High Carbon Stock Rural Development Pathways

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High-Carbon-Stock Rural Development Pathways in Asia and Africa: Improved Land Management for Climate Change Mitigation

Peter A Minang, Meine van Noordwijk and Brent M Swallow

Abstract

Low carbon (emission) economic development pathways are needed to contain and gradually slow emissions of the greenhouse gases (GHGs) that cause global climate change. As developing countries contribute to GHG emissions largely through land management practices that degrade landscape carbon stocks, climate change strategies in developing countries must give specific attention to land management. Yet, current mechanisms for international investment or incentives in emission reductions from the land use sector, especially Reduced Emissions from Deforestation and Degradation (REDD+) and the Clean Development Mechanism (CDM), have so far been slow to develop. Prospects remain good, however. Intensification of land use through tree-based production systems has emerged as a principal rural development pathway in much of Southeast Asia, with significant benefits for reducing GHG emissions, generating economic returns, providing ecosystem services, and adapting to climate change. In Africa, intensification of tree-based production systems has been much slower to develop despite great bio-physical potential. This paper develops the concept of a high-carbon-stock rural-development (HCSRD) pathway as an extension of the tree cover (forest) transition model, and compares experiences of HCSRDP development in Asia and Africa. Those experiences show that achieving a HCSRD pathway requires coordinated attention to interactions and trade-offs among forestry, agriculture, and rural development. Innovative finance mechanisms, enabling policy and institutional environments, effective and efficient extension systems, and appropriate investment strategies can catalyze tree-based or agroforestry enterprises and optimize trade-offs between the multiple functions of landscapes.

Key Words: Agricultural Intensification, Tree-based agricultural systems, REDD+, Low-Carbon Development Pathways, Trade-offs

Introduction

There is a growing consensus that low-carbon-emission economic development (i.e. improvements in social wellbeing, with reduced intensity of carbon emission) is required for reliable long-term solution to global climate change. With the rural economies of developing countries contributing about 30% of global greenhouse gas (GHG) emissions through land use change in agriculture, forestry, and other land management activities (IPCC, 2007), a sustainable land management approach to a low-carbon- emission economy has become imperative for developing countries. Reductions in carbon emissions can be achieved through reductions in emission intensity and maintenance of high carbon stocks in terrestrial ecosystems and agroecosystems.

The Clean Development Mechanism (CDM) of the Kyoto Protocol sought to contribute to low-carbon economic development through the transfer of low-emission technology to developing countries funded through emission offsets with Annex 1 countries. Despite its importance, however, virtually no land-based emission credits have been generated through the CDM. In recent years there has been widespread political support for Reduced Emissions from Deforestation and forest Degradation (REDD+) under the United Nations Framework Convention on Climate Change (UNFCCC), most recently demonstrated by the agreement on REDD+ that was achieved during the Conference of Parties (COP) held in Cancun, Mexico in December 2010 (UNFCCC, 2010). Support for REDD+ is partially due to the expectation that emission reductions from land use change will be cheaper than other sectors (Stern, 2006). Such a land-based approach through agriculture and forestry could be part of a larger green economy initiative that incorporates low-carbon economic development (UNEP, 2011a; 2011b)[1]. This chapter explores the role of trees in agricultural landscapes (agroforestry) and other tree-based systems in a low carbon economy. We refer to the role of agroforestry and tree-based systems in contributing to reducing carbon emissions and the full range of private and societal benefits in terms of livelihoods and environmental services as high-carbon-stock rural development. High-carbon stock rural-development (HCSRD) pathways are dynamic processes that couple the development of tree-based systems, improved human well-being, and long-term improvements in environmental services. We contend that HCSRD pathways could be an effective way for developing countries to synergize development plans with Nationally-Appropriate Mitigation Actions (NAMAs) and National Adaptation Plans that were called for by the Copenhagen Accord.

Worldwide, trees in agricultural landscapes hold great potential for climate change mitigation that at this time is not explicitly taken into account in any of the three UNFCCC mechanisms, namely REDD+, CDM, and NAMA. About 46% of agricultural land globally has at least 10% tree cover: in Southeast Asia and Central America, 50% of agricultural land has at least 30% tree cover, while in Sub-Saharan Africa about 15% of agricultural land has at least 30% tree cover (Zomer et al., 2009)[2]. The place of agroforestry and related tree-based systems in potential UNFCCC emission reduction mechanisms depends on what definition of forest is adopted by a country- i.e., whether the agroforestry system meets the forest canopy cover threshold chosen by the country (10 – 30% choice range) and/or whether the land is classified as forest even if it is "temporarily unstocked" (van Noordwijk and Minang, 2009). REDD+ only addresses forestry, CDM allows only afforestation and reforestation projects, while the design of NAMAs are left to discretion of individual countries, with no clear funding arrangement. . This means that small–scale farmers and agriculture cannot directly benefit from emission reduction incentive schemes.

Uncertainty is rife on how far both REDD+ and CDM can contribute to sustainable development partly because they have been slow to take effect in large parts of both Africa and Asia. Furthermore, mitigation mechanisms within the UNFCCC have so far been kept completely separate from adaptation actions that seem to be the primary climate change concern for most developing countries (Klein et al., 2005; Najam et al., 2003). Besides contributing to development and emission reduction, we contend that HCSRD can be an approach that developing countries can pursue as part of their strategies for climate change mitigation and adaptation (Verchot et al., 2007). It is important to keep in mind that climate change mitigation and adaptation are not among the most basic concerns of governments in most developing countries and, in instances where it is assigned priority, little is done due to lack of capacity and resources (Mumma, 2001; Najam, 2005). However, we argue that, unless climate change is more directly linked to issues of greater concern, it is likely to remain a 'luxury' perspective that keeps being assigned low priority.

Active participation in global climate change mitigation and adaptation (M & A) has been presented to and perceived by policymakers as a possible additional income stream or 'environmental service rent' (Angelsen, 2010) that may be competitive with low rents generated by the forest and agricultural sectors of the local economy. Returns to agriculture are often constrained by low food price policies that are aimed at appeasing urban masses (Bezemer and Headey, 2008). The low opportunity costs of current emissions caused by land use changes in developing countries that yield low economic returns (Swallow et al., 2007; van Noordwijk et al., 2011)[3] have been interpreted as easy targets for global emission reduction when viewed through a perspective of economic efficiency in global economies. These low opportunity costs, however, translate into poor economic opportunity for the rural poor whose only options are to migrate to a city and start at the bottom rank of the urban pecking order. If environmental service rents can be captured by the state or its urban elites, they may appear attractive in abstract, but to be effective they have to be fully integrated in HCSRD pathways that offer rural poor real prospects for better lives. Ironically, the argument for developing countries becoming involved in climate change mitigation for economic gain tends to resisted by the small but growing groups of people in developing countries who are actually concerned about global climate change, and want real emission reductions rather than offsets. It is argued that carbon markets effectively create emission rights, with offset markets shifting those rights around. Skeptics of offset markets argue that developing countries may get paid "to be an atmosphere cleaner," but should demand a fairer role in the global order (Najam, 2005).

Arguments for active engagement with climate change in developing countries are thus (Najam et al., 2003; Najam, 2005; van Noordwijk and Leimona,2010):

A) Climate change will affect territorial security, which is especially the case for small island states vulnerable to sea level rise;
B) Climate change will affect food security in urban areas, as it interferes with a fragile food production system that is poorly buffered against climate fluctuations;
C) Carbon-based environmental service rents may generate an income stream that is more profitable and sustainable than the current high emission/low return types of land use;
D) International funding streams and investment are, to a limited extent, available to address issues of global environmental integrity and climate security, avoiding global risks to every country's fundamental concerns.

In the next section of this paper, we articulate a model of high-carbon-stock rural development pathway through which agroforestry and tree-based systems could potentially enable developing countries to accommodate low carbon emissions, rural economic development, and food security in their policy priorities. Evidence from Southeast Asia and Africa shows that high-carbon-stock rural development pathways are possible, but by no means are automatic or easily obtained.

High Carbon Stocks Rural Development

The Inter-Governmental Panel on Climate Change (IPCC) has established the global importance of land use, land use change and other land use as sources of carbon emissions and sequestration. Land use changes often follow particular sequences or transitions, starting from primary forest or savannah woodlands, depending on the agroecological context. Land use transitions can take multiple pathways, with varied impact on forest cover (hence carbon), income, and human populations. Examples of such trajectories include intensification with deforestation, intensification with reforestation, abandonment with regrowth, abandonment, and irreversible degradation (Chomitz, 2007)[4]. Different combinations of demographic, market, and policy pressures can underlie forest transitions of forest cover reduction, stabilization, and ultimate increase. Figure 1a shows the forest transition in which forests initially decline due to encroachments from farms and settlements and then stabilize and eventually increase due to mechanisms that enable regeneration (Grainger, 1995; Mather and Needle, 1998). When mechanisms for maintaining forests in the landscape and enable regeneration dominate over time in the landscape, overall tree cover and carbon stocks increase (Figure 1b). When land use transitions enable reductions in emission intensities or maintenance of high carbon stocks in terrestrial ecosystems, they contribute to low carbon pathways. When such transitions simultaneously contribute to low carbon pathways, increased incomes, food security, and environmental services, they contribute to low carbon economic development.

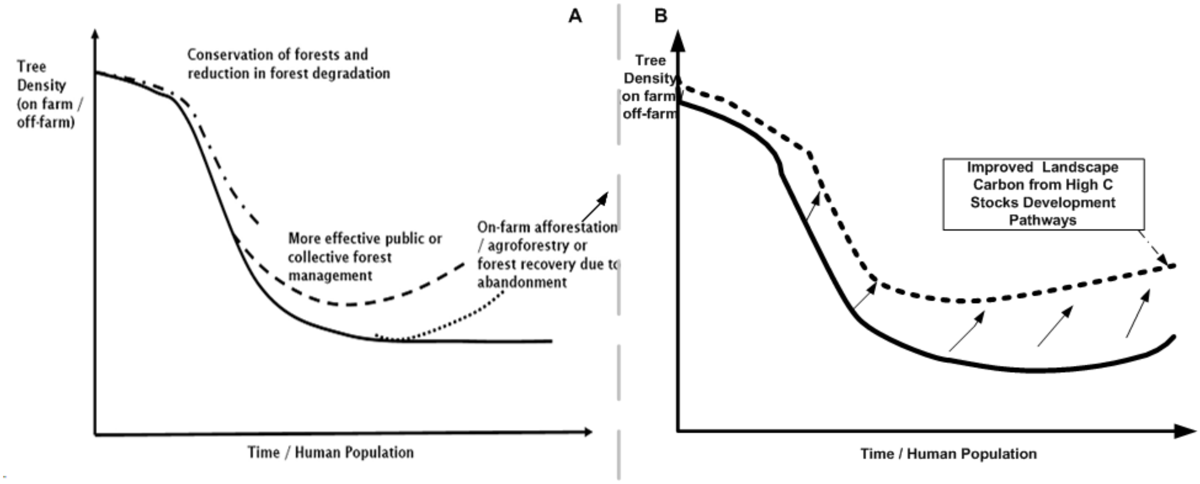


Figure 1: Shows the overall aim of HCSRD on the tree cover transition. 1a-shows the multiple pathways of landuse transitions for high carbon stocks rural development pathways (Source: Modified from Rudel et al. 2005 and Chomitz 2007); 1b shows the overall objective in terms of shift in tree cover transition that should be targeted in the high carbon stocks rural development process.

HCSRD can be seen as rural development through improved land management systems that ensure increased productivity, incomes and environmental services – notably reduced carbon emissions. This can be achieved through the management of carbon in three related pools: 1. tree-based above-ground and below-ground carbon in agricultural landscapes (e.g., trees along field boundaries, small woodlots, woody fallows, tree crops, and agroforestry systems), 2. Soil and above-ground carbon in agricultural landscapes, and 3. tree carbon and soil carbon in standing forests. By managing each pool and all pools collectively, overall tree cover and carbon can increase over time as shown in Fig. 1b. HCSRD improves tree cover in landscapes through a rural development process that generates positive benefits for the rural livelihood asset base, including positive direct benefits for food, income and carbon, and indirect benefits for biodiversity and hydrology. Therefore, HCSRD could be seen as complimentary to landscape approaches to land management and sustainable intensification.

Key features of HCSRD can include:

Better management of soil carbon (Lal, 2004) through:

- Reform and public investment in markets for inorganic fertilizer, combined with "smart" targeted subsidies for inorganic fertilizer (Palm et al., 2010);
- Integration of inorganic and organic sources of soil nutrients into agricultural production systems, including both perennial and annual crops (Van Lauwe et al., 2010).

Maintenance of carbon stocks in primary and secondary forests through:

- Community forestry for sustained harvesting of non-timber forest products (e.g., Blomley et al., 2008);
- Better control of fire risks and restoration of degraded forest lands (e.g., Pye-Smith, 2010)[5].

Enhancement of tree-based carbon in agricultural lands (Albrecht and Kandji, 2003):

- Improved soil fertility and belowground carbon storage in roots and soil;
- Increased sequestration and aboveground carbon storage in trees within agricultural systems;

Tree-based systems of value creation in rural landscapes:

- Tree-based commercial crops and agroforestry through provision of appropriate information, germplasm and land tenure reform;
- Development of value chains for trees and tree-products and services including improved germplasm, inputs, harvesting techniques, processing and marketing;
- Taking advantage of relevant incentive systems to promote tree-based systems, their products and services, possibly taking advantage of REDD+, CDM, and NAMA mechanisms to enhance land based emission reductions.
- Specifically ensure that tree-based systems minimize the externalities of ecosystem services and / or enhance climate change adaptation and ecosystem services.

In some circumstances, good management of soil carbon and avoided land degradation can reduce the need to expand cultivation into forests or wooded areas. Since the advent of REDD+, there has been renewed research interest in the drivers of deforestation. DeFries et al., (2010) argue that expansion of export-oriented agriculture has become the main driver of deforestation in much of the developing world, while Fisher (2010) argues that expansion of agricultural production for subsistence needs remains a primary driver for deforestation in Africa. Agriculture remains the largest employment sector in many developing countries, constituting a large share of exports in certain countries (World Bank, 2008). Yet, these same developing countries need to continuously increase food production to ensure food security for their growing populations. Economic growth and greater prosperity tend to shift food consumption patterns toward dairy and meat products that often have larger carbon footprints than staple foods (Subak, 1999).

Regarding soil carbon, a large difference between Africa and most of Asia is that production increases in Africa have mostly been generated from expansion at the extensive frontier of land use, while production increases in much of Asia have mostly been generated from more intensive use of already cleared land (World Bank, 2008). Soil carbon has been maintained through both organic and inorganic fertilizer. Research by the Tropical Soil Biology and Fertility programme (TSBF) and the World Agroforestry Centre have shown the possible complementary effects of organic and inorganic sources of nutrients (Akinnifesi et al., 2011; Vanlauwe et al., 2010). More efficient fertilizer markets and more organic sources of soil nutrients (e.g. biological nitrogen fixation by tree legumes) are important. Here, trees are also an important source of soil fertility improvement and aboveground carbon.

Regarding carbon in intact standing forests, experience has shown that sustainable forest management can be achieved in ways that enhance local livelihoods while reducing deforestation pressures. Community forestry systems that are relatively effective in countries like Nepal and the Philippines are now showing promise in African countries like Tanzania and Cameroon (Larson and Ribot, 2004). In some cases, forest management systems can be enriched through simple management techniques such as the *ngitili* system that is practiced in the Sukuma area of western Tanzania (Pye-Smith, 2010). The *ngitili* system is a traditional management system in which an area of standing vegetation of grasses, trees, shrubs, and forbs is retained from the onset of the rainy season and managed for grazing and other purposes (Kamwenda, 2002)[6]. Better management of secondary forests can generate income while maintaining carbon stocks and providing ecosystem services to surrounding farms.

The Potential for High Carbon Stocks Rural Development Pathways

HCSRD aims at enabling effective and efficient achievement of the full potential of enhancing private and social livelihoods as well as environmental benefits from agroforestry and other tree based systems. Long-term studies across the tropical forest margins show that intermediary land uses (agroforestry and tree-based production systems) enable moderate profits while sequestering or maintaining high carbon and sustaining relatively high levels of biodiversity (Palm et al., 2005,). For example, Figure 2 shows the trade-offs between carbon and profitability for multiple systems in the tropical forest margins in Cameroon, with agroforestry systems being moderately profitable and holding moderate levels of carbon compared to non-tree agricultural systems. There is evidence that these and other intermediary land uses have high potential for carbon sequestration (Verchot et al., 2007).

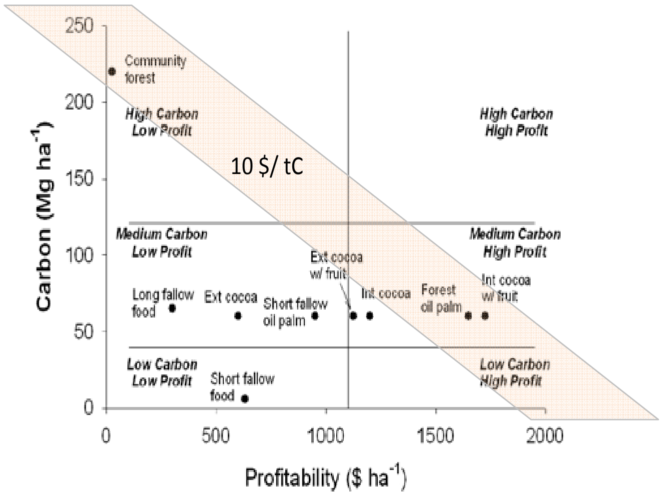


Figure 2: Carbon storage and private profitability of different systems in the humid forests of Cameroon (Palm et al. 2005); the main negative diagonal represents an opportunity cost of carbon of 10$/ tC when converting forest to the most profitable agroforestry system; conversions to systems in the lower left triangle yield less benefits per unit Carbon loss (van Noordwijk et al., 2011).

A number of factors are crucial to the success of any HCSRD pathway. We postulate that these factors include: an effective and efficient extension service (including the provision of improved germplasm), an enabling policy and institutional environment (including unambiguous land and tree tenure, incentive schemes for environmental services), the development of markets and market infrastructure, investments in various tree-based enterprises (including processing and transformation of products), and functional systems for delivery of carbon services (Monitoring, Reporting and Verification, etc.).

In the next sections we review the dynamics of tree-based intensification in both Asia and Africa as a pointer to the potential for HCSRD pathways. Sub-Saharan Africa and Southeast Asia (SEA) were chosen for a number of reasons including deforestation rates, human population density, and potential for increasing trees on agricultural land. Africa and Asia are loosing much higher proportions of forest cover than other regions of the world (FAO, 2010), while population densities on agricultural land are much higher in Asia (many areas having 25 to 250 persons /km^2) and sub-Saharan Africa (66 to 125 persons / km^2) than comparable regions in Latin America (often less than 65 persons / km^2) (Zomer et al., 2009). Lower population pressure implies less need for intensification of land use. Lastly, Africa and Asia have far larger areas of land with under-developed potential for tree-based systems compared to Latin and Central America (Zomer et al., 2009). The distribution and evolution of tree-based systems varies tremendously across the continents, with notable advances in SEA and slower progress in Africa. These different rates indicate varied potential for HCSRD. The case studies from Asia are based on studies from the Alternatives to Slash-and-Burn program (ASB), while the Africa case studies represent success stories reported from across the continent.

Tree-Based Agrarian Transformation in Southeast Asia (SEA)

Swidden systems have been the starting point for agriculture across the sub-humid tropics, including most of SEA. 'Swidden' or shifting cultivation refers to lands cleared of woody vegetation for temporary production of local staple crops for food or other uses, then left to fallow and allowed to re-generate. Padoch et al., (2007) estimated that 15 to20 million people in Myanmar, Thailand and Malaysia (Sarawak and Sabah) depended on swidden in the 1980s, cultivating an area of 5.5 million and 6 million hectares. There is growing consensus that swiddens have been evolving rapidly in many parts of SEA, though data on its extent and evolution are still inconsistent. Fallow periods of about 13 years between rice crops have been reduced to 3–5 year herbaceous fallows and permanent farms. Conversion from swidden fields to cash crop plantations and reforested land also occurs. For example, rubber plantations began to be established in the 1960s and by 1998 occupied more than 136,000 ha of land in SEA (Guo et al., 2002). More than half of the reported swidden cases are being replaced by some forms of permanent, annual agriculture (Schmidt et al., 2009). Of over 90 cases reported in the reviewed literature, 52 were reported to be replaced by tree crops or tree-related enterprises with 17, 14, and eight reporting replacements with rubber (*Hevea brasiliensis*) (see figure 3), fruit tree cultivation (orchards) and oil palm (*Elaeis guineensis*) respectively.

In many ways, evolution of forest and agroforestry systems in northern Thailand over the last 20 years appears to be a good example of a HCSRD pathway. The proportion of farmland increased from 11% to 27% in this period, largely through expansion of traditional agriculture within forests. Traditional agriculture is high carbon, mostly complex agroforests of jungle tea (*Camellia sinensis L.)* embedded in hill evergreen forests (also known as "miang"). Though variations exist among ethnic groups, the trend has been towards gradual transformations of miang by substituting fruit trees and seed crops for many of the forest and tea tree species. There has also been active reforestation by government and communities, such as in the context of the Sam Mun Project, where the Forest Department was able to reforest 4,855 ha (out of 200,000 ha) in the area. A further

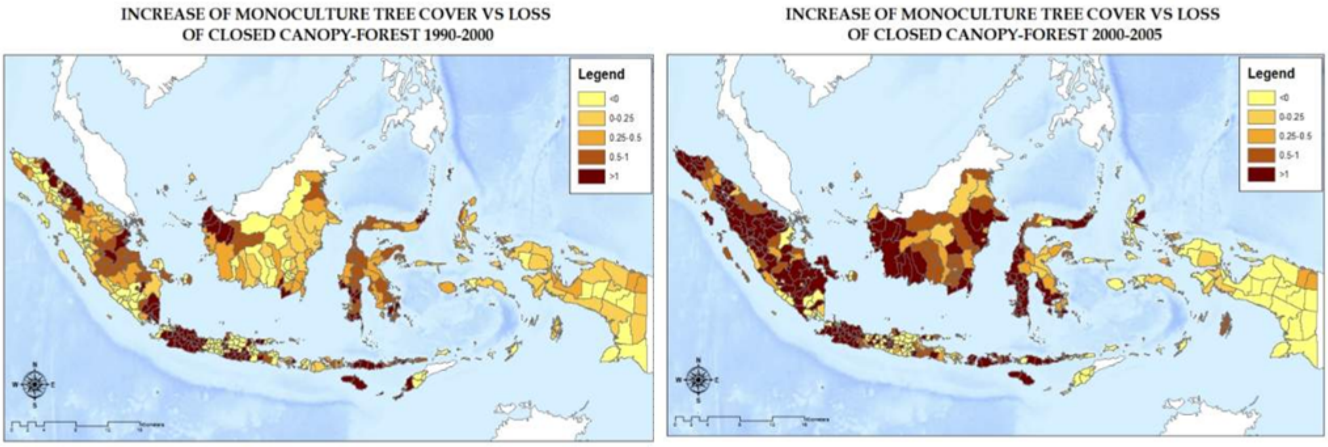
60,000 additional ha were regenerated by villagers through mutual agreement in a land use planning process in which communities were given mandate to control access, use

Figure 3 Jungle rubber (Hevea brasiliensis) in Jambi, Indonesia. Currently being replaced by more commercial rubber and oil palm.

fires, and other factors (Suraswadi et al., 2005).

Recent analysis of historical and ongoing swidden transformations in Indonesia by the ASB Partnership (van Noordwijk et al., 2008)[7] suggests that there has been strong agrarian transformation, but also differentiation within the country, with major parts of Java and Sumatra moving out of shifting cultivation and into permanent cropping before 1990, and the province of Papua still mostly relying on swiddens. Swiddens usually occur in landscapes with high forest cover and low population density. An important shift in the dynamics of swidden systems occurs if trees in the fallow vegetation gain major economic importance. This has happened in the case of the development of rubber, oil palm and mixed fruit-tree agroforests. In Sumatra, smallholder oil palm production is an emerging economic activity, while in Kalimantan, companies are making deals with local communities to establish oil palm monoculture systems.

Figure 4 shows that the nature of tree-based land use has changed in Indonesia between 1990–2000 and 2000–2005. An index of tree-based land use was created for each district of Indonesia, calculated as the ratio of increased monoculture tree cover to the area of loss of closed canopy forest. An index less than zero implies that monoculture tree cover reduced in area, an index between 0 and 1 indicates an increase in monoculture tree cover that was less than the loss of closed canopy forest, while an index greater than one indicates an increase in monoculture tree cover that exceeded the loss of closed canopy forest. Figure 4a shows that most districts in Indonesia experienced reductions in overall tree cover between 1990 and 2000, while figure 4b shows that most districts experienced increases in overall tree cover between 2000 and 2005 (Ekadinata et al., 2011)[8]. The nature of the tree transition clearly changed between the two time periods, with the latter period showing more evidence of HCSRD.



A: In the 1990's loss of natural cover increased the amount of 'low C-stock'/low economic value land; tree (crop) planting was 28% of the loss of natural forest area

B: After 2000 planting of tree (crop)s equals 90% of concurrent loss of natural forest; the amount of low C-stock/low economic value land decreases

Figure 4: Spatial illustration of developments in tree-based systems in Indonesia in the 1990s and 2000s (source: Ekadinata et al., 2011)

Tree-Based Agrarian transformation in Africa

In Africa, like much of Southeast Asia, trends and directions of agrarian change are only indicative, with current evidence being largely drawn from case study narratives / analyses rather than coarse large-scale empirical studies. Nonetheless these analyses suggest that tree-based and managed agroforestry systems are beginning to emerge at some scale. In a recent analysis of developments in sustainable intensification in Africa four cases were reported of developments in agroforestry and soil conservation on over three million hectares in Burkina Faso, Cameroon, Malawi, Niger and Zambia (Pretty et al., 2011). Two distinct categories of developments in agroforestry systems were reported-- agrarian change through the adoption of nitrogen fixing trees -- e.g., *Tephrosia and Calliandra* in Malawi, Zambia and Cameroon (Ajayi et al., 2007); and change through the introduction of fruit and timber trees in agroforestry systems in Tanzania and Kenya (Jama and Zeila, 2005)[9]. Another impressive case is the transformation of the Sahel through increased tree planting in parkland systems in Niger and Burkina Faso. For example, in the Zinder and Maradi regions of Niger, there has been a 10-to-20 fold increase of shrub- and tree cover over an area of over five million hectares and more than 200 million trees protected and managed (Reij and Smaling, 2008; Sendzimir et al., 2011). This has helped reclaim degraded lands, enhanced soil fertility, improved biodiversity and generated income and livelihood benefits. The landscape transformation in Niger was enabled by a strong policy shift in tree tenure following reforms. Until the mid 1980s, trees were declared to be owned by the state and therefore people had little or no incentive to plant and care for them. Tenure reform strengthened farmers' rights to trees. Restoration of tree cover has also happened at a large-scale in western Tanzania through the re-emergence of the ngitili system of pasture management (Pye-Smith, 2011).

In west and Central Africa, cacao (*Theobroma cacao* L.) agroforestry systems continue to dominate the agricultural landscape, currently occupying about 5 million ha in the Guinea and Congo humid forest zones. Cacao cultivation continues to expand into the Western Region of Ghana and the Bas Sasandra region of Côte d'Ivoire – with projected growth in 2005 of 125,000 ha yr^{-1} (Gockowski and Sonwa, 2011). Oil palm is now emerging as a growing sub-sector and could soon overtake cacao. There is evidence that the main drivers of cacao plantation expansion in Cameroon are economic boom and bust cycles, international cocoa prices, and labour availability (Sunderlin et al., 2000). These cacao systems range from full-sun mono-specific systems to complex cacao-timber-medicinal agroforestry systems- see figure 5. Full-sun systems are found mostly in the lower guinea forest systems in Liberia, Ghana, Côte d'Ivoire and Nigeria, while the more complex systems are mainly found in Cameroon and the Congo Basin countries. Complex systems have biodiversity values nearly equivalent to secondary forests (Gockowski and Sonwa, 2011), with non-cocoa products accounting for 23% of total revenue. Adding tree species to full-sun cacao systems would improve shade to between 30-40% (low shade) and optimize yield. However, when tree cover is increased beyond 30-40%, as in multi-storey cacao systems that promote biodiversity, yield decreases, and so other benefits are needed to offset the cost of increased shade. For these systems to be economically viable to farmers, they must generate income comparable to full-sun systems. By sequestering carbon as well as optimizing production, a low-shade system stores new and additional carbon that would not be generated under a low shade system. Financial incentives might be devised to account for the carbon and biodiversity benefits of higher shade systems. However, input, organizational, and marketing challenges abound to constrain such transitions.

Figure 5: Multistrata cacao (Theobroma cacao L.) agroforestry systems in Cameroon

Discussion and Conclusions

From the foregoing it can be seen that agrarian transformations in both Southeast Asia and Africa have been different both in terms of nature and speed. There has been rapid adoption of more profitable and valuable tree-based systems in Asia (e.g., rubber, oil palm, orchards, and teak (*Tectona grandis* L.) plantations) as opposed to expansion in traditional cacao systems and management of trees in the parklands of Africa. These land use transitions have been largely influenced and weaved into the broader economic trends and dynamics of each region. It can be said that better market access and connections to processing and industry in growing urban areas, dynamics in labour migration (rural –urban), and investment flows through remittances from urban areas have characterized the transformations that have occurred in Southeast Asia (Cramb et al., 2009; van Noordwijk et al., 2008). The slower pace of agrarian transformation in Africa has in several instances matched the boom-and-bust cycles of economic development (Sunderlin et al., 2000). Very weak extension systems, lack of inputs, poor physical and market infrastructure, lack of capital, and weak enabling policy environments have characterized this transformation in most of Africa, although there have been exceptions (Jama and Ziela, 2005; Gockowski and Sonwa, 2011). A glaring example of these differences can be seen in the rapid growth in Vietnam's coffee production compared to the stagnation (and failings in some cases) observed in Africa and other regions of the world (Greenfield, 2009)[10].

Thus, rural development pathways that result in landscapes dominated by tree-based / agroforestry systems are about rural and economic development that yields corresponding co-benefits for sustainable development and climate change mitigation. High carbon development pathways are about adding value (both economic and environmental) to land, and the opposite of land degradation pathways that reduce those values. In Africa, there is potential to leverage carbon and climate adaptation finance to meet the financing gaps that impedes the development of these systems. There is also a rights policy agenda around tree and carbon tenure that provides the opportunity to bring the kind of shift that was experienced in Niger to enable the transformation of landscapes into high carbon, high economic value landscapes.

However, there are challenges that must be kept in mind when moving in this direction. The majority of these challenges relate to understanding and managing trade-offs in the development of high C development pathways. Firstly, there is evidence that a focus on high value mono-culture tree plantation systems could deliver high incomes but leave farmers exposed to high levels of risk from global price fluctuations (Greenfield, 2009) and / or endanger farmer food security (Cramb et al., 2009). Due consideration needs to be given to multipurpose tree-based systems that can help spread risks and hence reduce vulnerabilities. Secondly, most high-carbon and high-profit tree systems take 3–5 years to recoup initial investments compared with food crop systems. Such long waiting periods can be prohibitive for small-scale farmers, thus representing the same kind of up-front financial requirements that has inhibited the development of Clean Development Mechanism projects. Investments might also be required to support the development of alternative income generating activities if and when high-carbon systems are adopted as part of a low carbon development strategy within the land use sector. Specific financial incentives could help high-carbon options to succeed, advancing the multiple objectives of carbon storage, biodiversity conservation, and poverty alleviation.

Thirdly, there are concerns that rural households could lose access to the natural products from forest fallow fields during the intermediate stages where swidden systems shift to more permanent forest cover. Little is known about the environmental costs and benefits of changes in the traditional systems and landscapes and indeed what policy options might better optimize benefits. Further research could be very instructive for the future development of HCSRD strategies. There may be advantages to whole landscape approaches where forest reserves are managed through community forestry or co-management regimes, alongside other multiple land uses. The fourth challenge relates to the development of an enabling policy environment. Tree tenure policy and market infrastructure are extremely important to farmer incentives to plant and maintain tree-based systems. The Vietnam coffee example shows how an effective export oriented policy model can overcome global instabilities in the coffee sector (Greenfield 2009), while the Niger example shows how a simple policy change can catalyze agrarian change through tree-based systems which have otherwise been documented to inhibit the same in Africa and Asia (Ruf, 2011; Santos-Martin et al., 2011). Lastly, promoting public and private investments and investing in improvements in extension services for HCSRD would need urgent and sustained attention. Remittances from urban areas in Southeast Asia have proven to be a vital investment lifeline for the development of small holder tree-based systems (Van Noordwijk et al. 2008). Similarly, investments in viable extension services and the tree product value chain have driven Vietnam's coffee boom over the last two decades (Greenfield, 2009). Only by addressing these challenges carefully can Africa and other developing regions begin the high-carbon stock rural development journey and eventually towards a low-carbon and green economy.

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