Agroforestry: contribution to food security and climate-change adaptation and mitigation in Southeast Asia

WHITE PAPER

AWG-SF
ASEAN Working Group on Social Forestry

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Delia C. Catacutan, Meine van Noordwijk, Nguyen Tien Hai, Ingrid Öborn, Agustin R. Mercado

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World Agroforestry Centre (ICRAF)
Southeast Asia Regional Program
Jl. CIFOR, Situ Gede, Sindang Barang, Bogor 16115
[PO Box 161, Bogor 16001] Indonesia
Tel: +(62) 251 8625415, Fax: +(62) 251 8625416
Email: icraf-indonesia@cgiar.org
www.worldagroforestry.org/region/southeast-asia
blog.worldagroforestry.org

AWG-SF Secretariat
Manggala Wanabhakti Building, Block VII, 4th Floor,
Jalan Gatot Subroto, Senayan, Jakarta 10270, Indonesia
Tel: +62-21-5703246, ext. 478, Fax: +62-21-5730136

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LIST OF ACRONYMS

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
CBFM	Community-Based Forest Management
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
ICRAF	International Centre for Research in Agroforestry trading as World Agroforestry Centre
IIRR	International Institute of Rural Reconstruction
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
NAMA	Nationally Appropriate Mitigation Actions
NDC	Nationally Determined Contribution
NAPA	National Adaptation Plan of Action
PHP	Philippine peso
IDR	Indonesian rupiah
SALT	Sloping Agricultural Land Technology
SDGs	Sustainable Development Goals
THB	Thai baht
UNFCCC	United Nations Framework Convention on Climate Change
USD	US dollar

INTRODUCTION

Figure 1. Landscape restoration through community forestry managed by the Mae Tha Community in Chiang Mai, Northern Thailand. In this photo can be seen individual farms with irrigated rice in the valley surrounded by homegardens and agroforestry bordering production forest on the slopes managed by the community and, at higher altitudes, protection forest. Photo: World Agroforestry Centre/Ingrid Öborn

Southeast Asia is going through an economic boom with a 5.7% average growth rate in gross domestic products or GDP[6], and has reportedly achieved the Millennium Development Goal of reducing by half the number of hungry people[18]. While this is a laudable achievement, 60 million people (>10% of total population) remain food insecure[18]. Rapid population growth, coupled with land and forest degradation, may cause many countries in the region to fail to feed their projected populations in the future. Climate change is an additional threat to the 'supply' dimension of food security. According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report[32], Southeast Asia is expected to be seriously affected by the adverse impacts of climate change since most economies rely on agriculture and natural resources.

Agroforestry, the practice of using trees on farms, and the integration of forestry and agriculture as part of multifunctional landscapes, can provide multiple economic, social and environmental benefits[46]. In a global comparison, Southeast Asia had the highest biomass carbon stock (per hectare) on agricultural land of all regions, with an increasing trend (60 tonnes of carbon per hectare in 2000 and 65 tonnes per hectare in 2010[116]).

Farmers in different parts of the region have been adopting diverse agroforestry systems and practices, increasing the productivity of farmlands, and helping to secure food, income and other basic needs. At the same time, the significant amount of carbon sequestered by trees in agroforestry systems is contributing to climate-change mitigation, while forests and trees are 'air conditioners' cooling their surroundings by bringing water back into the atmosphere[13]. Yet, wide-scale agroforestry adoption remains limited due to many obstacles and challenges, notably, the lack of institutional home and specific policy support for agroforestry.

To realize the potential of agroforestry in achieving food security and climate-change adaptation and mitigation in Southeast Asia, specific agroforestry policies and effective delivery mechanisms are necessary.

SOUTHEAST ASIA AT A GLANCE

The Southeast Asia region consists of eleven countries with 4.7 million km^2 (3.6 % of the world) in total land area. All of them, except Timor-Leste, are members of the Association of Southeast Asian Nations or ASEAN. With 650 million people (8.6% of the world) and an annual growth rate of 1.1% (equal to the average for the world), Southeast Asia has, on average, 137 people per km^2 (global average 58.2). More than half (52.8% in 2015) of this is 'rural' rather than 'urban'[5;70]. If the population continues to grow at the current rate of more than 1%, the population in 60 years will be more than 1 billion.

Agriculture is providing livelihoods for about 255 million people or more than a third of the total population[5], although the GDP value of agriculture (including fisheries and forestry) relative to the employment it provides remains below par in all of Southeast Asia[70]. Malaysia has come closest to parity at 12% of employment and close to 10% for GDP contribution; for Philippines, Indonesia and Viet Nam, the ratio converged on 3:1 while in Thailand it remains lowest at 4:1 although the agricultural share of GDP rose over the period 1996–2014 while its share of employment fell[70]. Indonesia and Viet Nam have the largest share of total producers who farm less than 1 ha of land.

Agricultural land in Southeast Asia is about 127 million hectares or 29% of total land, whilst forestland is 214 million hectares or 49%. 'Forestland' is an institutional category, while 'forest' describes a vegetation type. Deforestation and forest degradation are prevailing issues in vast forestlands. From 2000 to 2010, approximately 900,000 hectares of forests were lost annually[16]. This has been attributed to several factors, such as overexploitation, agricultural expansion and infrastructure development. Southeast Asia produces 9.5% of global market value of agricultural and fishery products. It dominates global palm-oil production (> 85%) and contributes disproportionally to global fishery capture (19%) and aquaculture (14%).

As elsewhere in the world, economic progress measured in per capita GDP is associated with an 'out of agriculture' trend, with Cambodia the least, and Malaysia the most advanced in this process (excluding off-scale urban Singapore and Brunei). The size of agricultural land per capita is lowest in Viet Nam and the Philippines, the two countries with the highest dependence of agriculture on freshwater (blue-water) resources. The smallest blue-water resources per capita ('000 m^3) are found in Thailand (3.3), Viet Nam (3.9) and the Philippines (4.3); while the largest are in Malaysia (33.1) and Lao PDR (28.0).

Food security exists 'when all people at all times have access to sufficient, safe and nutritious food to maintain a healthy and active life'[1]. As currently understood, food security has four aspects—supply, access, utilization and sovereignty—that relate to 'agricultural intensification' in different ways[92;95]. In practice, these four aspects are jointly influenced by decisions and choices at the landscape scale.

Food security can be assessed at multiple scales, from individual or household, through to national and regional like ASEAN, where policy remains 'rice-centric'[70]. However, rice decreased from 40% of the total economic value of agriculture (based on international market prices) in Southeast Asia in 1963 to 30% in

Figure 2. ASEAN

2013, with palm oil increasing from a negligible amount to 12% and small shifts in other commodities. In 2013, the agricultural sectors of Cambodia and Malaysia were most reliant on one product: rice and palm oil, respectively[70].

Income security is closely linked to food security but not identical to it. Increased rural incomes derived from a shift to cash (tree) crops may be used for less-nutritional, processed food sources. Different components of the preferred diet can be 'outsourced' and obtained from elsewhere (other households and production areas within the district, country or region), rather than being produced locally, when income sources become available. In remote parts of the region (active forest margins), outsourcing of staple food production (especially rice) can be an efficient response to income opportunities based on forest resources, with positive environmental impacts, while other components of healthy diets remain dependent on local resources[95]. Outsourcing can be seen as symptomatic of economic progress (efficiency enhancement) at sub-national scale but tends to be more politically sensitive between nations even though economic cooperation and specialization in ASEAN can reduce political risks. ASEAN is a net agro-food exporter with USD 139 billion of exports against USD 90 billion of imports in 2014[70].

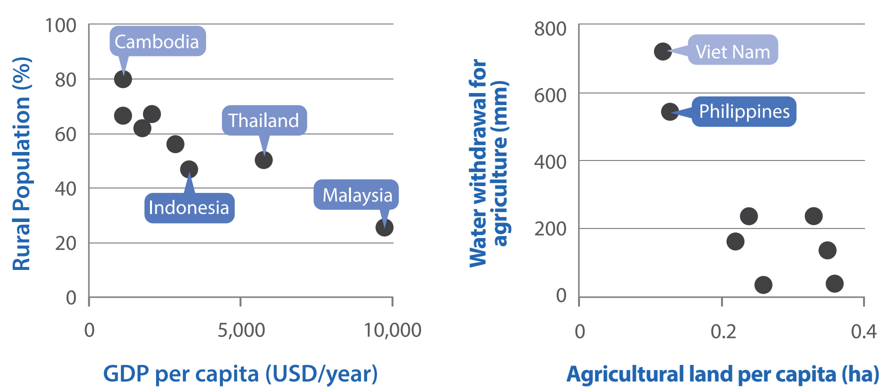

Figure 3. GDP and agricultural land per capita in ASEAN

Source: Based on World Bank statistics 2015, presented in OECD and FAO [70]

AGROFORESTRY: AN EVOLVING CONCEPT

Figure 4. The modern definition of agroforestry is relatively youthful and changes as it grows, like these children walking to school through agroforests in Sibolga, Batang Toru, North Sumatra, Indonesia. Photo: World Agroforestry Centre

The term 'agroforestry' is about 40 years-old although the practice of combining trees, crops and domestic animals has existed for thousands of years. The need for a term emerged when it became clear that the treatment of Agriculture and Forestry as separate sectors and domains of policy, and the collection of statistics with a firewall between them, did not match reality on the ground[103].

A first agroforestry concept focused on the plot-level practice of combining trees with other farm components. After creating a typology of the many forms of agroforestry that exist, emphasis shifted to tree–soil–crop interactions, the microclimatic effects of trees, bio-economic trade-offs, and management options using diversity to reduce risk. Initially, the 'trees on farms' or 'trees outside forests' were the primary interest but the issues of 'farmers in the forests' could not be ignored. Around the same time, a stronger people-and-community focus emerged in the forestry segment of the landscape.

A second, broader concept of agroforestry emerged with a focus on all aspects of the agriculture–forest interface, the landscape-level interactions in multifunctional landscapes, trees outside forests[118], and farmers/communities actively involved in (institutional) forests. Tenure, rights, conflicts and migration became part of the agenda, as did the ecosystem services related to the flows of water and movement of flora and fauna in the landscape (as a basis of agrobiodiversity change). Drivers of change became the basis for 'theories of change', including low-emission development options and 'green growth'.

Stronger interactions at policy level highlighted that the primary challenge posed by institutional segregation of Agriculture and Forestry was still a major bottleneck, forcing all the 'in-betweens' to choose one side or the other, highlighting inconsistencies. For example, rules designed to control illegal logging of state-controlled forests were a primary constraint to

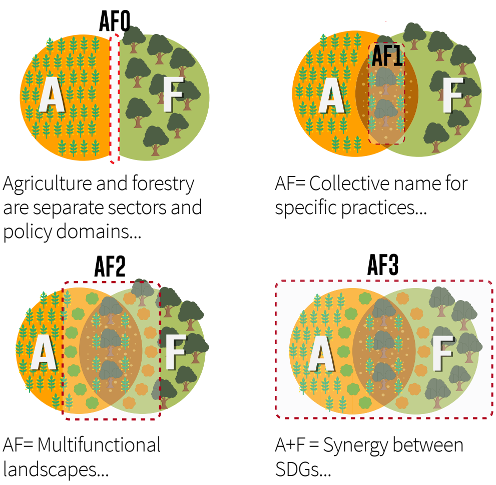

Figure 5. Three concepts of agroforestry (AF) compared to a null situation where Agriculture (A) and Forestry (F) are seen as fully segregated land uses

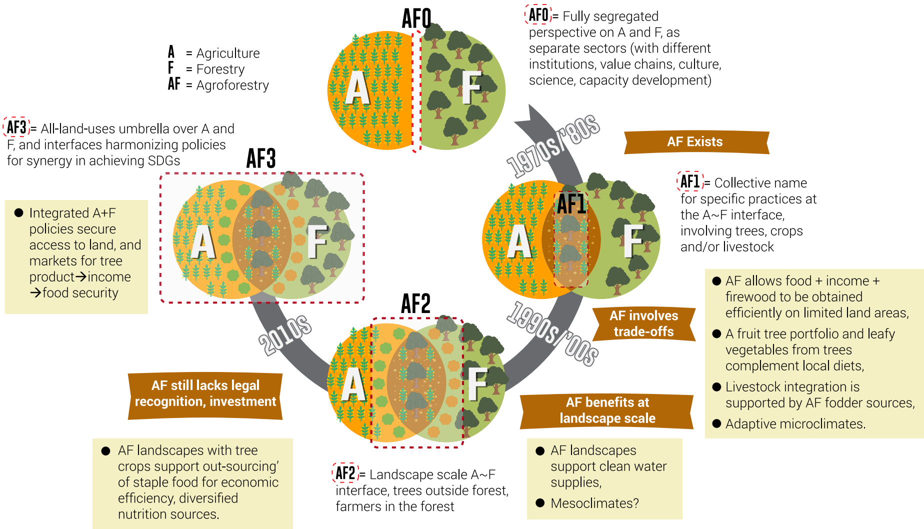

Figure 6. Historical development of the agroforestry concept

production of trees on farms because systems of permits and levies were too great a burden. Rather than claiming a separate space for agroforestry in between the two other sectors, agroforestry became a platform for harmonizing policies relating to all land uses and gearing public-private investment towards synergy of the complete set of Sustainable Development Goals (SDGs)[102].

Agroforestry has real potential to simultaneously tackle food insecurity and climate change[43;38;44;45;63;98;54;61]. There is rich evidence indicating that through its productive and environmental services' functions, agroforestry can provide multiple benefits, helping to arrest land degradation, rural poverty and food insecurity, as well as mitigate other environmental issues such as climate change (Table 1). Further, agroforestry can provide a wide range of products that diversify farm outputs, giving a broader economic base and greater food security for farmers[116]. Other studies suggest that agroforestry can be more profitable than agriculture or forestry[14]. It also has high 'land equivalent ratio', indicating efficient use of space[40].

Global evidence indicates the importance of agroforestry in local livelihoods and rural landscapes. According to Zomer et al[116], in 2010, 43% of the world's agricultural land had at least 10% tree cover, suggesting that farmers do plant trees on their land; in fact, agroforestry is practised by more than 1.2 billion people worldwide[34].

Investments in agroforestry could, thus, play a strategic role in helping countries meet their key national development goals related to poverty eradication, food security and environmental sustainability[17].

Table 1. Agroforestry benefits from productive and environmental services' functions

Productive functions	Environmental services' functions
• Diverse products e.g. fruits, nuts, edible leaves, fuelwood, fodder, fibre, timber, gum, resin, medicines • Increased crop yield • Enhanced productivity of land • Increased income • Clean water	• Micro- and meso-climatic buffering (reduced variability) • Ground/soil vegetative cover, maintenance of soil organic matter and soil physical properties • Increased rainwater infiltration, control of surface run-off and soil erosion, increased flow persistence and reduced flooding risk • Improved soil fertility through nitrogen fixation and nutrient cycling • Rehabilitation of degraded land and reduced risk of land depletion • Contribution to biodiversity and sustainable forest management • Carbon sequestration and storage

OVERVIEW OF AGROFORESTRY IN SOUTHEAST ASIA

In Southeast Asia, farmers have practised agroforestry for a long time. The types of agroforestry can typically be distinguised by their origin.

1. Derived from natural forest by understorey planting, selective cutting, and gradual increase of the most desirable species. Some traditional home gardens across countries in the region[35;56;31;43;112] started as modified forest, as did part of the coffee- and cacao-based systems in Indonesia[21].

2. Evolution from swidden/fallow rotations[31;10;96;68;64] in which desirable trees were added to the fallow and came to dominate, as in the jungle rubber agroforests of Sumatra and Kalimantan[22;37;99]. Agroforests tend to be enriched in frequency of local fruit trees relative to natural secondary forests[88].

3. 'Taungya' or 'tumpangsari' in rotational plantation forestry is where farmers obtain the right to plant their food crops between the young trees planted by a forest management company or agency, with a strong conflict of interest unless farmers benefit from future timber yields[33;31;21]. In Viet Nam, farmers in an acacia-based system own the trees but commercial operators harvest them[89].

4. Agroforestry practices based on trees deliberately planted at wide spacing, often after a prolonged phase of open-field agriculture. Prominent examples include forest–rice terrace systems in the southern and northern Philippines[106]. Deliberate planting of timber becomes more common when access to remaining forests as sources of wood becomes restricted but can be burdened by 'illegal logging' rules[79; 53].

For most of the uplands in Southeast Asia, which are susceptible to soil erosion, agroforestry practices based on contour hedgerow intercropping have also been advocated as biological means to control soil erosion. In these systems, hedgerows of leguminous tree or shrub species (Table 2) are planted in single or double rows along contour lines of sloping fields. The stems and cut branches of hedgerow plants are placed on the ground to decelerate runoff while soil particles are deposited and accumulated to create terraces, allowing for water infiltration behind the barrier. If leguminous shrubs are used, the foliage can i) provide high-protein forage for ruminants; ii) provide nutrient-rich mulch or green manure; iii) reduce soil erosion; iv) increase soil organic matter and nutrients; v) provide sustainable crop yields under continuous cropping; and vi) provide fuelwood. These approaches were advocated by Kerkhoven[39] for soil conservation in Indonesia a century ago[41]. Wangkapattanawong et al[107] also recently summarized the various ways in which agroforestry has evolved in Southeast Asia in combination with rice and become part of rice-production landscapes.

In Indonesia, examples of all four ways of starting agroforestry coexist, with differences between densely populated Java with its long tradition of teak forests and coffee; Sumatra with its long history of trade in locally

Figure 7. Farmer-to-farmer extension to disseminate agroforestry technology to increase durian production from fruit agroforestry system in South Sulawesi, Indonesia. Photo: World Agroforestry Centre/Endri Martini

Figure 8. Farmers processing rubber slab in Batanghari, Jambi, Indonesia. Photo: World Agroforestry Centre/Noviana Khususiyah

domesticated fruits (benzoin, damar, durian, duku etc) or introduced (coffee, cacao, rubber, oil palm) tree crops; Kalimantan with its rubber and rattan agroforests; Sulawesi (cacao and coffee); the eastern islands (nutmeg and other spices, sandalwood); and Papua with the lowest human population density and the most remaining forest and swidden/fallow rotations.

In the Philippines, improved fallow, home gardens, and windbreak systems have also been practised by farmers[31;20;49;48;87] but alley cropping and multi-storey systems are the most common[50]. Since the 1980s, the government has promoted alley cropping (known as Sloping Agricultural Land Technology or SALT), which involves planting woody perennials, e.g. fodder trees or shrubs, along contour lines and agricultural crops between two hedgerows. Multi-storey systems, such as coconut-, rubber-, coffee- or cacao-based systems are also widespread in many provinces in the country.

Mercado et al[55] also documented vegetable–agroforestry systems in the Philippines and found that vegetable yields can increase up to 40% without additional inputs with proper choice of tree species spaced at 20–25 m between tree rows and appropriate pruning management. The early economic return from vegetables complements the benefits from fruit and timber leading to sustainable and more profitable vegetable–agroforestry systems, which provide positive incentives for resource-poor smallholders[72;55].

In Thailand, upland communities throughout the country have practised home gardens for centuries, notably, the Karen and the Lua ethnic groups[31]. Taungya systems, initially aiming to establish teak plantations, expanded to include fruit and rubber trees. Rubber-and-food-crop and rubber-and-fruit-tree systems are also found in the southern, eastern and north-eastern regions[85]. Various coffee-based systems are also widely practised in the highlands of the country[76].

In Viet Nam, diverse agroforestry systems have been developed, including improved fallow, alley cropping, taungya, home gardens, multi-strata systems/forest gardens and small woodlots[66]. Facilitated by the government since the early 1990s, taungya became popular in the northern, southcentral, and central highland regions[66]. Improved fallow and alley cropping have also been adopted in the northcentral and northwestern provinces[91] while multi-strata systems with fruit trees and forest gardens have expanded throughout the country[66]. Windbreak or boundary planting prevails in many provinces in the northcentral region. Other systems consist of *Casuarina equisetifolia* (planted in lines or around field boundaries) with annual crops such as rice, sweet potato and peanut[65].

Figure 9. Agroforestry practice on sloping land with grass strips along the contour lines and fruit trees intercropped with annual crops. Photo: World Agroforestry Centre

Figure 10. H'mong farmers harvesting fodder grass in their 'son tra' and grass system in Dien Bien, Viet Nam (left). Photo: World Agroforestry Centre/Robert Finlayson; Longan, maize and fodder grass (right). Photo: World Agroforestry Centre/La Nguyen

Table 2. Common agroforestry practices in Southeast Asia

Type of agroforestry	Indonesia	Philippines	Thailand	Viet Nam
Improved fallow	*Pueraria javanica* planted in abandoned fields to rehabilitate soil fertility; food crops planted after 3–4 years	Native *Leucaena* spp. used to shorten fallow period		Reclamation of degraded land by accelerated stimulation of natural succession
Taungya	Annual crops planted in plantations of rubber, teak or other timber species during the first two years	Agricultural crops planted in newly-established reforestation areas	*Tectona grandis, Pinus kesiya, Pseudotsuga macrocarpa*, fruit and rubber are planted with intercrops in early years of establishment	Cassava/soybean planted in newly established plantations of *Acacia, Cassia, Hopea, Dipterocarpus*; cinnamon–upland rice–cassava, *maglietia*–cash crops; *tectona*–bamboo–cash crops; litsea–cassava; cashew or rubber–cash crops
Hedgerow planting/ alley cropping	*Gliricidia sepium, Flemingia congesta, Erythrina* spp, *Senna spectabilis, Calliandra calothyrsus* planted in hedgerows; annual crops planted between hedgerows	Sloping Agricultural Land Technologies (SALT): *Leucaena leucocephala, G. sepium, F. congesta* are planted as hedgerows; agricultural crops are planted in between		SALT: *Tephrosia* shrubs or *Indigofera* trees are planted in hedgerows; staple food crops or tea and fruit trees
Boundary planting	Fodder trees (*Ficus, Lannea, Hibiscus*) and shrubs (*Gliricidia* or *Leucaena*) are planted around farm boundaries	*L. leucocephala, Sesbania grandiflora, Casuarina equisetifolia, Acacia auriculiformis, G. sepium* are planted along farm boundaries	*Thysostrycus siamensis, Bambusa nana, Bambusa flexuosa, Acacia* spp, *Azadiractha excelsa* are planted around farm fields	*C. equisetifolia* planted along farm boundaries in coastal areas
Home garden	Coconut + fruit trees, clove etc. + banana, papaya and others + vegetables and spice around homestead	Coconut with a variety of species, varying between provinces. An important land use practised by 70% of rural households	Multi-storey system with *Erythrina dadap* + banana + crops and vegetables; *Eugenia caryophyllus* with fruit trees etc.	Fruit trees, vegetables, tubers, fish, livestock, fodder, medicine, timber, fuelwood, fibre and various minor products are grown in a multi-layered structure around the homestead
Multi-storey system/forest garden	Intensive integration of forest species and commercial crops, forming a forest-like system	Coconut–coffee–pineapple–banana; *Albizia*–coffee/cacao; *Gliricidia*–coffee	Coffee with *Acacia* sp, *Betula* sp, *Toons* sp, castor bean with *Calliandra callothyrsus, Dracontomelon* sp, *Gmelina arborea, L. leucocephala*	Multi-strata systems with fruit trees in forest gardens
Rice terraces with forest agroforestry system		Indigenous system. Bench terraces constructed along steep mountainsides Irrigation provided from natural forest		

Sources: 19, 30, 46, 86, 65

CONTRIBUTION TO FOOD SECURITY AND ADAPTATION

Agroforestry and food production

Agroforestry contributes to all four dimensions of food security

Supply: Agroforestry systems allow sloping land to be used for food production without the negative consequences of erosion and land degradation that would otherwise cause unsustainability[29;19;28]. Food production, either directly or indirectly, is a basic function of agroforestry[8;43;45;12]. Combinations of trees and food crops, however, involve both competition and complementarity above and belowground[71;95] and need to be managed. Rather than focusing on 'closing yield gaps' only, a perspective that balances environmental impacts ('efficiency gap') as well as yield gaps is needed to give space for agroforestry[93]. Agroforestry can also indirectly enhance and maintain food production through a range of mechanisms, such as nitrogen fixation, soil erosion control, soil fertility improvement, and microclimate modification[45;34].

Access: Home gardens are specifically relevant for dietary diversity, rather than production of staple food[44]. A study in Cagayan Valley, Philippines found that 65% of interviewed households maintained their home gardens to have year-round supply of fruit, vegetables and spices. Typically, a home garden can feature mango, guava, coconut, horseradish, banana, eggplant, tuber crops like taro and sweet potato, and spices and condiments such as hot pepper[84]. Similarly, in West Sumatra and West Java, Indonesia households make use of wild forest fruits and vegetables, and annual crops like chili, tubers, beans and eggplant for food[56;35]. Dietary supplies from home gardens can account for 3–44% of the total calorie and 4–32% of the protein intake in Java, Indonesia[90]. In Viet Nam, the level of satisfaction of interviewed households in three provinces in the north and northcentral regions regarding home gardens as source of food was 55–70% (ICRAF Viet Nam database 2016). Home gardens seldom meet the entire basic staple-food needs and are, at best, complementary to rice or maize[43], however, diverse products, which are available year-round in home gardens, contribute especially to food security during lean seasons[45] and form a significant source of minerals, nutrients and vitamins for rural people[43;84].

Utilization: The availability of firewood or charcoal, as well as clean water, is essential for food security. Diversity of tree and crop species in agroforestry systems promotes better agro-ecology that is less susceptible to pests and diseases.

Sovereignty: In the transition from food that is mostly produced locally to food that is primarily bought, consumer choice may initially seem to increase but then declines depending on market dynamics and price strategies. A considerable increase in consumer awareness is generally needed before food diversity is appreciated. In urban centres, consumer-level food diversity is currently higher than ever before in history even though much is produced in landscapes and production systems that are less diverse than ever before[86]. A more gradual transition between rural and urban livelihoods may be needed, with space for (peri-) urban agroforestry to maintain the benefits of user-controlled production of diverse food sources.

Agroforestry and income generation

Agroforestry provides important sources of income for rural households, helping to raise their food purchasing power[8;45]. In Indonesia, for instance, the net income generated from home gardens ranged 7–56% of total household income[43]. In West Java, the productivity of home gardens was more than twice the productivity of rice fields[35]. Furthermore, in West Sumatra, agroforestry products accounted for 26–80% of the total income from agricultural produce (rice fields and gardens). A hectare of home garden produces about IDR 365,000–5,000,000 or USD 365–5000[56;57]. Households with both rice and home gardens have higher incomes than those with rice only. In Kalimantan and Sumatra, there are 2–2.6 million hectares of jungle rubber agroforests. Some 5 million people obtain their incomes from rubber, which is the only profitable agricultural product for most smallholders in nutrient-poor lowlands[30].

In the Philippines, Snelder[84] reported that about 60% of studied households in northern Luzon sold something from home gardens. Twenty-eight percent (28%) sold only livestock (raised in home gardens), 16% only fruit and vegetables, and another 16% a combination of fruit, vegetables and livestock. The annual gross income generated from home gardens varied, with an average of PHP 3739 (USD 74) per household and up to 18% of total household income[84]. Research by Pattanayak and Mercer[74] in the Eastern Visayas also revealed that investments in agroforestry to improve soil capital can increase annual agricultural profit by USD 53 for a typical household, which was 6% of total income. Likewise, Watson and Laquihon (1987) indicated that adopting SALT provided farmers in Mindanao almost year-round harvests. A family could obtain an income from a hectare of SALT of about PHP 1000 per month.

In Thailand, studies have also shown that agroforestry can provide greater income for farmers. Agroforests such as rubber–cassava, rubber–banana, rubber–rice, rubber–corn,

Figure 11. Rubber trees with legumes as cover crop in Indonesia. Photo: World Agroforestry Centre

rubber–pineapple, rubber–custard apple and rubber–salacca systems have yielded significant net income increases in comparison to monocultural rubber plantations. Somboonsuke et al[85] found that growing rubber and pineapple brought farmers THB 500,000 per year, which was more than four times the income from monocultural rubber (THB 83,428).

In Viet Nam, economic benefits were compared by Thang Hoang and Do Tran et al[89] for different agroforestry systems such as *Melia azedarach* + cassava, *Acacia* hybrid + cassava, *Acacia mangium* + maize and star anise (*Illicium verum*) + tea. The authors found that the latter had the highest annual net profit (USD 6527 per hectare per year), much higher than either monocultural tea or star anise.

Agroforestry and fuelwood

Fuelwood supply is the last, but not the least, way in which agroforestry can contribute not only to food security but also to climate-change adaptation and mitigation. Fuelwood is the primary source of household energy for cooking and heating in almost all areas in the developing world. Supplies of fuelwood are essential not only for nutrition but also disease prevention[9;108]. According to Pimentel et al[75], fuelwood for cooking and heating may cost almost as much as food in some developing countries.

On average, a rural household in Southeast Asian needs about 2800 kg of fuelwood annually (Table 3). Although available information on agroforestry and fuelwood supply is somewhat scattered, there are strong indications that agroforestry systems are already a very important source of fuelwood for rural households and definitely have the potential to meet fuelwood demands in most countries in the region[35]. The studies of Krishnakutty[42], Wickramasinghe[111] and Shanavas and Kumar[80] have shown that traditional home gardens constitute a principal source of biofuels for rural households[43]. In Java, Indonesia, 51–90% of the fuelwood collected is from home gardens[90]. The Food and Agriculture Organization of the United Nations[15] estimated that as little as 50–100 trees would be enough to supply, on a continuous basis, the necessary fuelwood for one household. Meanwhile, Jensen[35] argued that about 140 trees in humid areas and 400 in sub-humid areas were needed to supply enough fuelwood for a household, which could be achievable if farmers devoted 20–30% in humid areas and 25–50% in drier areas to agroforestry.

Table 3. Estimated annual fuelwood demand in rural Southeast Asia

Country	Annual household demand (kg)	Country consumption (million tonnes per year)	Average household size
Indonesia	2288–2470	93.2	4.9
Lao PDR	3538	2.4	6.1
Myanmar	3276	630	5.2
Philippines	2262	29.1	5.6
Thailand	2865	23.9	5.2
Viet Nam	2650	33.0	5.3
Average	2813		5.4

Source: 34

Figure 12. Female H'mong farmers returning from collecting firewood in northwest Viet Nam.
Photo: World Agroforestry Centre/Tran Ha My

Agroforestry, water and adaptation

Tree cover in forests and/or agroforestry interacts with the hydroclimate and water balance in multiple ways, influencing a range of 'watershed services', depending on local contexts[2;98;100;104]. Distinctions have often been made in discussion of water on the basis of 'fresh water' resources in rivers, lakes and reservoirs that can be used for either irrigation or industrial/domestic use (blue water; roughly 40% of rainfall), water in the soil–plant system (green water; roughly 60% of rainfall), recycling of industrial/domestic water (grey water) and rainfall (rainbow water). Recent scientific reviews added credibility to strong local beliefs that rainfall itself is influenced by changes in tree cover at (sub-) continental scales[13].

The long-standing debate on the scale at which maintenance of permanent tree cover, and the soil conditions associated with it, protects downstream areas from flooding has seen recent progress that can help with a nuanced, context-specific assessment, avoiding the overgeneralized claims of the past, as well as their subsequent overgeneralized dismissal as 'myths'[105]. Current 'boundary work' in this domain pays explicit attention to local, as well as public/policy and science-based knowledge systems on issues of water flows, and seeks a fair and efficient way of combining regulations, rewards/incentives and motivation under a co-investment umbrella[51;52].

With changes in variability and uncertainty of rainfall among the most direct effects of climate change in Southeast Asia, ecosystem-based adaptation to climate change will depend on effective landscape management for watershed functions and related services[98;100;104].

CONTRIBUTION TO CLIMATE-CHANGE MITIGATION

Figure 13. A farmer shows his agroforestry farm in Peñablanca, Cagayan, Philippines: planted with corn interspersed with mango and banana. Photo: World Agroforestry Centre/Regine Evangeline

The importance of agroforestry in climate-change mitigation has been increasingly recognized worldwide. Through three mechanisms —carbon sequestration, conservation and substitution—agroforestry helps reduce atmospheric carbon dioxide levels and, hence, mitigates climate change[60;43]. Agro-ecosystems play a central role in the global carbon cycle and contain approximately 12% of the world's terrestrial carbon[61]. Carbon stored in agroforestry ranges 0.29–15.21 tonnes of carbon per hectare per year aboveground and 30–300 tonnes up to 1m depth in the soil[63]. About 630 million hectares of land all over the world is suitable for agroforestry[38;36]. Inclusion of trees in agricultural landscapes, thus, provides considerable opportunities to create carbon sinks. Potential carbon sequestration by 2040 in agroforestry is more than 550 megatonnes of carbon per year, which is the highest potential among different land-use and management options.

According to Kandji et al[38], the carbon-sequestration potential of agro-silvicultural systems in humid tropical eco-regions is between 12 and 228 tonnes of carbon per hectare. In Southeast Asia, recent studies have shown the great potential of agroforestry for sequestering atmospheric carbon (Table 4).

Table 4. Percentage of agricultural land in Southeast Asia per biomass carbon stock (above- plus belowground) in the years 2000 and 2010 [116]

Year	<10	11–25	26–50	51–75	76–100	>100
2000	13.7%	17.3%	17.7%	15.6%	12.8%	22.9%
2010	13.8%	16.2%	17.7%	15.1%	11.3%	25.9%

Table 5 provides a summary of carbon sequestration and storage potential of common agroforestry practices in three countries in Southeast Asia. Almost all agroforestry practices, except alley cropping, can sequester and accumulate a significant amount of carbon. Roshetko et al[78] estimated the aboveground carbon stock of Indonesian home gardens at 30–123 tonnes of carbon per hectare with an average of 35.3 tonnes per hectare at 13 years, which corresponds to carbon stock found in similarly aged secondary forests[44]. Furthermore, the carbon-sequestration potential of home gardens mimic the structure and diversity of mature evergreen forest, that is comparable to forest stands[44].

In addition, agroforestry systems have an indirect effect on carbon sequestration because they help to decrease the pressure on natural forests, which are the largest sink of terrestrial carbon. In Sumatra, Indonesia, for example, home gardens have greatly reduced farmers' dependence on adjacent forests[62;60]. On the boundary of the Kerinci-Seblat National Park, households that had irrigated rice and mixed home gardens had much less dependency on the resources of the national park than households that farmed only irrigated rice[62]. These latter registered the highest value of products obtained from inside the park. Households that farmed only mixed home gardens had an intermediate level of extraction of resources from the park.

Table 5. Carbon-storage potential of agroforestry systems in Southeast Asia

Country/agroforestry system	Carbon stock (tonnes of carbon per hectare)	Remarks	Sources
Indonesia			
Home gardens in Sumatra	55.8–163	Aboveground, 12–17 years	(44)
Home gardens in Lampung	30–123 Average 35.3	Aboveground 13 years	(78)
Simple systems (e.g. a single tree species and cocoa)	130	Total stock	(109)
Complex systems (e.g. many species of trees, shrubs and crops)	209	Total stock	(109)
Philippines			
Taungya agroforestry systems	174	Total stock	(47)
Mixed multi-storey systems	162	Total stock	(47)
Albizia falcataria and coffee multi-storey systems	92	Total stock	(47)
Leucaena leucocephala fallow	16	Aboveground, 6-year cycle	(49)
Alley cropping	1.5	Aboveground	(48)
Coconut-based multi-storey systems	39	Aboveground	(48)
Multi-storey systems	116	Aboveground	(48)
Viet Nam			
Home gardens	69.6	Total stock	(69)
Fruit gardens	46.8	Total stock	(69)
Litsea glutinosa and cassava	24.7–84.2	Total stock, 5–10 years	(7)

Figure 14. Measuring carbon stock in Papua, Indonesia. Photo: World Agroforestry Centre/Degi Harga

Last but not least, agroforestry systems can either act as sinks or sources of greenhouse gases depending on the land-use systems that they replace. If they replace natural primary forest or secondary forests, they will accumulate comparatively lower biomass and carbon but if they are established on degraded or otherwise tree-less lands their carbon sequestration value would be considerably higher(60). It was estimated that conversion of all 'sun coffee' to 'shade coffee' systems in Sumatra, Indonesia increased the average landscape carbon stock by 10 tonnes of carbon per hectare over 20 years(94). Further, a study in Sumatra(113), found that when soils are relatively degraded and carbon payments are available or discount rates are low then agroforestry is an optimal profit maximizer (without labour and credit constraints).

Interest in carbon sequestration in agroforestry and other land uses has come in a number of waves. Research in the early 1990s established simple but reliable methods aligned with international accounting systems(23) and provided the first globally comparative data that included forests and agroforestry systems(73). A second wave of interest started when afforestation/reforestation became eligible for investments under the Clean Development Mechanism program of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). This wave bogged down in the morass of forest definitions and rules(97). A third wave started with the realization that the economic benefits achieved by a substantial share of forest conversion were actually limited and, hence, opportunity costs were low(24;110). The translation of these insights into the Reducing Emissions from Deforestation and Forest Degradation plus Conservation (REDD+) program, however, again founded on issues of delineation, definition and tenure arrangements(101;58). The fourth and current wave is based on the inclusion of all land uses (agriculture, forestry and anything in between) in the Nationally Determined Contributions that are part of the Paris Agreement. Full operationalization and appropriate incentives that apply to agroforestry, however, are yet to emerge in any of the Southeast Asian countries.

ADOPTION OF AGROFORESTRY: ISSUES AND GAPS

A recent study of expert opinion on why there remains a gap between policy commitments to 'green' agriculture documented three dominant discourses, referring to a lack of i) appropriate incentives; ii) clarity of land-use regulations; and iii) knowledge, technology and extension[3]. Clearly, all three issues have to be addressed simultaneously to achieve synergy. Not coincidentally, these align with the barriers to tree planting faced by farmers, mentioned above[96].

Despite the demonstrated benefits and existence of diverse agroforestry systems, wide-scale adoption in Southeast Asia remains low. Even in countries where agroforestry is considered to be more developed, adoption is just a part of government programs to rehabilitate degraded forest land[33;106;66;114]. In Viet Nam, for instance, adoption of agroforestry practices, such as taungya, has been facilitated by reforestation programs, namely 327/CT from 1993 to 2000 and 661 from 1998 to 2005[66] but, in general, agroforestry adoption remains limited, particularly, in the northern mountainous regions[4].

Similarly, in the Philippines, government programs, including the Integrated Social Forestry Program in 1982 and, later on, Community-Based Forest Management (CBFM)[106], promoted agroforestry. However, the implementation of CBFM has been slow and uncoordinated[106] and just over 500,000 hectares of agroforestry farms have been developed[50], accounting for less than 10% of the area (5.5 million hectares) estimated to be suitable for agroforestry in the country[12].

However, the implementation of the National Greening Program, a major reforestation program that begun in 2011 and was extended to 2028, can be expected to change the situation as local governments nationwide are mobilized to support tree planting on farms and forestland within their administrative jurisdictions.

In summary, the myriad of issues and challenges faced by agroforestry in the Philippines, Indonesia and Viet Nam and in Southeast Asia as a whole include:

- Little recognition of, and attention paid to, the uniqueness of agroforestry among policy makers and government agencies[52;106]
- Absence of specific and adequate agroforestry policies[45;106;25;81]
- Lack of market links for agroforestry products[106;66]
- Poor information sharing on agroforestry[106]
- Low awareness and capacity in extension networks[87]
- Insecurity of land and tree tenure[114]
- Farmers lacking capital and land resources[27]
- Non-availability of planting stock[50]
- Poor incentives, and insufficient financial and technical support, to farmers[106;25;87]
- No specific guidelines for undertaking agroforestry development[106]

Figure 15. Agroforestry products throughout the region can suffer from a lack of policy support and market links. Photo: World Agroforestry Centre/Robert Finlayson

Amongst the issues and challenges outlined above, the absence of specific and adequate agroforestry policy is perceived as the most critical issue in agroforestry development. In the Philippines, for instance, Visco argued that policy-related issues were regarded as most critical in comparison to other major issues in agroforestry promotion[100]. In Viet Nam, the lack of agroforestry policies is one of the key challenges to overcome in agroforestry development[75]. Fortunately, the Government has supported a national review of agroforestry-related policies.

The lack of policy instruments is one of the key challenges for wider agroforestry adoption in Asia as a whole[42]. FAO argued that policy is a key driver for agroforestry development[15].

Putting it simply, adoption of agroforestry is a policy issue because a number of important factors affecting agroforestry are directly linked to policy. Agroforestry generates significant public environmental services and without government involvement in providing incentives the level of private investment in agroforestry will be less than socially optimal[76]. FAO[17] and ICRAF in a collaborative policy analysis concluded that the right policies are crucial for agroforestry development in order to co-invest in:

- **Eliminating** *legal and institutional constraints on agroforestry*. Effective agroforestry techniques should not be impeded by regulatory constraints or prohibitions. Policy failures can override others, so policy revision is critical to wider adoption.
- **Supporting** *positive outcomes of agroforestry.* Financial support to farmers to introduce trees onto their farms can be considered in the form of payment for environmental services because agroforestry, especially at landscape level, produces many benefits for local communities and, on a larger scale, for ecosystems upon which whole populations depend. Adjusted systems of (eco-) certification have a role to play[59].
- **Compensating** *farmers for the delay in returns.* Changes in production systems require investment and take time before producing benefits. Farmers are reluctant to engage in tree planting or managing natural regeneration if they see their income dwindle. As many of the investments in agroforestry produce environmental services that benefit everyone, the associated losses should be compensated.

AGROFORESTRY POLICIES

At a global level, the role of agroforestry in contributing to sustainable development has been recognized in the international policy arena[17]. It is acknowledged by the UNFCCC as a key mitigation method within the agricultural sector[83] and considered as an important component of National Adaptation Plans of Action and Nationally Appropriate Mitigation Actions[17].

Recently, there have been policy reforms directly targeting the development of agroforestry in many countries around the world.

- ***In Niger,*** the relaxation of restrictive forestry regulations (Forestry Code) by the Government awarded tree tenure to farmers, providing them with incentives to farm more intensively with *Faidherbia* and other trees and helping to expand the agroforestry practice of farmer-managed natural regeneration to over 5 million hectares[19].
- ***In Kenya,*** the Government, in particular the Ministry of Agriculture, passed new Farm Forestry rules in 2009, requiring 10% of all farms to be covered with trees, in response to deforestation, increased demand for agricultural land and farmers' desire to plant trees. The Government also allocated funds to assist farmers to meet this requirement[34].
- ***In Guatemala,*** simplified procedures for timber harvesting in agroforestry systems were recognized in the Forest Act in 1996, resulting in increased timber production by farmers on their farms and in other land uses, creating another source of income in 15 years[76].
- ***In France,*** the role of trees on farms was recognized in a new agricultural policy in 2010. In this policy, agroforestry plots with 30 to 300 trees per hectare are regarded as eligible for subsidies within the framework of the Common Agricultural Policy of the European Union[17].
- ***In Brazil,*** an agroforestry strategy was developed in 1997 and is now being refreshed in a participatory way, with local communities actively involved[12].
- ***In China,*** the Ministry of Forestry carried out nationally significant programs related to agroforestry, such as the ‘Shelterbelt Development of the North, Northeast and Northwest’ and ‘Shelterbelt and Afforestation in the Taihang Mountain Range’. Further, the 'Green Plains County Program' was launched in the 1980s. About 918 out of 2000 counties were identified as 'plains counties', integrating tree planting with cultivation of grains[33].
- ***In India,*** the Government has embarked on a program called ‘Greening India’, aiming to increase tree cover outside forests through agroforestry. India was the first country to adopt a national agroforestry policy, in 2014. The policy deployed agroforestry guidelines and established an agroforestry commission. In India,

Figure 16. Coffee grown under shade trees, northwest Viet Nam. Photo: World Agroforestry Centre/Tran Ha My

'trees outside forests' (trees grown on farms) produce 65% of the timber and almost half of the fuelwood. The Indian state of Chhattisgarh adopted an agroforestry policy in 2009, which establishes a price floor and a guaranteed market for agroforestry products to ensure adequate production[76]. The most attractive market-linked agroforestry is when farmers are facilitated with bank loans, supplied with good quality seedlings and constant technical guidance in the field, as well as guarantee to be paid at market prices when the trees are harvested after 7–8 years[33].

- ***In Viet Nam,*** recognizing the potential benefits of agroforestry, the Ministry of Agriculture and Rural Development recently created a national Agroforestry Technical Working Group with the task of reviewing the policy environment for agroforestry development in the country.

In general, there is increasing recognition of the role and importance of agroforestry at global and national levels, which can potentially lead to policy reforms both in the forestry and agricultural sectors, and programs to support the development of agroforestry. Policy reforms would help to remove legal and institutional constraints and provide incentives to farmers, such as tree tenure, food for work, planting materials, credit/bank loans and market establishment.

A call for action by ASEAN

Recognition at global level and emerging policy reforms should inspire ASEAN Member States to formulate policies that clearly support agroforestry throughout the region. Agroforestry has been identified as one of the priorities of the Vision and Strategic Plan for ASEAN Cooperation on Food, Agriculture and Forestry 2016–2025. The Paris Agreement that came into force on 4 November 2016 provides a global framework for advancing agroforestry within Southeast Asia because trees in forests and on farms are central to climate-change mitigation and adaptation. Agroforestry can be instrumental in reaching the SDGs, helping to eradicate hunger, reduce poverty, support gender equity and social inclusion, provide affordable and cleaner energy, protect life on land, reverse land degradation and combat climate change. Because of trees' capacity to sequester carbon, agroforestry can also contribute to achieving Nationally Determined Contributions. The moment is here to seize the myriad opportunities to harness agroforestry to help ASEAN achieve its ambition to become a food-secure, wealthy, sustainable and resilient region.

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For more information, contact

World Agroforestry Centre (ICRAF)
Southeast Asia Regional Program
Jl. CIFOR, Situ Gede, Sindang Barang, Bogor 16115
[PO Box 161, Bogor 16001] Indonesia
Tel: +(62) 251 8625415, Fax: +(62) 251 8625416
Email: icraf-indonesia@cgiar.org
www.worldagroforestry.org/region/southeast-asia
blog.worldagroforestry.org

AWG-SF Secretariat
Manggala Wanabhakti Building, Block VII, 4th Floor,
Jalan Gatot Subroto, Senayan, Jakarta 10270, Indonesia
Tel: +62-21-5703246, ext 478, Fax: +62-21-5730136

World Agroforestry Centre

AWG-SF ASEAN Working Group on Social Forestry

Schweizerische Eidgenossenschaft
Confédération suisse
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Confederaziun svizra

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ASEAN Working Group on Social Forestry (AWG-SF) is government-initiated network that aims to strengthen social forestry in Southeast Asia through the sharing of information and knowledge. AWG-SF was established by the Association of Southeast Asian Nations (ASEAN) Senior Officials on Forestry (ASOF) in August 2005, linking government forestry policy makers directly with the civil society organizations, research organizations, academia, private sector, and all of whom share a vision of promoting social forestry policy and practices in ASEAN.

The ASEAN-Swiss Partnership on Social Forestry and Climate Change (ASFCC) is a Partnership Programme of ASEAN that aims to contribute to the ASEAN Mandate and Policy Framework through support for the ASEAN Working Group on Social Forestry and the ASEAN Multi sectoral Framework on Climate Change towards Food Security.