years*
5. Does the household head belong to the largest ethnic group/caste in the village?	*(1-0)*

C. Land

1. Amount of land (*ha*) that currently own and have rented in/out.

Category	**1. Area**	**2. Ownership** *(code tenure)*	**Main products collected in the past 12 months Max 3**		
			3. Rank1	**4. Rank2**	**5. Rank3**
1. Swidden					
2. Homestead					
Other land:					
3. Cropland (other than swidden)					
4. Pasture (natural or planted)					
5. Fallow					
6. Other vegetation types/land uses (forest, plantation, bush, grassland, wetland, etc.)					
7. Total land owned (1+2+3+…+6)					
8. Land rented out (**included** in 1-6)					
9. Land rented in (**not included** in 1-6)					

D. Assets and savings

1. Type of house.

1. Do you have your own house? 1)	
2. What is the type of material of (most of) the walls? 2)	
3. What is the type of material of (most of) the roof? 3)	
4. How many m^2 approx. is the house?	m^2

1) Codes: 0=no; 1=own the house on their own; 2=own the house together with other household(s); 3=renting the house alone; 4=renting the house with other household(s); 9=other, specify:

2) Codes: 1=mud/soil; 2=wooden (boards, trunks); 3= metal sheets; 4=bricks or concrete; 5=reeds/straw/grass/fibers; 9=other, specify:

3) Codes: 1=thatch; 2=wooden (boards); 3=iron or other metal sheets; 4=tiles; 9=other, specify:

2. Number and value of implements and other large household items that are owned by the household.

	1. No. of units owned	**2. Total value (current sales value of all units, not purchasing price)**
1. Car/truck		
2. Tractor		
3. Motorcycle		
4. Bicycle		
5. Handphone/phone		
6. TV		
7. Radio		
8. Cassette/CD/ VHS/VCD/DVD/ player		
9. Stove for cooking (gas or electric only)		
10. Refrigerator/freezer		
11. Fishing boat and boat engine		
12. Chainsaw		
13. Plough		
14. Scotch cart		

15. Shotgun/rifle		
16. Wooden cart or wheelbarrow		
17. Furniture		
18. Others (worth more than approx. 50 USD purchasing price)		

3. Savings and debt of the household.

1. How much does the household have in savings in banks, credit associations or savings clubs?	*Lc$*
2. How much does the household have in savings in non-productive assets such as gold and jewelry?	*Lc$*
3. How much does the household have in outstanding debt?	*Lc$*

4. Occupation, income and expenditure of the household

	1. Occupation 1	**2. Occupation 2**	**3. Occupation 3**
1. What is your occupation?			
2. What is your total yearly income?			
3. What is your yearly total expenditure?			

E. Income from agriculture – crops

1. Quantities and values of crops that household has harvested from **swidden** in **the past season/year**?

1. Crops *(code-product)*	**2. Ownership** *(code-tenure)*	**3. Area of production** *(ha)*	**4. Total production (unit) (5+6)**	**5.Own use (unit) (incl. gifts)**	**6. Sold (unit)**	**7. Costs of total production** *(ha)*	**8. Price of total production** *(ha)*	**9.Total value [4*(7-8)]**

2. Quantities and values of crops that household has harvested **(other than swidden)** in **the past season/year**?

1. Crops *(code-product)*	**2. Ownership** *(code-tenure)*	**3. Area of production** *(ha)*	**4. Total production (unit) (5+6)**	**5.Own use (unit) (incl. gifts)**	**6. Sold (unit) (incl. barter)**	**7. Costs of total production** *(ha)*	**8. Price of total production** *(ha)*	**9.Total value [4*(7-8)]**

F. Crisis and unexpected expenditures

2. Major income shortfalls or unexpectedly large expenditures during the past 12 months.

Event	**1. How severe?[1)]**	**How did you cope with the income loss or costs?** *Rank max. 3[2)]*		
		2. Rank1	**3. Rank2**	**4. Rank3**
1. Serious crop failure				
2. Serious illness in family (productive age-group adult unable to work for more than one month during past 12 months, due to illness, or to taking care of ill person; or high medical costs)				
3. Death of productive age-group adult				
4. Land loss (expropriation, etc.)				
5. Major livestock loss (theft, drought, etc.)				
6. Other major asset loss (fire, theft, flood, etc.)				

7. Lost wage employment				
8. Wedding or other costly social events				
9. Other, specify:				

1) Codes severity: 0=no crisis; 1=yes, moderate crisis; 2=yes, severe crisis.
2) Codes coping:

12. *Harvest more forest products*
13. *Harvest more wild products not in the forest*
14. *Harvest more agricultural products*
15. *Spend cash savings*
16. *Sell assets (land, livestock, etc.)*
17. *Do extra casual labour work*
18. *Assistance from friends and relatives*
19. *Assistance from NGO, community org., religious org. or similar*
20. *Get loan from money lender, credit association, bank etc.*
21. *Tried to reduce household spending*
22. *Did nothing in particular*
19. *Other, specify:*

G. Forest clearing

1. Did the household clear any forest during the past 12 months? *If 'no', go to 9.*		*(1-0)*		
If YES:	2. How much forest was cleared?	*ha*		
	3. What was the cleared forest used for? *Codes: 1=swidden; 2=permanent monoculture; 3=tree plantation; 4=pasture; 5=non-agric uses (Rank max 3)*	1.Rank1	2.Rank2	3.Rank3
	4. If used for crops (code '1' in question above), which principal crop was grown? *(code-product) Rank max 3*	1.Rank1	2.Rank2	3.Rank3
	5. What type of forest did you clear? *(code-forest)*			
	6. If secondary forest, what was the age of the forest?	*years*		
	7. What was the ownership status of the forest cleared? *(code tenure)*			
	8. How far from the house was the forest cleared located?	*km*		
9. Has the household over the last 5 years cleared forest? *If 'no', go to 11.*		*1-0*		
10. **If 'yes':** how much forest (approx.) has been cleared over the last 5 years? *Note: This should include the area reported in question 2.*		*ha*		
11. How much land used by the household has over the last 5 years been abandoned (left to convert to natural re-vegetation)?		*ha*		
12. IF ABANDONED, why?				
13. Did you collect any firewood from forest? if yes please specify		*Kg/month*		
14. Did you collect any fodder from forest? if yes please specify		*Kg/month*		
15. Did you collect any food (e.g. mushroom, fruits) from forest? if yes please specify		*Kg/month*		

H. Welfare perceptions and social capital

1. All things considered, how satisfied are you with your life over the past 12 months? *Codes: 1=very unsatisfied; 2=unsatisfied; 3=neither unsatisfied or satisfied; 4=satisfied; 5=very satisfied*	
2. Has the household's food production and income over the past 12 months been sufficient that you consider to be the needs of the household? *Codes: 1=no; 2=reasonable (just about sufficient); 3=yes*	

3. Compared with other households in the village (or community), how well-off is your household? *Codes: 1=worse-off; 2=about average; 3=better-off*		
4. How well-off is your household today compared with the situation **5 years ago?** *Codes: 1=less well-off now; 2=about the same; 3=better off now* *If 1 or 3, go to 5. If 2, go to 6.*		
5. **If worse- *or* better-off:** what is the main reason for the change? *Please rank the most important responses, max 3.*	**Reason: Change in …**	**Rank 1-3**
	1. off farm employment	
	2. land holding (e.g., bought/sold land)	
	3. forest resources	
	4. output prices (forest, agric,…)	
	5. outside support (govt., NGO,..)	
	6. remittances	
	7. cost of living (e.g., high inflation)	
	8. war, civil strife, unrest	
	9. conflicts in village (non-violent)	
	10. change in family situation (e.g. loss of family member/a major bread-winner)	
	11. illness	
	12. access (e.g. new road,…)	
	13.	
	14.	
	15. other (specify):	
6. Do you consider your village (community) to be a good place to live? *Codes: 1=no; 2=partly; 3=yes*		
7. Do you **in general** trust people in the village (community)? *Codes: 1=no; 2=partly, trust some and not others; 3=yes*		
8. Can you get help from other people in the village (community) if you are in need, for example, if you need extra money because someone in your family is sick? *Codes: 1=no; 2= can sometimes get help, but not always; 3=yes*		
9. Do you exchange any goods (e.g., serials, fruits, fuelwood, etc.) with neighbors?	1. If yes, what types?	
	2. In what reason?	

I. Forest services

1. Has the household over the past 12 months received any cash or in kind payments related to the following forest services?

Principal purpose	**1. Have received?** *(1-0)*	**2. If yes, amounts (values) received** *(Lc$)* *(if nothing, put '0')*
1. Tourism		
2. Carbon projects		
3. Water catchments projects		
4. Biodiversity conservation		
5. Others, specify:		

J. Other income sources

1. Other income that the household has received during **the past year**.

1. Type of income	2. Total amount received past year
1. Remittances	
2. Support from government, NGO, organization or similar	
3. Gifts/support from friends and relatives	
4. Pension	
5. Payment for forest services	
6. Payment for renting out land (if in kind, state the equivalent in cash)	
7. Compensation from logging or mining company (or similar)	
8. Other, specify:	

K. Swidden

1. What kind of labour do you use for swidden?	1. Hired 2. Family labor 3. Others	
2. Do you know about agroforestry?	1. Yes 2. No *If Yes go to 3, if No go to 4.*	
3. What is the reason to not practicing agroforestry?	1. Lack of sufficient knowledge	
	2. No interest	
	3. Lack of capital	
	4. Delay in profit earning	
	5. Lack of technical assistance	
	6. Management risk: a. Social b. Economic c. Natural	
	7. Unstable market price	
	8. Land is not suitable	
4. How long is your fallow period?	*month*	
5. Do the market parties provide you necessary capital or any kind of help?	1. Banks	
	2. NGOs	
	3. Other, specify:	
6. Are you interested to practice agroforestry?	1. Yes 2. No	

Thank you

Farm household interview (HQ3): Food-crop-based monoculture farmers

Control information

Task	Date(s)	By who?	Status OK? If not, give comments
Interview			
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Identification

Identification and location of household

1. Household name and code	*(name)*	*(HID)*
2. Village name and code	*(name)*	*(VID)*
3. Name and PID (see B. below) of primary respondent	*(name)*	*(PID)*
4. Name and PID (see B. below) of secondary respondent	*(name)*	*(PID)*
5. Distance of the household from the centre of village (in *minutes of walking* and in *km*)	*1.* *min*	*2.* *km*
6. How far is the household from the edge of the nearest natural or managed forest?	1. … measured in terms of distance (straight line)?	*km*
	2. … measured in terms of time (in minutes of walking)?	*min*

B. Household composition

1. Who are the members of the household?

1. Personal Identification number (PID)	*** Name of household member**	**2. Relation to household head**	**3. Year born** *(yyyy)*	**4. Sex** *(0=male 1=female)*	**5. Education** *(number of years completed)*
1		Household head = code 0			
2					
3					
4					
5					
6					
7					
8					
9					
10					

Codes: *1=spouse (legally married or cohabiting); 2=son/daughter; 3=son/daughter in law; 4=grandchild; 5=mother/father; 6=mother/father in law; 7=brother or sister; 8=brother/sister in law; 9=uncle/aunt; 10=nephew/niece; 11=step/foster child; 12=other family; 13=not related (e.g., servant).*

2. Questions regarding the head of this household.

1. What is the marital status of household head? *Codes: 1=married and living together; 2=married but spouse working away; 3=widow/widower; 4=divorced;; 5=never married; 9=other, specify:*	
2. How long ago was this household formed	

	years
3. Was the household head born in this village? *If 'yes', go to 5.*	*(1-0)*
4. **If 'no':** how long has the household head lived in the village?	*years*
5. Does the household head belong to the largest ethnic group/caste in the village?	*(1-0)*

C. Land

1. Amount of land (*ha*) that currently own and have rented in/out.

Category	**1. Area**	**2. Ownership** *(code tenure)*	**Main products collected in the past 12 months Max 3**		
			3. Rank1	**4. Rank2**	**5. Rank3**
1. Agriculture					
2. Homestead					
Other land:					
3. Other cropland (other than agriculture, i.e. swidden)					
4. Pasture (natural or planted)					
5. Fallow					
6. Other vegetation types/land uses (forest, plantation, bush, grassland, wetland, etc.)					
7. Total land owned (1+2+3+…+6)					
8. Land rented out (**included** in 1-6)					
9. Land rented in (**not included** in 1-6)					

D. Assets and savings

1. Type of house.

1. Do you have your own house? 1)	
2. What is the type of material of (most of) the walls? 2)	
3. What is the type of material of (most of) the roof? 3)	
4. How many m^2 approx. is the house?	*m^2*

1) Codes: 0=no; 1=own the house on their own; 2=own the house together with other household(s); 3=renting the house alone; 4=renting the house with other household(s); 9=other, specify:
2) Codes: 1=mud/soil; 2=wooden (boards, trunks); 3= metal sheets; 4=bricks or concrete; 5=reeds/straw/grass/fibers; 9=other, specify:
3) Codes: 1=thatch; 2=wooden (boards); 3=iron or other metal sheets; 4=tiles; 9=other, specify:

2. Number and value of implements and other large household items that are owned by the household.

	1. No. of units owned	**2. Total value (current sales value of all units, not purchasing price)**
1. Car/truck		
2. Tractor		
3. Motorcycle		
4. Bicycle		
5. Handphone/phone		
6. TV		
7. Radio		
8. Cassette/CD/ VHS/VCD/DVD/ player		
9. Stove for cooking (gas or electric only)		
10. Refrigerator/freezer		
11. Fishing boat and boat engine		
12. Chainsaw		
13. Plough		
14. Scotch cart		

15. Shotgun/rifle		
16. Wooden cart or wheelbarrow		
17. Furniture		
18. Others (worth more than approx. 50 USD purchasing price)		

3. Savings and debt of the household.

4. How much does the household have in savings in banks, credit associations or savings clubs?	*Lc$*
5. How much does the household have in savings in non-productive assets such as gold and jewelry?	*Lc$*
6. How much does the household have in outstanding debt?	*Lc$*

4. Occupation, income and expenditure of the household

	1. Occupation 1	**2. Occupation 2**	**3. Occupation 3**
2. What is your occupation?			
2. What is your total yearly income?			
3. What is your yearly total expenditure?			

E. Income from agriculture – crops

1. Quantities and values of crops that household has harvested from **Agriculture** in **the past season/year**?

1. Crops *(code-product)*	**2. Ownership** *(code-tenure)*	**3. Area of production** (*ha)*	**4. Total production (unit) (5+6)**	**5.Own use (unit) (incl. gifts)**	**6. Sold (unit)**	**7. Costs of total production** *(ha)*	**8. Price of total production** *(ha)*	**9.Total value [4*(7-8)]**

2. Quantities and values of crops that household has harvested **(other than agriculture)** in **the past season/year (if applicable)**?

1. Crops *(code-product)*	**2. Ownership** *(code-tenure)*	**3. Area of production** (*ha)*	**4. Total production (unit) (5+6)**	**5.Own use (unit) (incl. gifts)**	**6. Sold (unit) (incl. barter)**	**7. Costs of total production** *(ha)*	**8. Price of total production** *(ha)*	**9.Total value [4*(7-8)]**

F. Crisis and unexpected expenditures

3. Major income shortfalls or unexpectedly large expenditures during the past 12 months.

Event	**1. How severe?**[1)]	**How did you cope with the income loss or costs?** *Rank max. 3*[2)]		
		2. Rank1	**3. Rank2**	**4. Rank3**
1. Serious crop failure				
2. Serious illness in family (productive age-group adult unable to work for more than one month during past 12 months, due to illness, or to taking care of ill person; or high medical costs)				
3. Death of productive age-group adult				
4. Land loss (expropriation, etc.)				
5. Major livestock loss (theft, drought, etc.)				
6. Other major asset loss (fire, theft, flood, etc.)				

7. Lost wage employment				
8. Wedding or other costly social events				
9. Other, specify:				

1) Codes severity: 0=no crisis; 1=yes, moderate crisis; 2=yes, severe crisis.
2) Codes coping:

23. Harvest more forest products
24. Harvest more wild products not in the forest
25. Harvest more agricultural products
26. Spend cash savings
27. Sell assets (land, livestock, etc.)
28. Do extra casual labour work
29. Assistance from friends and relatives
30. Assistance from NGO, community org., religious org. or similar
31. Get loan from money lender, credit association, bank etc.
32. Tried to reduce household spending
33. Did nothing in particular
19. Other, specify:

G. Forest clearing

1. Did the household clear any forest during the past 12 months? *If 'no', go to 9.*		*(1-0)*		
If YES:	2. How much forest was cleared?	*ha*		
	3. What was the cleared forest used for? *Codes: 1=swidden; 2=permanent monoculture;3= agroforestry; 4=tree plantation;5=pasture;6=non-agric uses (Rank max 3)*	1.Rank1	2.Rank2	3.Rank3
	4. If used for crops (code '1' in question above), which principal crop was grown? *(code-product) Rank max 3*	1.Rank1	2.Rank2	3.Rank3
	5. What type of forest did you clear? *(code-forest)*			
	6. If secondary forest, what was the age of the forest?	*years*		
	7. What was the ownership status of the forest cleared? *(code tenure)*			
	8. How far from the house was the forest cleared located?	*km*		
9. Has the household over the last 5 years cleared forest? *If 'no', go to 11.*		*1-0*		
10. **If 'yes':** how much forest (approx.) has been cleared over the last 5 years? *Note: This should include the area reported in question 2.*		*ha*		
11. How much land used by the household has over the last 5 years been abandoned (left to convert to natural re-vegetation)?		*ha*		
12. IF ABANDONED, why?				
13. Did you collect any firewood from forest? if yes please specify		*Kg/month*		
14. Did you collect any fodder from forest? if yes please specify		*Kg/month*		
15. Did you collect any food (e.g. mushroom, fruits) from forest? if yes please specify		*Kg/month*		

H. Welfare perceptions and social capital

1. All things considered, how satisfied are you with your life over the past 12 months? *Codes: 1=very unsatisfied; 2=unsatisfied; 3=neither unsatisfied or satisfied; 4=satisfied; 5=very satisfied*	
2. Has the household's food production and income over the past 12 months been sufficient that you consider to be the needs of the household? *Codes: 1=no; 2=reasonable (just about sufficient); 3=yes*	

3. Compared with other households in the village (or community), how well-off is your household? *Codes: 1=worse-off; 2=about average; 3=better-off*		
4. How well-off is your household today compared with the situation **5 years ago?** *Codes: 1=less well-off now; 2=about the same; 3=better off now* *If 1 or 3, go to 5. If 2, go to 6.*		
5. **If worse- *or* better-off:** what is the main reason for the change? *Please rank the most important responses, max 3.*	**Reason: Change in …**	**Rank 1-3**
	1. off farm employment	
	2. land holding (e.g., bought/sold land)	
	3. forest resources	
	4. output prices (forest, agric,…)	
	5. outside support (govt., NGO,..)	
	6. remittances	
	7. cost of living (e.g., high inflation)	
	8. war, civil strife, unrest	
	9. conflicts in village (non-violent)	
	10. change in family situation (e.g. loss of family member/a major bread-winner)	
	11. illness	
	12. access (e.g. new road,…)	
	13.	
	14.	
	15. other (specify):	
6. Do you consider your village (community) to be a good place to live? *Codes: 1=no; 2=partly; 3=yes*		
7. Do you **in general** trust people in the village (community)? *Codes: 1=no; 2=partly, trust some and not others; 3=yes*		
8. Can you get help from other people in the village (community) if you are in need, for example, if you need extra money because someone in your family is sick? *Codes: 1=no; 2= can sometimes get help, but not always; 3=yes*		
9. Do you exchange any goods (e.g., serials, fruits, fuelwood, etc.) with neighbors?	1. If yes, what types?	
	2. In what reason?	

I. Forest services

1. Has the household over the past 12 months received any cash or in kind payments related to the following forest services?

Principal purpose	**1. Have received?** *(1-0)*	**2. If yes, amounts (values) received** *(Lc$)* *(if nothing, put '0')*
1. Tourism		
2. Carbon projects		
3. Water catchments projects		
4. Biodiversity conservation		
5. Others, specify:		

J. Other income sources

1. Other income that the household has received during **the past year**.

1. Type of income	**2. Total amount received past year**
1. Remittances	
2. Support from government, NGO, organization or similar	
3. Gifts/support from friends and relatives	
4. Pension	
5. Payment for forest services	
6. Payment for renting out land (if in kind, state the equivalent in cash)	
7. Compensation from logging or mining company (or similar)	
8. Other, specify:	

K. Agriculture

1. What kind of labour do you use for agriculture?	4. Hired 5. Family labor 6. Others	
2. Do you know about agroforestry?	1. Yes 2. No *If Yes go to 3, if No go to 4.*	
3. What is the reason to not practicing agroforestry?	1. Lack of sufficient knowledge	
	2. No interest	
	3. Lack of capital	
	4. Delay in profit earning	
	5. Lack of technical assistance	
	6. Management risk: a. Social b. Economic c. Natural	
	7. Unstable market price	
	8. Land is not suitable	
4. How long is your fallow period?		*month*
5. Do the market parties provide you necessary capital or any kind of help?	1. Banks	
	2. NGOs	
	3. Other, specify:	
6. Are you interested to practice agroforestry?	1. Yes 2. No	

Thank you

Village Survey (VQ)

Control information

Task	Date(s)	By who?	Status OK? If not, give comments
Checking questionnaire			
Coding questionnaire			
Entering data			
Checking & approving data entry			

A. Geographic and climate variables

1.	What is the name of the village?	*1. (name)*	*2. (village code)*
2.	What are the GPS coordinates of the centre of the village? (UTM format)		
3.	What is the latitude of the village?		*degrees*
4.	What is the longitude of the village?		*degrees*
5.	What is the altitude (masl) of the village?		*masl*
6.	What has been the average annual rainfall (mm/year) in the area?		*mm/year*

B. Demographics

1.	In what year was the village established?	
2.	What is the current population of the village?	*persons*
3.	How many households live currently in this village?	*households*
4.	What was the total population of the village 10 years ago?	*persons*
5.	How many households lived in the village 10 years ago?	*households*
6.	How many persons (approx.) living here now have moved to the village in the past 10 years (in-migration)?	*persons*
7.	How many persons (approx.) have left the village over the past 10 years (out-migration)?	*persons*
8.	How many different groups (ethnic groups, tribes or castes) are living in the village?	

C. Infrastructure

1.	How many households (approx.) in the village bordering natural areas?				*households*
2.	How many households (approx.) have access to 'scenic routes'?				*households*
3.	How many households (approx.) in the village have access to electricity (from public or private suppliers)?				*households*
4.	How many households (approx.) in the village have access to safe drinking water?				*households*
5.	How many households (approx.) have access to formal credit (government or private bank operating in the village)?				*households*
6.	Are informal credit institutions such as savings clubs and money lenders present in the village?				*(1-0)*
7.	Is there any health centre in the village?				*(1-0)*
8.	Does the village have at least one road useable by cars during all seasons? *If 'yes', go to 8.*				*(1-0)*
9.	**If 'no':** what is the distance in kilometers to the nearest road usable during all seasons?				*km*
10.	Is there a river within the village boundaries that is navigable during all seasons? *If 'yes', go to 10.*				*(1-0)*
11.	**If 'no'**: what is the distance to the nearest river that is navigable during all seasons?				*km*
12.	What is the distance from the village centre to the nearest …		**1. km**	**2. min**	***3. code-transport***

(in *km* and in *minutes* by *most common means of transport*)	1. district market			
	2. market for major consumption goods			
	3. market where agric. products are sold			
	4. market where forest products are sold			

D. Forest and land cover/use

1. Land categories in the village (approx. area in hectares).

1. Land category	**2. Total area** *(ha)*	**Ownership** (*ha*)			
		3. State	**4. Community**	**5. Private**	**6. Open access** (*de facto*)
Forest:					
1. Natural forest					
2. Managed forests					
3. Plantations					
Agricultural land:					
4. Cropland					
5. Pasture (natural or planted)					
6. Agroforestry					
7. Silvipasture					
8. Fallow					
Other land categories:					
9. Shrubs					
10. Grassland					
11. Residential areas, infrastructure					
12. Wetland					
13. Other, specify:					
14. Total land					

2. What are the main forest types, users and products in the village?

Note: The total forest area should be the same as in the above table.

1.Type of forest *(code-forest)*	**2.Ownership** *(code-tenure)*	**3.Approx. area** *(ha)*	**Main users[1)] (max. 3)**			**Main products (max. 3)** *(code-product)*		
			4.Rank1	**5.Rank2**	**6.Rank3**	**7.Rank1**	**8.Rank2**	**9.Rank3**

1) By "main users" is meant those who have acquired the highest value of forest products (subsistence and cash) from a given forest type in the past 12 months.

Codes: Choose the most appropriate among the following groups (as some do overlap):

1 = villagers that are members of FUG;
2 = villagers not members of FUG;
3 = subsistence oriented users in the village;
4 = small-scale commercial users in the village;
5 = large-scale commercial users in the village;
6 = subsistence oriented users from outside the village;
7 = small-scale commercial users from outside the village;
8 = large-scale commercial users from outside the village;
9 = other, specify:

3. Does the village practice any form of active and deliberate forest management?

Type of management	**Code**[1)]
1. Planting of trees	
2. Cutting down undesired (competing) trees	
3. Protecting certain desired (patches of) trees in the forest to promote the natural regeneration of these species	
4. Protecting areas of forest for particular environmental services, like water catchment	
5. Establishing clear use rights for a limited number of people to particular forest products (e.g., honey trees)	
6. Other, specify:	

1) Codes: 0=no, not at all; 1=yes, but only to a limited extent; 2=yes, they are common.

E. Forest resource base

Note: The questions should be asked in a village meeting or focus group for each of the categories

		1. Fire-wood or charcoal	**2. Timber or other wood**	**3. Food from the forest**	**4. Medicine from the forest**	**5. Forage from the forest**	**6. Other**[1)]
1. What is the most important product (MIP) for the livelihood of the people in the village (in this category)? [2)] *(name)*							
2. *(code-product)*							
3. How has availability of the MIP changed over the past 5 years? *Codes: 1=declined; 2=about the same; 3=increased*							
4. If the availability of the MIP in this category has **declined**, what are the reasons? *Please rank the most important reasons, max. 3 (leave rest blank).*	**Reason**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**
	1. Reduced forest area due to small-scale clearing for agriculture						
	2. Reduced forest area due to large-scale projects (plantations, new settlements, etc.)						
	3. Reduced forest area due to people from outside buying land and restricting access						
	4. Increased use of MIP due to more local (village) people collecting more						
	5. Increased use of MIP due to more people from other villages collecting more						
	6. Restrictions on use by central or state government (e.g., for forest conservation)						
	7. Local restrictions on forest use (e.g., community rules)						

	8. Climatic changes, e.g., drought and less rainfall						
	9. Other, specify:						
5. If the availability of the MIP in this category has **increased**, what are the reasons? *Please rank the most important reasons, max. 3.*	**Reason**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**
	1. Less clearing of forests for agriculture (incl. pastoralism)						
	2. Fewer local (village) people collecting less						
	3. Fewer people from other villages collecting less						
	4. Reduced use from large-scale commercial users/projects						
	5. Changes in management of forests						
	6. Climatic changes, e.g., more rainfall						
	7. Other, specify:						
6. What would be most important to increase the benefits (use or income) from the MIP? *Please rank the most important reasons, max. 3.*	**Action**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**	**Rank 1-3**
	1. Better access to the forest/MIP, i.e., more use rights to village						
	2. Better protection of forest/MIP (avoid overuse)						
	3. Better skills and knowledge on how to collect/use it						
	4. Better access to credit/capital and equipment/technolog y						
	5. Better access to markets and reduced price risk						
	6. Other, specify:						

1) Select the most important product for the village that do not fall into any of the other five categories.
2) "Most important" is defined as the most important for the wellbeing of the village, whether it be through direct use in the home, or through sale for cash, or both.

F. Forest institutions

Note: The questions should be asked in a village meeting or focus group for each of the categories

	1. Fire-wood or charcoal	**2. Timber or other wood**	**3. Food from the forest**	**4. Medicine from the forest**	**5. Forage from the forest**	**6. Other[1)]**
1. What is the most important product (MIP) for the livelihood of the people in the village (in this category)? [2)]						

(name)						
2. *(code-product)*						
3. What is the ownership status of this forest *(code-tenure)*						
4. Are there customary rules regulating the use of the MIP in the village? *Codes: 0=none/very few; 1=yes, but vague/unclear; 2=yes, clear rules exist* *If code '0', go to 7.*						
5. **If 'yes'**: are the customary rules regarding forest use enforced /respected by the population of the village?[1)]						
6. Are there government rules that regulate forest use? *Codes: 0=none/very few; 1=yes, but vague/unclear; 2=yes, clear rules exist* *If code '0', go to 9.*						
7. **If 'yes' (code '1' or '2' above):** are the government rules enforced/respected by the members in the village?[1)]						
8. Do the villagers require any permission to harvest the MIP? *Codes: 0=no; 1=yes, users have to inform the authorities; 2=yes, written permission needed* *If code '0', go to next section.*						
9. If 'yes' (code '1' or '2' above): does the user have to pay for the permission?	*(1-0)*	*(1-0)*	*(1-0)*	*(1-0)*	*(1-0)*	*(1-0)*
10. **If 'yes'**: who issues this permit? *Codes: 1=village head; 2=FUG; 3=forest officer (forest departments); 4=other government official; 9=other, specify:*						

1) Codes: 0=no/very little; 1=to a certain extent by some groups of villagers; 2=to a certain extent by everyone; 3=yes, but only by some groups of villagers; 4=yes, by everyone; 9=no particular rules exist.

G. Forest User Groups (FUG)

1. Existence of forest user groups (FUG).

1. How many forest user groups (FUG) are there in the village?	

2. Information about each FUG (use one column per FUG).

	1. FUG1	*2. FUG2*	*3. FUG3*
1. When was the group formed? *(yyyy)*			
2. How was the group formed? *Codes: 1=local initiative; 2=initiative from NGO; 3=initiative from government, e.g., Forest Department; 4=other, specify:*			
3. Is the FUG's main purpose related to the management of a particular forest area or of particular forest product(s)? *Codes: 1=area; 2=product(s); 3=both*			
4. If for a product (code 2 or 3above), what is the (main) product? *(code-product)*			
5. How many members are there in the group?			
6. How many times per year does the FUG have meetings?			

7. Does the group have a written management plan?		*(1-0)*	*(1-0)*	*(1-0)*
8. What are the main tasks of the FUG? *Select as many as appropriate: 1-0 code*	1. Setting rules for use	*(1-0)*	*(1-0)*	*(1-0)*
	2. Monitoring and policing	*(1-0)*	*(1-0)*	*(1-0)*
	3. Silviculture & management	*(1-0)*	*(1-0)*	*(1-0)*
	4. Harvesting forest products	*(1-0)*	*(1-0)*	*(1-0)*
	5. Selling forest products	*(1-0)*	*(1-0)*	*(1-0)*
	6. Other, specify:	*(1-0)*	*(1-0)*	*(1-0)*
9. Has any development project been implemented in the village over the past 5 years using proceeds from the FUG?		*(1-0)*	*(1-0)*	*(1-0)*
10. Has anyone in the village been violating the rules of the FUG over the past 12 months? *If 'no', go to 14.*		*(1-0)*	*(1-0)*	*(1-0)*
11. **If 'yes'**: did the FUG imposed any penalties on those violating the rules? *If 'no', go to 14*		*(1-0)*	*(1-0)*	*(1-0)*
12. **If 'yes'**: what type of penalties? *Codes: 1=fee (cash payment); 2=returning collected products; 3=labour (extra work); 4=exclusion from group; 9=other, specify:*				
13. Which group of forest users have most commonly violating the rules over the past 5 years? *Codes: 1=members of FUG; 2=non-FUG members in the village; 3=people from other villages; 9=other, specify:*				
14. Overall, on a scale from 1-5 (1 is highest, 5 is lowest) how effective would you say that the FUG is in ensuring sustainable and equitable forest use?				

H. Risk

1. Has the village faced any of the following crises over the past 12 months? *Codes: 0=no; 1=yes, moderate crisis; 2=yes, severe crisis*	1. Flood and/or excess rain	
	2. Drought	
	3. Wild fire (in crops/ forest/grasslands etc)	
	4. Widespread crop pest/disease and/or animal disease	
	5. Human epidemics (disease)	
	6. Political/civil unrest	
	7. Macro-economic crisis	
	8. Refugee or migration infusion	
	9. Other, specify:	

I. Wages and prices

1. What was the typical daily wage rate for unskilled agricultural/casual adult **male/female** labour during the **peak/slack** season in this village over the past 12 months? *(Lc$/day)*		**Male**	**Female**
	Peak	1.	2.
	Slack	3.	4.
2. What is the main staple food in the village? *(code-product)*			
3. What was the price of a kg of the main staple food during the past 12 months **before** and **after** the main agricultural harvest? *(Lc$/kg)*		**1. Before harvest**	**2. After harvest**
4. What is the sales value of one hectare of good agricultural land in the village (i.e., not degraded, not too steep, and suitable for common crops, and within 1km of the main road or settlement) *(Lc$/hectare)*			

J. Forest services

1. Has the village (as a community or individuals in the village) received any direct benefits (in kind or in cash) related to forest services over the past 12 months? *Codes: 0=no; 1=yes, directly to households; 2=yes, directly to*	

	village (e.g., development project); 3=yes, both to household and village		
2.	If the village has received payment (code 2 or 3 above), please indicate the amount the village has received.	**Payments related to:**	**Amount**
		1. Tourism	
		2. Carbon sequestration	
		3. Water catchment	
		4. Biodiversity conservation	
		5. Compensation from timber company	
		6. Compensation from mining company	
		7. Other, specify:	
3.	Has the village received any forestry-related external support (technical assistance, free inputs, etc.) from government, donors, NGOs) over the past 12 months?	*(1-0)*	

Note: If any such payment or assistance has been received it should be elaborated more by asking relevant questions.

Thank You

FGD key questions

Control information

FGD location (village/country)	
Date	
Time start	
Time end	
Name of moderator	
Checking & approving the summery	

13. What are the major land use systems (e.g. forest, agriculture, settlement) in the area?
14. What are the major land use challenges facing by local people?
15. What are the major causes of deforestation in the area?
16. What are the available forest products and the state of their accessibility (easy/restricted)?
17. Specific farming information:
    a) Types of agroforestry systems (including the popular systems), products and contribution to local livelihoods.
    b) Types of swidden systems (including the popular systems), products and contribution to local livelihoods.
    c) Types of permanent monoculture agriculture (including the popular systems), products and contribution to local livelihoods.
18. Is there any risks (e.g. crop failure, landslides, land grabbing) associated with swidden, permanent monoculture, and agroforestry practices?
19. What is the reason of practicing traditional swidden (if not profitable enough comparing to other land use alternatives)?
20. What is the reason of practicing permanent monoculture?
21. Is there any barriers of agroforestry practices and their wider adoption in the area?
22. What is the local market condition (e.g. price stability, physical structure, market information availability)?
23. What is the status of local land tenure system (owned by state/community/private), and associate consequence (e.g. access to the land, transfer right)?
24. What types of off-farm work available for the local people?
25. What is the basic charectersistics and power structure of local community?
26. What is the relationship of goverment with the local community (e.g. policy formulation)?
27. What is the available and most common credit sources for agriculture?
28. How easy or hard to get credit from Banks/NGOs (for swidden, permanent monoculture and agroforestry)?

Thank you

Code list for questionnaires

1. General

Several questions are 1-0 questions, where **1 = yes** and **0 = no.**

Some questions may not apply or the respondent simply cannot answer. The following codes are used for that:

- 8 = **does not apply**

- 9 = the respondent (or I) **does not know**

Note the **minus (-)** to be put in front. This is done to clearly distinguish between these answers (-8, -9) and any regular answer.

All years are written with 4 digits, i.e., **yyyy**. All dates should be written in the date -month- year format, i.e.: **ddmmyyyy**

2. Codes for the questionnaire

2.1. *Occupation*

Category	Code	Comments
Farmer	1	
Gardener	2	
Day labourer	3	
Business	4	
Wood-cutter	5	
Service	6	
Rickshaw/ van puller	7	
Priest	8	

2.2. *Measurement unit*

Category	Code	Comments
Kilogram	1	
Bunch	2	
Foot	3	
Piece	4	
	5	
	6	
	7	

2.3. Forest categories (code-forest)

The forest categories follow the same three forest categories in the classification below. In addition, each forest category is split between open and closed forest, the dividing line being 40 % canopy cover. To the extent possible, the researchers should use the open/closed categories, that is, use codes: 11, 12, 21, 22, 31, 32. In some cases, however, it may be very hard to make this distinction and the aggregate categories can be used, that is, codes: 10, 20, 30.

Category	Code	Comments
Natural forest	10	
Natural forest – closed	11	Canopy cover > 40 %
Natural forest – closed (seasonally-inundated)	111	
Natural forest – closed (dominated by palms)	112	

Natural forest – open	12	Canopy cover < 40 %
Managed forests	20	
Managed forests – closed	21	Canopy cover > 40 %
Managed forests - open	22	Canopy cover < 40 %
Plantations	30	
Plantations – closed	31	Canopy cover > 40 %
Plantations - open	32	Canopy cover < 40 %

2.4. Mode of transport (code-transport)

Mode of transportation	Code	Comments
Foot	1	
Bike	2	
Motorbike	3	
Donkey/horse/ox cart	4	Include directly carrying the load on their back
Tractor	5	Refers to the conventional tractors with 2 (or more) large driving wheels, and 2 (or 1) steering wheels. Does *not* include the small, two-wheel engine-powered devices (sometimes called hand-tractors).
Car/van	6	
Truck/lorry	7	
Bus	8	
Non-motorized boat/raft	9	
Motorized boat/raft	10	
Other	11	

2.5. Tenure regime (code-tenure)

In the 3 digit tenure code the first digit refers to *de jure* owner, the second to the *de facto* user, and the third digit to the degree of rules enforcement. Only codes which specify all the three dimensions should be used, i.e., only the codes in **bold** in the table**.**

In short, land tenure should be categorized by asking three questions:
1. Who are the formal (*de jure*) owners: state, community or private? (1-3)
2. Who are the actual users: state, community, private, or some combination? (1-7)
3. To what extent do rules of access and use exist, and if they do, how well are they enforced? (1-3)

This generates a total of 3 x 7 x 3 = 63 combinations, shown in the table below. But, some of the codes will probably never be used as they are unlikely combinations.

Tenure regime	Code	Comments/examples
State *de jure* owner	1	
State *de facto* user	11	
High enforcement of rules	**111**	E.g., a well-protected national park
Medium/low enforcement of rules	**112**	
No enforcement of rules (open access)	**113**	
Community *de facto* user	12	
High enforcement of rules	**121**	E.g., a community forest management system, where the state is the legal owner, but the forest is managed and used by the community with strong enforcement of the rules set.
Medium/low enforcement of rules	**122**	
No enforcement of rules (open access)	**123**	A typical open access case: forest owned *de jure* by the state, but used by villagers and few/no rules exist or are enforced.
Private *de facto* user	13	E.g., squatters on public (state) land which use it for agriculture.

High enforcement of rules	**131**	
Medium/low enforcement of rules	**132**	
No enforcement of rules (open access)	**133**	
State-community *de facto* user	14	
High enforcement of rules	**141**	
Medium/low enforcement of rules	**142**	E.g., a forest reserve owned *de jure* by the state, but with weak enforcement and some (illegal) local use
No enforcement of rules (open access)	**143**	
State-private *de facto* user	15	
High enforcement of rules	**151**	
Medium/low enforcement of rules	**152**	
No enforcement of rules (open access)	**153**	
Community-private *de facto* user	16	E.g., shifting cultivators in *de jure* state forest, with individual use rights based on regular forest clearing and cultivation, and collection by community of NTFPs.
High enforcement of rules	**161**	
Medium/low enforcement of rules	**162**	
No enforcement of rules (open access)	**163**	
State-community-private *de facto* user	17	
High enforcement of rules	**171**	
Medium/low enforcement of rules	**172**	
No enforcement of rules (open access)	**173**	
Community *de jure* owner	2	
State *de facto user*	21	These categories seem unlikely.
High enforcement of rules	**211**	
Medium/low enforcement of rules	**212**	
No enforcement of rules (open access)	**213**	
Community *de facto* user	22	Similar to 12, but the community fully owns the forest.
High enforcement of rules	**221**	
Medium/low enforcement of rules	**222**	
No enforcement of rules (open access)	**223**	
Private *de facto* user	23	
High enforcement of rules	**231**	
Medium/low enforcement of rules	**232**	
No enforcement of rules (open access)	**233**	
State-community *de facto* user	24	
High enforcement of rules	**241**	
Medium/low enforcement of rules	**242**	
No enforcement of rules (open access)	**243**	
State-private *de facto* user	25	
High enforcement of rules	**251**	
Medium/low enforcement of rules	**252**	
No enforcement of rules (open access)	**253**	
Community-private *de facto* user	26	E.g., a community owned forest with community use but also some agricultural encroachment by farmers.
High enforcement of rules	**261**	
Medium/low enforcement of rules	**262**	
No enforcement of rules (open access)	**263**	
State-community-private *de facto* user	27	
High enforcement of rules	**271**	
Medium/low enforcement of rules	**272**	
No enforcement of rules (open access)	**273**	

Private *de jure* owner	3	
State *de facto* user	31	These categories seem unlikely.
High enforcement of rules	**311**	
Medium/low enforcement of rules	**312**	
No enforcement of rules (open access)	**313**	
Community *de facto* user	32	
High enforcement of rules	**321**	
Medium/low enforcement of rules	**322**	
No enforcement of rules (open access)	**323**	
Private *de facto* user	33	
High enforcement of rules	**331**	The 'classical' private property case. May also include land rented in/out in this category
Medium/low enforcement of rules	**332**	
No enforcement of rules (open access)	**333**	
State-community *de facto* user	34	
High enforcement of rules	**341**	
Medium/low enforcement of rules	**342**	
No enforcement of rules (open access)	**343**	
State-private *de facto* user	35	
High enforcement of rules	**351**	
Medium/low enforcement of rules	**352**	
No enforcement of rules (open access)	**353**	
Community-private *de facto* user	36	E.g., NTFP harvested by villagers from a *de jure* private forest, but neither logging nor agriculture accepted.
High enforcement of rules	**361**	
Medium/low enforcement of rules	**362**	
No enforcement of rules (open access)	**363**	
State-community-private *de facto* user	37	
High enforcement of rules	**371**	
Medium/low enforcement of rules	**372**	
No enforcement of rules (open access)	**373**	

2.6. Products (code-product)

This code list covers all products for which data are being collected. Thus it includes forest products (raw and processed), agricultural products, and products collected from non-forest areas (labelled "non-forest environmental income" in the questionnaire).

One important distinction is made between unprocessed (raw-material) forest products and processed forest products. "Processed" means a significant modification or change of the product, e.g., turning wood into charcoal or a chair, or turning clay into a pot. Minor modifications, for example, cutting rattan canes or bark into smaller pieces, or washing and drying the product would not qualify, and the products should still be classified as unprocessed.

Note that codes from the agricultural products code list (201-) can be used for products collected from the forest. For example, a wild fruit can be classified under the general code for wild fruits (21) or as that particular fruit, e.g., durian (315).

Product	Code	Comments
1. Harvested products from the wild (incl. forests)	**(1-73)**	
i. Wooden perennials and wooden-based products	**(1-20)**	

Bamboo	1	
Fence posts	2	
Frond	3	Leaves of palms
Fuelwood/firewood	4	
Lianas and vines	5	
Logs	6	Can also be classified in the broader category of timber ("logs" often refer to short pieces of timber)
Poles	7	
Rattan	8	
Timber	9	This includes trees cut for charcoal production
Tree barks	10	
Tree branches	11	
Tree leaves	12	
Tree roots	13	
Tree seedlings	14	
Agora	15	
	16	
	17	
	18	
	19	
	20	
ii. Non-wooden plants and plant-based products	**(21-50)**	
Wild fruits	21	
Nuts	22	Brazil nuts has a separate code (45)
Mushroom	23	
Roots and tubers	24	Tree roots are included above (code 6)
Wild vegetables	25	
Seeds	26	
Medicinal plants	27	All (parts of) plants used for medicinal purposes should be put here, e.g., a tree root or mushroom used for medicinal purposes (don't use categories above).
Ornamental/aesthetic/fashion	28	
Latex and resin	29	Note that latex and resin can also be tree based. Rubber has a separate code (46)
Oils	30	
Dyes	31	
Non-animal manure	32	
Fodder grass/livestock browse	33	
Thatching grass	34	
Other grasses	35	E.g., for basket making
Reeds	36	
Spices	37	
Stalks	38	E.g., from millet
Banana fibres	39	
Banana leaves	40	
Wild yam	41	
Wild coffee	42	
Wild coffee seedlings	43	
"Cabbage palm"	44	The heart of the palm during its development phase
Brazil nut	45	Nuts in general are code '22'
Rubber	46	Latex in general is code '29'

	47	
	48	
	49	
	50	
iii. Animals and animal-based products	**(51-65)**	
Game meat – mammals	51	
Game meat – reptiles	52	
Game meat – birds and bats	53	
Game meat – insects and worms	54	
Birds nests	55	
Fish	56	
Animal skin	57	
Animal-based medicine	58	As for medicinal plants, put any animals or animal parts used for medicine here.
Honey	59	
Game meat – amphibian	60	
Animal manure	61	Manure collected as an environmental resource
	62	
	63	
	64	
	65	
iv. Minerals and others	**(66-73)**	
Quarry stones	66	
Clay/mud	67	
Slate	68	
Sand	69	
Tooth cleaning twigs	70	
Quarry stones	71	
	72	
	73	
2. Processed products from the wild (incl. forests)	**(101-129)**	
i. Wooden-based products	**(101-118)**	
Sawnwood	101	
Charcoal	102	
Wooden furniture	103	
Other wooden tools/utensils	104	E.g., spoons, bowls, hoe handles
Woodcraft	105	E.g., figurines, cultural & symbolic artefacts
Rattan furniture	106	
Other rattan products	107	
Bamboo furniture	108	
Other bamboo products	109	
Canoe	110	
Drums	111	
Other musical instruments	112	
Walking sticks	113	
Offcuts	114	Residual from sawnwood production
Rubber shoes	115	
	116	
	117	

	118	
ii. Non-wooden based products	**(119-129)**	
Woden products	119	Mats, baskets, brooms, hats, etc.
Juice and oils from forest products	120	E.g., soaps
Alcoholic beverages	121	
Pottery	122	
Bricks	123	
Roasted cashew	124	
Fly swatter	125	Made from palm branch
Fishing trap	126	
Catapult	127	
	128	
	129	
3. Agricultural crops	**(201-340)**	**NOTE: The following codes can also be used if the product in collected from forests or other environments**
Cereals	**(201-214)**	
Rice	201	
Maize	202	
Wheat	203	
Barley	204	
Millet	205	
Sorghum	206	
Buck wheat	207	
Naked barley	208	
Amaranthus	209	Also used as green leafy vegetable
Oat	210	
	211	
	212	
	213	
	214	
Roots and tubers	**(215-224)**	
Cassava/manioc (fresh)	215	
Potato	216	Also called Irish potato
Sweet potato	217	
Yam	218	
Cocoyam/taro	219	
Cassava/manioc (flour)	220	Cassava general: 215
Arum	221	
Jicama (Mexican Yam)	222	
	223	
	224	
Legumes	**(225-243)**	
Soybean	225	
Mung bean	226	Also: chick pea
Stink bean	227	
Pigeon pea	228	
Cow pea	229	
Grams	230	Green grams or Mung bean
Groundnut (peanut)	231	
Bean (Mustang)	232	
String bean	233	
Red bean	234	
Field beans (fresh)	235	

Field beans (dried)	236	
Sesame	237	
Beans	238	General code for beans
Legumes (general code)	239	
Winged bean	240	
Yardlong Bean	241	
	242	
	243	
Vegetables	**(244-268)**	
Cabbage	244	
Carrot	245	
Cauliflower	246	
Chilli	247	
Cucumber	248	
Eggplant	249	
Garlic	250	
Ginger	251	
Lettuce	252	
Onion	253	
Paprika	254	
Pepper	255	
Pumpkin	256	
Spinach	257	
Squash	258	
Tomato	259	
Radish	260	
Turnip	261	
Gourd (bitter/spiny)	262	
Cucurbit	263	
Star gooseberry	264	
Garlic chives	265	
Blue ginger	266	
	267	
	268	
Fruits	**(269-300)**	
Apple	269	
Apricot	270	
Avocado	271	
Banana	272	This includes all types
Breadfruit	273	
Carambola/Star fruit	274	
Cashew fruit	275	
Cashew seed/nut	276	
Coconut	277	
Durian	278	
Grapefruit	279	
Guava	280	
Jack fruit	281	
Lemon	282	
Lichee	283	
Mango	284	
Mangosteen	285	
Orange	286	
Papaya	287	
Passion fruit	288	
Peach	289	

Pineapple	290	
Plum	291	
Rambutan	292	
Soursop (sirsak)	293	
Watermelon	294	
Tamarind	295	
Wood apple	296	
Hog plum	297	
Olive	298	
Berry	299	
Amla	300	
Acid fruit	301	
Shaddock	302	
Betel-nut	303	
Menteng (Baccauria)	304	*Baccaurea racemosa*
	305	
	306	
	307	
	308	
	309	
Beverages	**(310-315)**	Not including fruit juices
Cocoa	310	Also wild
Coffee	311	
Tea	312	
Jelly grass	313	*Mesona chinensis*
	314	
	315	
Spices	**(316-326)**	
Clove	316	
Curry	317	
Ginger	318	
Mint	319	
Pepper	320	
Turmeric	321	
Vanilla	322	
Lemongrass	323	
Nutmeg	324	
	325	
	326	
Other food crops	**(327-334)**	
Aloe vera	327	
Mustard	328	
Palm oil	329	
Sugar cane (and juice)	330	
Sunflower	331	
Sweets made from cultivated fruits	332	
Melinjo	333	
	334	
Non-food crops or non-food parts of crops	**(335-342)**	
Coca leaves	335	
Cotton	336	
Eucalyptus	337	
Jute	338	
Tobacco	339	

Cassia leaf	340	
Rudraksha	341	
	342	
Miscellaneous & unclassified	**(343-349)**	
Grass for domestic animals	343	
Legumes for domestic animals	344	
Leaves of cultivated crops	345	
Crop residues	346	
	347	
	348	
	349	

Classification of different land categories

In the questionnaire, a number of land categories are used which are defined in this section.

Category	**Brief definitions & comments**
Forests:	
Natural forest	Indigenous species with only limited management.
Managed forests	Predominantly indigenous species, and management including felling and planting of indigenous and/or exotic species.
Plantations	Forest stands established by planting and/or seeding.
Agricultural land:	
Cropland	Land cultivated with crops. But, there is a fine distinction between cropland and fallow, agroforestry or plantation.
Pasture	Land used for herbaceous forage crops, established by humans and/or with active management.
Agroforestry	Land use established by humans combing trees and crops, either on a spatial or temporal scale.
Silvipasture	Land use established by humans combining trees and pasture.
Fallow	Agricultural land temporarily (up to 15 years) not being used for crops or pasture.
Other land categories:	
Shrubs	Woody perennial vegetation less than 5 m in height.
Grassland	Land with grass as the predominant natural vegetation; may have scattered trees (savannah) of less than 10% canopy cover.
Residential areas, infrastructure	Land used for buildings, roads, etc.
Wetland	Land where water saturates the soil, not classified as by forests or agricultural land.
Others	Land not fitting into any of the above categories.

Forest

The most commonly used definition of *forest* is the one provided by FAO: “Forests are lands of more than 0.5 hectares, with a tree canopy cover of more than 10 %, which are not primarily under agricultural or urban land use… The trees should be able to reach a minimum height of 5 meters in situ.”

Open and closed forest

Closed forests have a canopy cover above 40 %, whereas **open forests** have a canopy cover between 10 and 40 %.

Categories of forests

1. ***Natural forest** consists of indigenous (native) tree species. It is managed only to a very limited degree, i.e., one may practice "tolerant forest management in which the native vegetation is largely conserved or reconstructed through successional processes"*

In natural forests, most beneficial trees occur spontaneously, although there may be some degree of management to stimulate the frequency and growth of these trees, e.g., by clearing competing vegetation.

2. ***Managed forest** consists predominantly of indigenous vegetation, and with active management to increase the frequency and productivity of beneficial species. The management will include felling (trimming, thinning in addition to regular harvesting) and planting of indigenous and/or exotic species.*

Managed forest will include both what is termed *production forest*, i.e., forests managed for timber production, and forests managed for various NTFPs. Forests and old forest fallows that have been enriched, e.g., by the planting of fruit trees, will therefore fall under this category. (See also discussion of *fallow* in the section below.)

3. ***Plantation** consists of forest stands established by planting and/or seeding in the process of afforestation or reforestation. They are composed either of (a) introduced species (all planted stands), or (b) intensively managed stands of indigenous species, which meet all the following criteria: one or two tree species planted, even age class, regular spacing.*

Tenure regime

The actual land tenure regimes consist of several dimensions, which should be reflected in the coding system used. We have used a lexicographic classification that consists of three dimensions or levels, where each dimension is represented by one digit in the three digit code used:

1. The formal or legal (*de jure*) owner of the land, which is the entity with the *transfer* rights (rights to sell, lease or rent out the land). We distinguish between three such entities: (1) the state at national or regional level; (2) communities or more generally: groups of people; (3) private entities (individuals or companies).
2. The actual or *de facto* owners of the land, that is, those that use it and have the *de facto* use rights (but normally not the transfer rights, neither *de facto* nor *de jure*). One problem in classifying land tenure is the overlapping use rights on the same piece of land, for example, some use rights can be held by individual households (e.g., using land for agriculture), while others are held by the community (e.g., collecting dead firewood or wild fruits). To capture this, we introduce a mixed category for community and individual *de facto* land rights, covering the situation used in the example. Thus we operate with seven categories: (1) state, (2) community, (3) private, (4) state-community, (5) state-private, (6) community-private, and (7) state-community-private.
3. The degree of enforcement of rules, which regulates access (who are the users), permissible uses, and possibly also the management of the land and its resources. Three categories are distinguished: (1) high, (2) moderate/low, and (3) no enforcement of rules. Note that the rules might be set by the *de facto* and/or the *de jure* owners, and may have the backing by either the state or customary institutions.

Note that *open access* is rarely a separate land category at the *de jure* level, in the sense that land almost always has a *de jure* owner (and the state often being the default owner). But *de facto* open access can appear within all categories of *de jure* owners, in situations with *no enforcement* of rules, or rules do not exist.

A distinction should be made between community and private *de facto* use rights. Private use rights refer to situations where only *one* individual, household or lineage has the rights to use the resource, while community rights refer to situations where a more or less well-defined *group* of people have the rights.