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Review paper

Multi-species and multifunctional smallholder tree farming systems in Southeast Asia: timber, NTFPs, plus environmental benefits

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Abstract - The rapid increase in human population, and the corresponding worldwide enhancement of social and economical conditions, are exerting a considerable pressure to convert forests to other uses. Moreover, these phenomena raise the demand for food, fuel, wood fibers and other non-wood products, contributing to a further boost of the production pressure in the surviving forests. Simultaneously, these forests are expected to provide a diverse array of environmental services. Furthermore, smallholder forestry systems are prominent components of 'trees outside the forest' in Southeast Asia and they are primarily 'planted' systems that rehabilitate or reforest marginal lands, in order to produce tree products and services. As they traditionally are a means of producing goods for home consumption, they have become significant suppliers of products for local, national and international markets. The aim of this paper is to demonstrate that smallholder forestry systems are a viable management system which is significantly contributing to global environmental goals and local economic objectives. This paper reviews global and Asian trends of human population growth, deforestation, and demand for forest and tree products. The origin, the diversity, the adaptable management and the importance of smallholder tree-based systems are here discussed and significant details are provided on the role of smallholder tree-based systems in the mitigation of deforestation, which could be obtained by expanding regional forest resources; in supplying alternative sources of forest products and environmental benefits; and in making significant contributions to local livelihoods for rural communities.

Keywords - Smallholder, tree-farming, livelihood enhancement, timber, NTFPs, environmental benefits.

Introduction

The global human population reached 7 billion in October 2011, only 12 years after having reached 6 billion, and having doubled since 1968 (Worldometers 2011). With an annual growth rate of 75 million, the population is projected to be over 9 billion by 2050 (United Nations 2015). This rapid human population growth, and a corresponding increase in the wealth of some nations, are exerting a significant pressure capable of converting forests to agricultural, industrial, and residential uses. This also increases the demand for food, fuel, wood and non-wood products, intensifying the pressure on the surviving forest systems. Simultaneously, these forest systems are expected to provide a diverse array of environmental services. For this reason, the United Nations Millennium Development Goals are calling for a more considerable per capita wealth growth which might lead to the eradication of extreme poverty and hunger, while ensuring environmental sustainability (United Nations 2012).

Agroforestry is a dynamic, ecologically based, natural resources management system which, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains the production of goods for the increased social, economic and environmental needs of land users at all levels (Mead 2004). These systems are increasingly recognized as important opportunities for smallholder livelihoods, with neutral-to-positive environmental impacts, and they have received significant research attention over the last two decades (Leakey et al. 2012).

'Agroforestation' refers to the establishment of smallholder agroforestry systems and implies land rehabilitation through the establishment of tree-farming systems and intensification of land management (Roshetko et al. 2007a). Farmers develop and manage such systems by nurturing trees on their farms, pasture lands and homesteads. These tree-farming systems are efficient agricultural and natural resources production systems. As a prominent component of 'trees outside the forest', smallholder tree-farming systems are primarily 'planted' systems that rehabilitate or reforest marginal farmlands where agricultural crop production is no longer biophysically or economically viable.

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These systems can also be used to reclaim degraded lands. Smallholder systems could be more productive and profitable if the common policy barriers that limited their development were removed (van Noordwijk et al. 2008).

This paper emphasizes the contribution of smallholder tree-farming systems to environmental sustainability and local livelihoods. It first reviews the trends of regional deforestation and human population growth both globally and in Asia, with an emphasis on South and Southeast Asia. Subsequently, common tree-farming systems are described and their potential to produce forest/tree products and environmental benefits are finally discussed. A particular emphasis is placed on the potential of smallholder tree-based systems to reduce the pressure on the remaining natural forests, to expand regional forest resources, to produce forest/tree products and environmental benefits as well as to make major contributions to local livelihoods for rural communities.

Forest loss, environmental degradation and loss of forest services

The rate of global forest loss in the 20 years between 1990 and 2010 was alarming: For the period 1990-2000, the global annual deforestation rate was 16 million hectares; for 2000-2010, it was 13 million hectares. In addition, this alarming rate likely underreports the damage sustained by the global forest resource, as forest degradation is not included.

Forest cover was reduced to slightly more than 4 billion hectares (30% of the global land area) and the two countries with the largest loss of forest area, over the 20 years period, were Brazil and Indonesia, which respectively lost 2.8 million and 1.2 million hectare/year, representing 0.5% and 1.1% of the annual loss of their forest area (FAO 2010). These changes primarily represent the loss of tropical forests to other land uses: conversion from diverse tropical ecosystems to annual agricultural systems, monoculture tree plantations and cleared (but left not used) landscapes.

Fortunately, the rate of forest loss in both countries and across the globe has declined, but the rate is still far from being sustainable. The rate of deforestation is somewhat offset by planting and natural forest regeneration. The total net change in global forest area was a decline of 8.3 million hectare/year in 1990-2000 and of 5.2 million hectare/year in 2000-2010, the difference with the above deforestation figures being between the areas planted or naturally regenerated (FAO 2011). Efforts to plant new forests and trees have gained momentum as the planted forests represent 7% of total global resources, with an increase of 5 million hectares in the first 10 years of the millennium (FAO 2010).

In Asia, the deforestation-afforestation trend has been mixed. On the basis of FAO data for the 1990-2000 period, the Asia-Pacific region lost forest cover at a rate of 700,000 hectare/year. However, in the subsequent 10 years the trend reversed, with the regional forest cover increasing by 1.4 million hectare/year (FAO 2011, FAO 2010). The reversal in regional deforestation was largely due to the successful tree planting programs in China, India, Vietnam and Thailand. In the 20 years under consideration, China amazingly planted 35.2 million hectares of forests, India 4.5 million, Vietnam 2.5 million and Thailand 1.3 million. Sub-regional and national performance varied significantly. East and South Asia both showed gains in forest cover, while Southeast Asia and the Pacific continued to lose forest cover (Table 1). In Indonesia, the rate of forest lost has greatly declined, but annual forest loss remained still high (100,000 hectares of primary forests and 30,000 hectares of planted forests).

Besides helping to reverse the loss of forest cover, planted forests are an important and efficient source of wood and non-wood products. In 2000, forest plantations accounted for approximately 5% of global forest cover, with industrial forest plantations accounting for only 3% but supplying 35% of global roundwood (FAO 2000). By reducing production pressure, planted forests may have a tempering effect on the rate of natural forest loss.

Established for diverse reasons, tree plantations have generally limited species diversity and they have frequently been monocultures of exotic species. Such systems are much inferior to natural forests in supporting most of the main ecosystem services: biodiversity and habitat conservation, genetic conservation, ecological resilience, water and soil conservation, and carbon storage. Additionally, in many cases, forest plantations are a main cause of natural forest conversion and loss, thus being a direct cause of natural forest growth, biodiversity and carbon stock loss. Hence, forest plantations are a paradox: they are an important and efficient source of wood and non-wood products but are also a main cause of the forest conversion and of the loss of environmental services provided by these natural systems.

Population growth, economic development and demand for forest products

While the forest base will decrease, human populations and economic development will grow, increasing the demand for, and the consumption of, forest and wood products throughout Asia and the

Table 1 - Forest areas in Asia and the Pacific, 1990-2010 (FAO 2011).

Sub-region[1]	Area (,000 ha) 1990	2000	2010	Annual change (,000 ha) 1990-2000	2000-2010	Annual change % 1990-2000	2000-2010
East Asia	209,108	226,815	254,626	1762	2781	0.81	1.16
South Asia	78,163	78,098	80,039	-7	221	-0.01	0.28
SE Asia	247,260	223,045	214,063	-2422	-898	-1.03	-0.41
Pacific	198,744	198,381	191,384	-36	-700	-0.02	-0.36
Asia-Pacific	733,364	726,339	740,383	-703	1404	-0.10	0.19
World	4,168,399	4,085,063	4,032,905	-8334	-5216	-0.20	-0.13

[1] **East Asia:** China, North Korea, Japan, Mongolia, South Korea
South Asia: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka
SE (Southeast) Asia: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Vietnam
Pacific: American Samoa, Australia, Cook Islands, Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru,, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Marina Islands, Palau, Papua New Guinea, Pitcairn, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands.

rest of the world. In 1995, South and Southeast Asia were home to, respectively, 1,109 million (23% of the world's population) and 437 million (9%) (ADB 2004). By 2010, the human populations of the regions had grown to 1,598 million and 593 million, respectively, with their proportional share of the global population remaining steady (United Nations 2010).

Current annual population growth rates for individual countries in South and Southeast Asia ranged between 0.7% in Thailand and Myanmar; 1.8% in Pakistan, Nepal, Bhutan and Brunei; 2.1% in Timor-Leste; and 3.5% in Singapore (United Nations 2010). Gross national income (GNI) per capita in the regions in 2005 varied from US $270 in Nepal through US $430 in Cambodia and Laos to US $2,720 in Thailand and US $4,970 in Malaysia. Increases in GNI per capita between 2000 and 2005 varied from 17% in Nepal and Bhutan to 35% in Thailand, 62% in India and Vietnam, and 125% in Indonesia (ADB 2006). The gross domestic products (GDP) of most South and Southeast Asian countries have grown at annual rates of about 5-8% between 2010 and 2012 (CIA 2012). At such growth rates, the size of the middle classes in Asia's developing economies (excluding Japan) would double or triple in the first decade of the new millennium, numbering 0.8 to 1 billion people and forming a middle-class market equal to or surpassing that of the US and Europe combined (Chipeta et al. 1998). Population growth and expansion of middle classes with greater disposable incomes will increase the consumption of forest products, which, in turn, will be reflected in the expanded global trade of these products.

The demand for all forest products is significant and is projected to increase, from the regional to the international level. For instance, the global demand for industrial roundwood is expected to increase to 2,165 and 2,436 million m^3 by 2020 and 2030, respectively, these representing increases of 29% and 49% over global production in 2005. During the same time, Asia-Pacific demand for industrial roundwood will increase by 58% and 78%, respectively, but production will not keep pace with demand (FAO 2009). This projection emphasizes the urgent need to expand the regional forest base, a process that should include afforestation, reforestation, and smallholder agroforestry systems (Roshetko et al. 2008).

Smallholder tree-farming systems: origin, multiple goods and environmental benefits in Southeast Asia

In this paper, the term 'smallholder tree-farming systems' is interchangeable with 'smallholder agroforestry systems'. Depending on local needs or opportunities, smallholder systems may focus on tree crops, agricultural crops, livestock or a combination of the three. These various systems will differ greatly in size, species components, tree density, tree longevity, and management intensity.

Smallholder tree-farming systems may originate from natural forests that have been altered in composition or structure by local people, tree-based systems established on agricultural or fallowed land, or a combination of both. There are examples of forest degradation being deflected by the establishment of smallholder tree-farming systems which avoid the more serious stages of environmental degradation. In these situations, good markets for non-wood products, such as fruits, resins and latex, have allowed a transition of substantial areas of Southeast Asian forests into 'agroforests', i.e. a land use that combines 'planted trees' with forest flora and fauna, with either retained or naturally regenerated vegetation (de Jong et al. 2001, Michon and de Foresta 1990, 1995). Similarly, by the production of wood and non-wood products on farms, smallholder agroforestry systems have been identified as a means of reducing pressure on and conserving natural forests (de Foresta et al. 2003, Scherr and McNeely 2008, Strandby-Andersen et al. 2008). Farmers in Sumatra cultivating agroforestry systems relied less on wood supplies harvested from natural forests than those

without agroforestry systems (Murniati et al. 2001). Dawson et al. (2013) comment on agroforestry's role in the conservation of tropical tree diversity through use.

In deforested regions, a shortage of local forest resources is often the catalyst of spontaneous expansion of smallholder agroforestry systems (Santos-Martín et al. 2012). This type of farmer-led, spontaneous, smallholder tree-farm development has been documented in Sri Lanka (Gunasena 1999), Philippines (Garrity and Agustin 1995, Schuren and Snelder 2008), Kenya (Scherr 1995) and Indonesia (Michon and Bompard 1987). In addition, proximity to urban centers creates high demand for timber, fruit and other forest products and stimulates spontaneous smallholder agroforestry. This is especially true for areas far from the extractive forest frontier and/or with farms large enough to support tree crops, in addition to seasonal cash crops. In other situations, the temporary migration of young people to cities results in the extensification of land use with tree farming evolving as a lower labour input alternative to annual crops (Bertomeu 2006). Thus, smallholder tree planting has led to land rehabilitation (Pulhin et al. 2006) and regional forest transition by restoring tree cover (Mather and Needle 1998).

Smallholder farmer tree-planting systems are generally successful on their own terms. Smallholders commonly have limited time, labour and financial resources. Planting trees represent a conscious investment chosen among other available options. Farmers generally restrict plantings to the number of trees that can be maintained and integrate tree-growing with agricultural crops and animal husbandry activities. The management practices undertaken to ensure good food crop yields, cultivation, weed control and fertilization, and tree pruning, also benefit trees (Bertomeu et al. 2011). The available land, labor and other resources are allocated according to the farmer's objectives. Because landholdings are small, farmers can select the farm niches most appropriate for tree production. The combination of limited resources, small individual plantings, and intimate familiarity with the planting site result in high species diversity, tree survival and good growth rates. Smallholder tree-growing activities benefit from intensive management over limited areas and vested self-interest: the desire of the farmer to profit from their investment of time and resources (Roshetko et al. 2008).

As opposed to forest plantations and other public-planted forests, smallholder tree-farming systems provide an array of tree and forest products and environmental benefits, including support of local livelihoods. Smallholder timber systems are frequently used to grow assets for emergencies or specific cash needs (Roshetko and Westley 1994, Bertomeu 2004, Perdana et al. 2012). Under these conditions, smallholder farmers look at tree farming as a means of diversifying their production, reducing risk, and building assets to enhance family incomes and security (Roshetko et al. 2007b, Schuren and Snelder 2008). Besides supporting family livelihoods, smallholder agroforestry systems also make a significant contribution to national economies and global trade. In the Philippines and Indonesia smallholder-produced timber has become an important source of raw material for the local industry and the international markets (Bertomeu 2004, Tukan et al. 2004, Bertomeu, 2008, Roshetko et al. 2013). Products from smallholder systems in Indonesia include rattan, forest honey, sandalwood, gaharu, damar, benzoin, cinnamon, cloves, nutmeg, candlenut, rubber, cacao, coffee, oil palm and tea (Dove 2004, de Foresta et al. 2003, Garcia Fernandez 2004, Rohadi et al. 2003, Sunderlin et al. 2000, DGEC 2012). The five major global tree commodities are oil palm, coffee, rubber, cacao and tea, with an export value of roughly US $80 billion in 2009 (Dawson et al. 2014). Indonesia is a major producer of all the five commodities. In 2011, smallholders in Indonesia produced most of the coffee and cacao, 80% of the rubber, 39% of the oil palm, and 26% of the tea (Table 2).

Smallholders' agroforestry also provide many environmental benefits, including soil fertility replenishment, water catchment protection, biodiversity conservation, genetic conservation, reforestation, carbon storage, besides the reduction of pressure on natural forests (Garrity 2004, Roshetko et al. 2007a, Idol et al. 2011, Dawson et al. 2013). In societies where the majority of people live in urban areas, concerns over the accelerating loss of open and green space are becoming prominent. This is a quality-of-life issue to many and increases the recognition of agroforestry systems value to provide ecological functions also.

The main purpose of diversified productions and the complementary achievement of private and public environmental benefits, attribute dynamic, productive, risk-averse values to agroforestry systems. Additionally, but less recognized, agroforestry systems demonstrate a valuable potential in both

Table 2 - Smallholder production of oil palm, coffee, rubber, cacao and tea in Indonesia, 2011 (DGEC 2012).

	Smallholder area (,000 ha)	% of total area	Smallholder production	% of total production (,000 ton)
Oil palm	3,315	42	7,774	39
Coffee	1,255	96	679	96
Rubber	2,935	85	2,104	80
Cacao	1,641	94	828	92
Tea	56	46	40	26

mitigation and adaptation to climate change. On a per area basis, tree-rich, smallholding systems store a significant amount of carbon. Multi-storey agroforests and tree gardens 60 years-old or more can store up to 350 Mg ha^{-1}; home-gardens and smallholders' timber systems around 40 years-old can store up to 280-300 Mg ha^{-1}. The amount of carbon stored by specific systems will depend on biophysical conditions and tree density. However, the amounts of carbon stored in smallholders' agroforestry systems are similar to those in some secondary forests over similar time periods and greatly exceed the carbon stored in the low-biomass systems - such as fallow agricultural land and *Imperata* grasslands - that smallholders' systems often replace (Roshetko et al. 2002).

Other factors bearing on carbon stock are the species composition and management practices, specifically, the time trees are being mantained in a system. For carbon storage it may be beneficial to limit the number of low-biomass species - such as coconuts (*Cocos nucifera*) and bananas (*Musa x paradisica*) - and the amount of timber harvested. These options have to be balanced with farmers' goals for their own livelihood and land management. To farmers, carbon is even less tangible than other environmental benefits, such as watershed protection or biodiversity conservation. First, farmers' agroforestry systems must be socially and economically viable because then they are less likely to be converted to other, lower carbon, land uses. Carbon payments to farmers would promote transparency and increase farmers' understanding of the services the agroforestry systems provide. Any income received for carbon should be treated as an additional return for services already provided by such systems. This approach would help protect smallholders from project or market failure (Roshetko et al. 2007a).

Smallholders can also play a key role in protecting, through use, plant and tree diversity. Although smallholder tree-based systems are less diverse than native forest, agroforestry landscapes of the tropics usually contain dozens or even hundreds of tree species (Idol et al. 2011, Dawson et al. 2013). In complex agroforests, farmers may retain remnants from natural forests because of the products they provide or for religious, cultural or aesthetic reasons. The high tree species richness found in these agroforests suggests a strong role for smallholders to conserve plants and trees in farmland (i.e., circa situm conservation) (Dawson et al. 2013).

In deforested landscapes, smallholder tree planting can increase tree diversity and density, using indigenous or exotic planting materials produced either on-farm or in commercial tree nurseries (Ordoñez et al. 2014). Farmer-led reforestation may initiate forest transition, accelerating the restoration of degraded lands and resulting in higher biodiversity value (van Weerd and Snelder 2008, Idol et al. 2011). Compared to large-scale forest plantations, smallholder systems contain a much greater number of plant and animal species (Michon and de Foresta 1995, Murdiyarso et al. 2002). This diversity can provide ecological resilience and contribute to the recovery and maintenance of beneficial ecological functions. Smallholder tree-based systems, similar to plantations, are 'working forests' and they can help relieve some of the pressure to harvest native forests (although their presence as such is not a sufficient condition for the protection of old-growth forests (Angelsen and Kaimowitz, 2001, Tomich et al. 2002). For instance, in watersheds, linked systems of upland and riparian tree-based buffer systems, designed with regard to other landscape practices and features, can optimize soil and water conservation (van Noordwijk et al. 1998), along with other economic and social services.

Conclusions

Smallholders with diverse, risk-averse farms that include a significant tree component, have been producing a range of tree-commodities and could be efficient producers of other tree-commodities in the future. As described above, their tree-farming systems have high potential to yield both wood and non-wood products and play a key role in the recovery of degraded lands. Smallholder tree-farming systems have the potential to be one component of a general poverty alleviation strategy for agrarian-based, poor rural communities (Roshetko et al. 2007a, Snelder 2008). Although the social potential of tree-farming systems has not been fully exploited and the extent to which these systems can alleviate poverty and enhance food security is poorly documented, the importance and potential of the systems will continue to rise, especially with the continued development of market economies and rural infrastructure (Roshetko et al 2002). The importance of smallholder systems first as a source of forest and tree products and secondly as provider of environmental benefits will only increase as global forest resources continue to shrink and human populations expand (Roshetko 2013).

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