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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.

1. 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). Evi-

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[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).

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dence 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 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,b; Alavalapati et al., 2004). 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, 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 et al., 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).

2. Materials and methods

2.1. 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 6° 32′ 11.31" S and 6° 40′ 08.94" S latitudes and between 106° 46′ 12.04" E and 106° 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 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 21° 11′ 55.27" N and 23° 41′ 32.47" N latitudes and between 91° 51′ 53.64" E and 92° 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

[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.

[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.