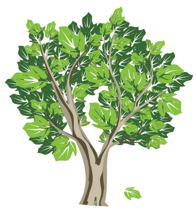
TECHNICAL ASPECTS OF AGROFORESTRY



Enhancing adoption, economic and environmental benefits of agroforestry through better management of tree-crop interaction

Agustin R. Mercado, Jr and Manuel Reyes

Abstract

The lack of understanding of tree-crop interaction and resources capture in agroforestry is restraining the economic and ecological benefits of agroforestry resulting to poor adoption by farmers. Tree and crop management in the context of agroforestry systems are critical in attaining optimum complementarity benefits while reducing competition between components. Improving complementarity and reducing competition between and among components as well as putting emphasis on valuable tree components into the system can greatly increase the benefits in agroforestry systems. These include among others tree-crop matching, tree silvicultural and crops agronomic management. Under vegetable agroforestry system, vegetable yields can increase up to 40% due to the environmental ameliorative effects of trees on associated vegetable crops. Agroforestry in various forms and systems is inevitably the most appropriate option particularly for watersheds that are currently under intensive production.

Keywords: agroforestry, tree and crop management, complementarity, competition

Introduction

Growing woody perennials with crops is a good foundation for conservation-oriented farming while addressing shortage of timber, fuelwood, and fodder, among others. The role of trees in minimizing leakage of nutrients from a system and recycling them, preventing soil erosion, improving microclimate and influencing the growth of associated crops, is the biological premise of agroforestry. In agroforestry, the trees should provide economic and ecological benefits at all levels. However, a major concern is that, competition from the trees to the crops may outweigh the otherwise positive aspects of tree-crop integration.

The key to increasing productivity in agroforestry is understanding the nature of interaction between species in the mixture (Figure 1). The net benefit of agroforestry is simply expressed as:

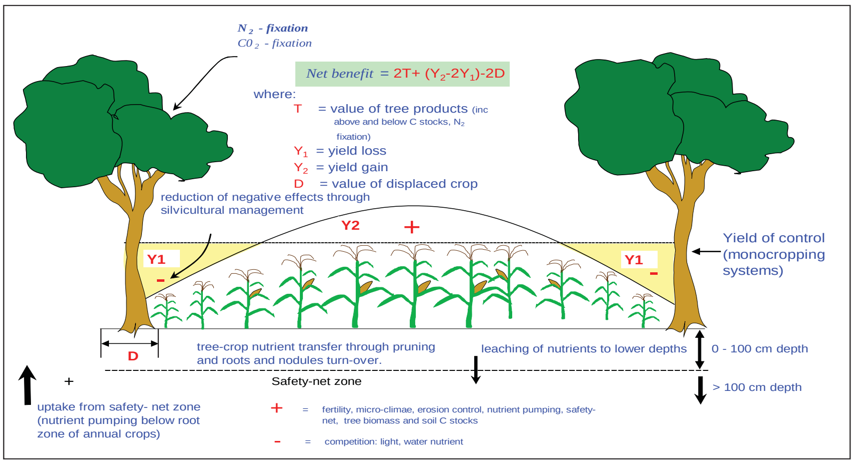


Figure 1: Schematic diagram of tree-crop interaction in hedgegrow intercropping system

Net Benefit (NB)= 2T+ (Y2-Y1)-2D
Where:
T= Value of trees
Y1= Yield at competition zone
Y2- Yield at complementarity zone
D= Crop displacement area

Both crops and trees compete for growth factors such as light, water and nutrients. Such competition can result in poor plant growth and species performance. Competition between species in mixed stands (interspecific) differ from that between plants within monocultures (intraspecific), in that, the trees and crop may impose different demands in available growth resources and less severe as opposed to monocultures where the demand is greatest (Ong et al., 1996). Plants growing in monoculture are usually all of the same genotype and their growth and development proceed synchronously. When resources are not limiting, densely planted monocultures usually provide the most efficient systems. However, when one or more resources are limiting, it may be possible to improve productivity by using species mixtures that would expand resource use capture both above and below ground. This is commonly observed in intercropping systems, and is often expressed in land equivalent ratio (LER). If LER is greater than 1, it is assumed that the productivity of the mixture is superior to that of monoculture and hence, complementarity occurred.

Ways of improving the economic benefits of agroforestry

PK Nair (1994) alluded that agroforestry must provide environmental, biological and economic benefits, which means that environmental and biological benefits must lead to economic benefits. In the context of agroforestry systems as expressed in Figure 1, the economic net benefit (NB) is the result of the sum values of the tree products (T), the crop yield in the complementarity zone (Y2) less the crop yield in the competition zone (Y1), and minus the opportunity cost of the crop displacement area (D). The basic principle underlying this tree-crop integration is that competition or complementarity between trees and crops depends on their ability to capture and use the most limiting and essential growth resources effectively. Growth resources capture such as light, water and nutrients depends on the number, surface area, distribution, effectiveness and efficiency of the individual elements in the canopy or root systems of the tree and crops in the mixture. The use of acquired resources depends on the conversion efficiency of the tree and crop species in the mixture, as well as, the environmental conditions, and management strategies used. Thus, tree and crop management is central to the success of any agroforestry system. Tree and crop management includes, among others, the selection of appropriate tree and crop species that are adapted to the agroforestry system, as well as, manipulating the trees to reduce their negative impact on the associated crops.

Several ways have been identified to improve the net benefit of agroforestry systems as expressed in Figure 1, which are as follows:

- Increase the value of trees (T)
- Increase the value of complementarity or supplementarity zone (Y2)
- Decrease or eliminate the value of competition zone (Y1)
- Decrease or eliminate the value of crop displacement area (D)

The above are basic elements in understanding tree-crop integration particularly in the context of hedgerow intercropping, which can be applied on flatlands and more importantly on sloping lands where tree rows are aligned along the contour lines to serve as filters to control soil erosion. The same basic principles can also be applied when trees are planted as boundary or windbreaks, except that the number of trees may be fewer. Random planting may have a different tree-crop interaction that does not necessarily follow those of either the hedgerow intercropping or boundary planting.

1. ***Increase the value of trees***

Increasing the economic value of the tree species used in agroforestry systems is one of the important considerations in vegetable agroforestry systems by:

1.1. Optimizing the vertical use of aboveground resources (space and light) through a multi-storey hedgerow system like integration of trees + banana + forage grasses (Figure 2). A multi-level canopy plant combination allows vertical stratification of light capture which provides higher overall light capture as opposed to flat or plane canopies in monoculture systems. Trees can be rubber, fruit or timber trees, which provide better and long-term economic benefits to farmers, whereas, bananas and forage grass provide short and medium term incomes. The range of economic outcomes (short, medium and long term) is an important consideration in introducing technical innovations especially to subsistence smallholders in the tropics.

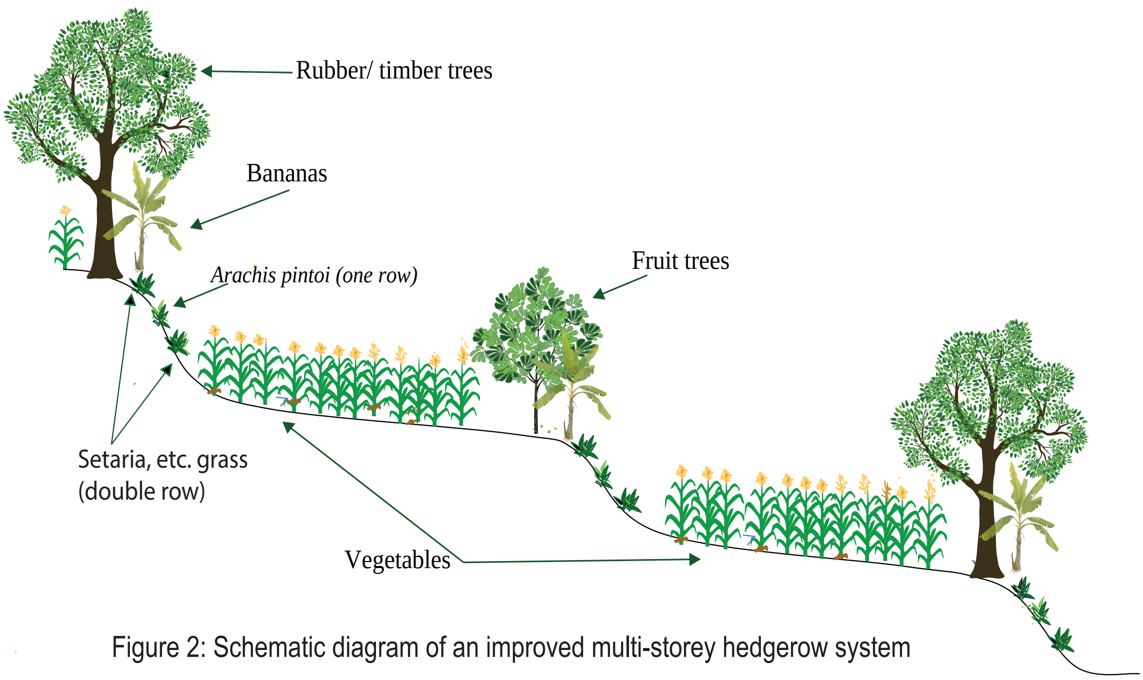


Figure 2: Schematic diagram of an improved multi-storey hedgerow system

1.2. Optimizing the use of vertical and horizontal belowground resources (space, water and nutrients) through plant combinations with different rooting patterns such as shallow, moderate and deep rooted trees like *Acacia mangium* (Mercado, 2007), *P. phelthoporum* (van Noordwijk et al., 1995), and *Eucalyptus spp* (Nissen and Midmore, 1999). This combination allows extraction of growth resources at different soil layers, which have greater overall uptake of water and nutrients as opposed to uniform rooting pattern in monoculture systems. The combination, 'rubber + banana + forage legume (*Arachis pintoi*) and fodder grasses' (e.g. *Setaria spachealata*) (Figure 2) has different rooting patterns. The roots of forage legume and grasses occupy the surface soil layer, banana roots in the mid-layer, and rubber or other trees at deeper soil layer. Different rooting patterns are important in the context of sloping lands, particularly in areas, which are prone to landslides or landslips. The shallow roots of forage legumes, grasses and bananas provide soil binding functions due to their high root length densities that keep the soil surface intact and protected from dispersing and eroding, while the deep roots of rubber or other trees provide the soil anchorage function.

1.3. Optimizing the use of inert resources such as atmospheric nitrogen (N_2) and carbon dioxide (CO_2) by using N_2-fixing trees and fast growing trees to accumulate more carbon.

1.4. Choosing tree species that provide products with greater economic value such as latex, fruits, and timber. The overall economic benefit of agroforestry systems is highly influenced by the income from tree products (Figure 1). Smallholders in the tropical uplands plant trees because of the perceived long-term benefits and better returns to labor, which is the most important farm capital asset they can invest. Tree planting with greater economic benefits is also a risk aversion mechanism in the context of climate change.

2. *Increase the complementarity effect*

Increasing the value of complementarity zone (Y2) through the use of optimum tree line or hedge spacing. Mercado et al (2012) found that the complementarity zone of vegetable-agroforestry system begins at 3.5 meters from the tree line up to 16 meters. In this zone, the growth and yield of vegetables were better than those without trees. Thus, the optimum tree row spacing is the distance from the tree line up to the peak of the curve line of the complementarity zone multiplied by two, which is equal to 20-25 meters. This refutes the 6-8 meters tree hedgerow spacing, which had been recommended for many years (Watson and Laquihon, 1987; Kang and Wilson, 1987). This also shows that the tree line spacing recommended in earlier Sloping Agricultural Land Technologies (SALT) or alley cropping, which 8-12 meters at both sides of the tree rows (4-5 meters in each side of the tree line), which is less than twice the width of the competition zone was too close. The crop yield in this zone is only 60% on average compared to open field control. Using leguminous hedgerow, in which the pruning were used as mulch or green manure, alleviated yield reduction. As there is a trend towards economic trees, tree spacing must be observed carefully as competition for nutrients particularly N in the competition zone (Figure 1) is more severe since most of these trees are not N_2-fixing. Controlling soil erosion is however, a caveat to wide tree line spacing. However, based on previous studies by Mercado et al., (1999) adding 1-2 strips of natural grasses between tree lines (Figure 3) and alley crops can effectively control soil erosion. The grasses can be used as animal feed, which can generate manures for crops and income from animal products (meat and milk).

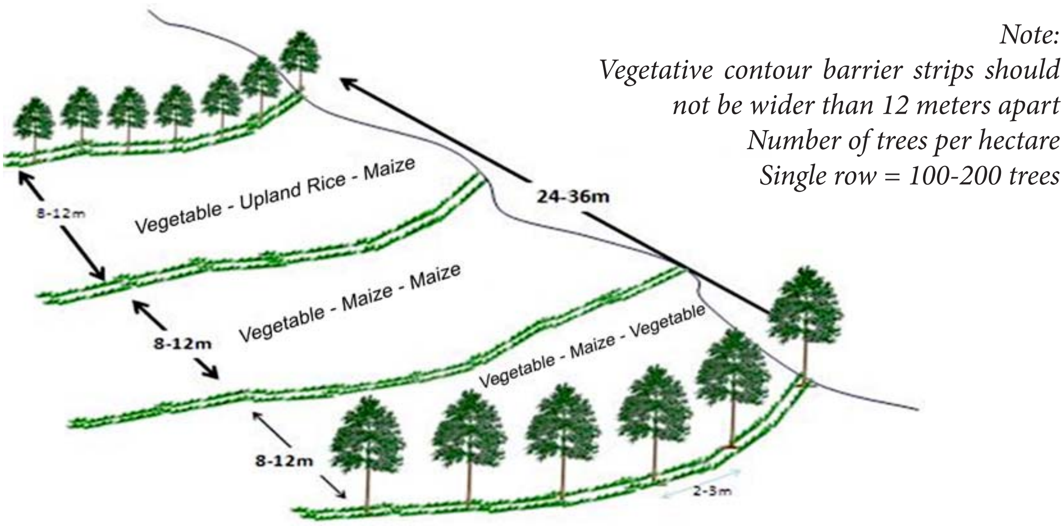


Figure 3. Schematic diagram of widely spaced single line tree hedgerow with two grass strips in vegetable agroforestry system.

2.1. Responsive crops to micro-climate improvement. Broad-leaved plants like vegetables, cassava and cowpea are more responsive to micro-climate amelioration associated to the presence of trees, as well as, adapted to reduce light transmission due to tree partial shading. Mercado (unpublished data) found that cacao and coffee yielded about three times higher when planted together with rubber trees as opposed to planted in open field.

2.2. Optimum tree pruning regime (silviculture). Mercado et al., (2012) found that vegetable farmers in Lantapan, Philippines and other places significantly prune the trees prior to planting vegetables. Some farmers removed up to 90% of the tree canopy to reduce light competition. But the supplementarity effect was also reduced. Figure 5 shows the relationship between canopy left after planting and the net complementarity effect. It indicated that the optimum canopy left must be 40-60% to achieve a reasonable net complementarity. This level of pruning is conventionally recommended as proper silvicultural management in tree plantations, which is also applicable to vegetable agroforestry system.

3. ***Decrease competition between trees and vegetables***

Reducing or eliminating tree and vegetable competition is a tall order in agroforestry systems particularly if growth resources such as light, water and nutrients are insufficient for both trees and crops. However, competition can be reduced if not eliminated through the following:

3.1. Using adapted crops. Adaptability index was a simple tool used by Mercado et al., (2012) to identify adapted vegetables under tree-based systems, which can also be applied to other crops. An adaptability index close to '1'means that the trees have lesser negative influence on the vegetables or crops. Our survey revealed that farmers plant vegetables 3-4 meters away from the tree line, which is already a big crop area loss for them. To address this issue, our approach was to plant vegetables or crops as close as possible to the tree line, as long as the plants are not severely affected by the trees.

3.2. Using appropriate tree species. Choosing the right tree species is a basic rule in agroforestry. This involves looking both the above and belowground characteristics of the trees, as well as, their functional characteristics. Van Noordwijk et al., (1999) used tree crown architecture as a tool in choosing the right tree species for agroforestry. He prefers light conical canopies like *Eucalyptus spp* than thick broad canopies like *Gmelina arborea* and *Acacia mangium*. Species that have light to moderate and conical canopies similar to *Eucalyptus spp*, has higher net complementarities compared to *G. arborea* and *M. indigofera* (Mercado et al. 2012). Although A. mangium has broad and thick canopies, it has higher net complementarity due to its nitrogen fixation qualities. N_2-fixation is an important functional characteristic that needs to be considered in selecting tree species for agroforestry systems. Mercado (2007) found that a two–year-old *A. mangium* planted 8mx2 m as contour hedgerows in Claveria, Philippines contributed 69 kg N per hectare to the maize crop, while the trees had 144 kg N per hectare from N_2 fixation that was equivalent to 42% of total tree N requirement. The availability of N from N_2 fixation has reduced pressure on soil N, which is then spared to adjacent crops. In the context of low input systems, N_2 fixation could meet the N requirement of both trees and crops.

Tree deep rooting characteristic is another important criteria in choosing appropriate tree species for agroforestry systems. This is to reduce tree surface lateral roots extending towards the shallow rooted crops that are extracting water and nutrients on the same soil layers. Van Noordwijk and Purnomosidhi (1995) suggested the use of fractal branching analysis as a simple tool in determining tree competitiveness to the adjacent annual crops. Mercado (2007) used relative root length density as a tool in assessing tree competitiveness. Though being a more tedious process as opposed to fractal branching method, this method provides a more realistic estimate of tree root competitiveness. For rapid analysis, root fractal branching is more appropriate. Mercado (2007) found that *A.mangium* has a higher relative root length density in soil layer deeper than 100 cm, while 60% of *G. arborea* root mass was found in the first 60 cm soil depth, growing in the same soil layer of the associated maize crop.

3.3. Lateral branches pruning. Figure 4 shows the relationship between tree canopy height and vegetable net complementarity. Pruning lateral branches promote light to penetrate thus improving the performance of crops grown beneath the trees. Mercado (2006) found that removing 40-50% of a two year old *A. mangium* and *G. arborea* canopies, particularly the lower branches increased light transmission from 20 to 60%, which brought the maize yield similar to that in open field.

3.4. Root pruning and laying out of plastic barrier. Table 1 shows the effect of root pruning and root barrier on the net complementarity of bell pepper. This was a mechanical way of making tree roots grow into the soil subsurface, avoiding direct competition with the adjacent building thus avoiding competition, which results to lower reduction of growth at the competition zone and to better net complementarity. Root pruning may not have a long term effect on reducing tree-crop competition as the roots will recover later, but putting plastic barrier will provide lasting effect. Garrity et al., (1995) found that roots grew over or under a 50-cm width plastic barrier, thus a 100 cm width plastic used in this experiment was just right to avoid this problem.

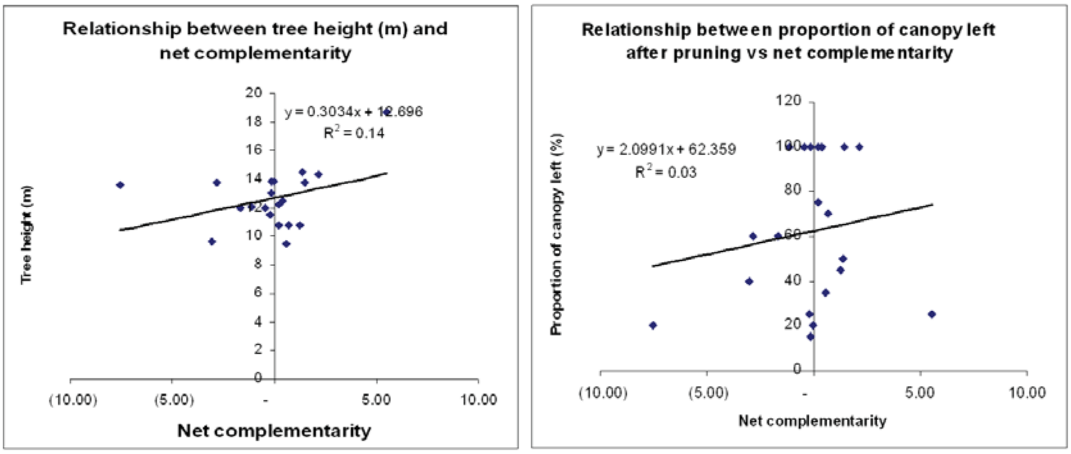


Figure 4: Relationship between tree height and net complementarity (a), and proportion of canopy left after pruning and net complementarity. Lantapan, Bukidnon, Philippines.

3.5. Supplemental water at competition zone. Table 1 shows the effect of drip irrigation on net complementarity. Providing water through drip irrigation has increased net complementarity. Water is a highly competed resource in agroforestry systems, particularly in low rainfall areas. In the humid tropics of Southeast Asia, annual rainfall is generally high but distribution has been problematic, causing plant drought stresses. Using drip irrigation alleviates water scarcity.

Table 1. Effect of drip irrigation and root pruning on the biomass and marketable yield of bell pepper in wet and dry season, Lantapan, Bukidnon, Philippines

Management	Wet season			Dry season		
	Marketable yield (t/ha)	Total biomass at harvest (t/ha)	Total (t/ha)	Marketable yield (t/ha)	Total biomass at harvest (t/ha)	Total (t/ha)
Control	3.0	4.7	7.7	1.2	2.8	4.0
Drip irrigation	4.6	6.1	10.7	1.8	3.5	5.3
Root barrier	3.9	6.9	18.8	2.1	4.2	6.3
Mean	3.8	5.9	12.4	1.7	3.5	5.2

3.6. Skewing the application of leaf pruning and fertilizers in the competition zone. The competition zone is where the demand for growth resources is more intense because trees and crops are extracting nutrients on the same volume of soil, particularly if these resources are not sufficient for both of them. The best approach to reduce if not eliminate nutrient competition is to skew the fertilizer application in the competition zone. This management strategy is important particularly if the trees grown are valuable species like rubber, fruits or premium timber where the overall economics of the system is largely influenced by the value of tree products.

3.7. Orient the tree rows parallel to the direction of the sun (east-west direction). Table 2 shows the effect of tree rows orientation related to the path of the sun (aspects) on net complementarity. Vegetables planted on the east side yielded better and had less competition for light than those planted in the west side. This is due to longer exposure of vegetables to the sun particularly in Lantapan where rainfall is frequent in the afternoon. Orienting the tree rows parallel to the direction of the sun eliminates this problem. The vegetables are getting similar exposure to the sun.

Table 2. Effect of aspects on vegetable net complementarity in vegetable agroforestry system, Lantapan, Bukidnon.

Aspects	Net complementarity
East (vegetable on west side)	-2.09
West (vegetable on east side)	-0.54
North (vegetable on south side)	-1.06
South (vegetable on north side)	-1.74

4. *Decrease or eliminate the value crop displacement area (D)*

4.1. Ensure that the value of the hedge area (T) is greater than the opportunity cost of the displacement area (D). This refers to the planting of valuable trees that produce valuable products like latex, fruits and timber, which are more valuable than annual crops because the hedge area could have been planted with vegetables if trees were not planted. The indirect benefits such as microclimate amelioration that improve vegetable yields, carbon stocks, organic matter due to litterfalls and root hydraulic lift provided both nutrients and water to the shallow rooted crops from the subsurface can also be quantified as additional benefits from growing trees in agroforestry systems.

4.2. Use of early maturing hedges such as clonally propagated trees such as rubber, coffee, timber and fruit trees. Clonally propagated trees shorten the gestation period, as well as improve tree productivity. Laxman (personal communication) indicated that asexually propagated rubber trees produce 2-3 times more latex than those from seedlings. Clonally propagated fruit trees also reduce gestation period from 8-10 years to 3-4 years and also produce more fruits.

4.3. Use of underneath vegetation like banana forage grass and legumes (Figure 2). Growing shade tolerant forage legumes and grass like *A. pintoi* and *S. splendida* provide fodder for livestock, which in turn, generates additional income and provides manure fertilizers. In sloping lands, bananas, fodder grass and legumes are effective in controlling soil erosion and landslips during high rainfall events as their roots act as soil binders (their root length densities at the soil surface area is 0-100 cm). Furthermore, the trees provide soil anchorage function. Combining plant species with high soil binding and anchorage functions in a s multi-story hedgerow system (Figure 2) can greatly reduce if not totally eliminate landslides and landslips in sloping areas. Bananas also provide medium term income to the farmers.

4.4. Reduce the displacement area by having fewer hedges (e.g. 20 meters instead of 5-6 meters apart). The rule of thumb of SALT is to space hedgerows at 6-8 meter interval. This is not possible because the tree competition zone extends up to 5-6 meters from the tree line, and both sides of the hedgerow have a total of 10-12 meters. Making the hedgerows spacing wider therefore reduces crop displacement area while enhancing the ameliorative effects of trees.

Impacts of trees on crop yields

With proper choice of tree and vegetable species and spacing, the yield of commercial vegetables across two seasons has increased up to 40% (Table 3) without any additional inputs aside from the trees planted on lines spaced at 20-25 meters apart. These yield increases were due to the micro-climate improvement created by the trees such as reduction of wind speed, increased relative humidity, increased soil moisture and higher organic matter due to tree litterfall. Trees reduce wind and soil erosion thus making nutrients more available (Cleugh 2003; Stirzaker et al. 2002). Trees can also improve water supply through increased fog drip by intercepting atmospheric moisture that would otherwise be unavailable, which has been found to be more nutrient enriched than rainfall (Liu et al. 2005).

Microclimate amelioration impacts on soil moisture and soil temperature relations results primarily from the use of trees (Nair 1993). Temperature, humidity and movement of air as well as temperature and moisture of the soil directly affect photosynthesis, transpiration and the energy balance of associated crops, the net effect of which will translate into increase of crop yields (Nair 1993; Rosenberg et al. 1983). Where soil structure is degraded, trees can enhance water movement into the soil and improve infiltration in their vicinity so that there is more soil water available to crops grown around the trees (Stirzaker et al. 2002; Wilson et al. 2006). Increased soil water infiltration and storage capacity is evident near to trees rather than distant from them, whereby roots, or their remains, create macropores within the soil, through which water can circulate (Stirzaker et al. 2002). Trees generally have a deeper root system than annual species particularly crops, and the presence of macropores would permit water circulation and drainage to the lower soil horizons (Zapata-Sierra and Manzano-Agugliaro 2008). Increased infiltration under trees has been linked with increased soil nutrient concentrations whereby elevated concentrations of carbon, mineralised nitrogen and extractable phosphorus, potassium and calcium have been found in soils below trees and their surroundings compared to open fields (Bird et al. 1993; Eldridge and Freudenberger 2005). Trees provide important associations with ectomycorrhizal fungi which aid in the uptake of nutrients from nutrient-poor soils (Bird et al. 1993; Oliver et al. 2006). Leguminous species can introduce nitrogen into crops while litter-fall from certain trees can recycle cations from depth and reverse the acidification of surface soils (Stirzaker et al. 2002), through root hydraulic lift (Keertisinghe, per comm). The total amount of tree litter and soil nutrient concentrations of extractable phosphorus, total nitrogen and organic carbon, decreased with increased distance from the tree suggesting the importance of trees in farming systems (Oliver et al. 2006). This high concentration of nutrients is attributed to the large quantities of litter accumulation around trees and the root activity within the soil, sourced from rainfall and wind-blown materials or through fog drip as well as being deposited by arboreal insects, birds and mammals using the trees (Oliver et al., 2006).

Table 3. Yield increases of commercial vegetables under vegetable agroforestry system, Lantapan, Bukidnon.

Vegetables	Wet season (June – Sept)	Dry season (Feb – May)	Average
Chinese cabbage	37	30	34
Cabbage	13	0	7
Tomato	40	10	25
Bell pepper	20	10	15
Carrots	37	30	34
Mean	29	16	18

Conclusion

Tree and crop management are key elements in improving the adoption, economic and environmental benefits of agroforestry systems, which include silvicultural and agronomic managements and selection of the right species and plant combinations that are compatible. These management strategies lead to increased value of trees, enhanced complementarity effects and reduced competition among the components, which contribute to up to 40% increase in crop yields. Integration of trees into intensive crop production systems offers better prospects, such as increased economic benefits, enhanced biodiversity due to the presence of arboreal birds and mammals, and higher system carbon sequestration, while controlling soil erosion and degradation, particularly in critical watersheds, compared to monoculture systems. Agroforestry is a superior land management option in Asian watersheds, which are facing significant threats from intensive agricultural production to feed a growing urban population.

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Intercropping short-rotation crops in rubber plantations during the establishment phase in northwestern provinces of Vietnam

Nguyen Huu La

Abstract

Planting rubber trees on sloping lands causes erosion and soil depletion. The transition of cultivated land into rubber plantation also reduces farmers' income significantly. To reduce the income gap between planting to tapping of rubber trees, the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI) conducted a research from 2009 to 2011 to test a number of species appropriate for intercropping with rubber trees during its establishment phase, and suggested three short-growth duration crops for intercropping, in the northwest region.

Keywords: NOMAFSI, rubber plantations, intercropping short day crops, northwest region of Vietnam

Introduction

The Northwest region covers four provinces located in the mountainous northwestern part of Vietnam, namely Hoa Binh, Son La, Lai Chau and Dien Bien. The whole region has a total land area of 3.5 million ha, of which agricultural land accounts for 14%. The Northwest's terrain is characterized by high mountains, with an average elevation of 1,500-1,800 meters above sea level (masl) and an average slope of 30^0. The region has an Asian temperate and tropical climate. The dry season lasts from October to April. The average temperature during the rainy season, which is from May to September, is around 20 degrees C. The highest temperature is 30 degrees C and the lowest is 10-12 degrees C. The average annual rainfall is 1,500-2,000mm. Rain is relatively heavy in the months of June, July and August, during which humidity level is around 80-85%. Generally speaking, the climate in the Northwest region is favorable for growing industrial and food crops. The region has potential for developing agroforestry for basic commodity products. However, access to science and technology is still limited and crop yield remains low than the total average of the country. Some factors for agroforestry development in the region have been identified and summarized below:

Enhancing factors

The region has a rich and varied natural resource base, which facilitates the expansion of industrial crops originating in tropical and temperate-tropical climates.

The completion of hydropower plant construction in Hoa Binh, Son La, Lai Chau provinces will create a micro ecological area for agroforestry production and tourism development.

Government economic policies are supportive of mountain area development.

Limiting factors

As the terrain is widely divided by mountains and infrastructure is under-developed, transport in the region is difficult. Local people's literacy is low, limiting their capacity to learn and adopt advanced science and technology. Hardworking as they are, they hardly earn enough from manual labor, and have no capital to expand production; hence, the regions domestic production (Gross Domestic Product) is low compared to other regions in the country. All these, contributed to increasing poverty rate in the region, which is already the lowest recorded level in Vietnam. Fragmented and self-subsistent production remains dominant. Quality and commodity prices of farm produce are low.

The weather is sometimes unfavorable such as prolonged winter, compounded with frost, heavy rainfall, hail and flash floods, making it difficult for farmers to secure continuous water supply for their crops.

Agriculture production is unsustainable, inefficient and has seriously impacted on the environment. A major environmental challenge in the region is soil erosion.

Overview of agroforestry practices

Northern Vietnam and certain areas in the Northwest in particular, have started adopting advanced agroforestry models mainly as part of international cooperation programs, which are somewhat different from indigenous agroforestry systems. Advanced systems are generally simpler in terms of the number of species and biological diversity than indigenous models. Alley intercropping system has become popular in the last 10 year. It is the practice of growing green trees to border food crops in between two rows of trees. The trees create a micro-climate for food crops to grow better and provide organic nutrients to the soil while producing timber and other tools for farm. The system has a number of strengths such as, reducing surface water velocity, providing green substances to livestock or land, and restoring and maintaining soil fertility. However, it is technically challenging and demands higher financial and labor inputs. The model, therefore, is applied mainly in project sites where farmers are provided with seeds and other planting materials such as in Hoa Binh, Son La, Dien Bien, and are not yet widely adopted.

Currently, rubber trees are planted vastly in the Northwest, as a result of the Prime Minister's decision No. 750/QD-Ttg that approves the rubber development master plan through 2015 and vision through 2020. The decision sets a goal of growing 50,000 hectares of rubber trees by 2020. Currently, the total planted area is already 20,000 hectares. The Ministry of Agriculture and Rural Development (MARD) meanwhile has issued circulation No. 58/2009/TT-BNNPTNT on 09 September 2009, providing guidelines to the planting of rubber trees on forestlands and decision No. 2855 QD/BNN-KHCN on 17 September 2008 that announces rubber tree to be a multi-purpose plant. Rubber tree is a long-term industrial tree that takes 6 – 9 years to reach maturity and produce latex. The distance between rubber trees is wide enough (7m x 7m x 2.5m), providing enough space for planting adapted crops between rows of trees before the tree canopy closes. As rubber trees are mainly planted on sloping lands, soil erosion was accelerated causing rapid soil fertility decline. Today, most rubber farmers in the Northwest are not yet earning since the rubber plantations have just been established.

Spring summer season (maize) – Winter autumn season (black bean, mung bean) intercropped with rubber trees at Muong Bon, Mai Son, Son La

Photo by NOMAFSI

To mitigate the income gap from planting to tapping the rubber trees, it was deemed necessary to maximize the alley space by planting adapted crops. Doing so will also help protect the soil from erosion, improve land use efficiency and save labor for cultivation activities, including weeding. There has not been any specific scientific findings on associated species that can be intercropped in rubber plantations at a large scale, in the northern mountainous region in general, and the northwest in particular. A study was therefore conducted on ‟identifying intercropping techniques and structures of associated crops for interplanting on rubber tree-planted hills during the establishment phase".

The study was aimed to (i) identify short-day species and structures of associated crops for interplanting on rubber plantations; (ii) assess erosion control and soil protection of the associated crops and intercropping models/ structures; and (iii) assess the growth of rubber trees when intercropped with other species.

Method

System components

1. Main crop: Rubber tree species *GT1* were planted with a density 571 trees/ha, spaced at 7mx2.5m. Planting started in 2008 and 2009.

2. Intercropped species: Maize species *LVN10, LCH9, LVN14, LVN184, LVN37; LVN105, TN041, LS0712;* Peanut species *MD7, MD9, L14, L18, HL5,* local red pea nut; bean species including soya bean (*DT 84, DT 96, DT 12, DT 22*) and mung bean species (*DX15, DX11, V123, VN99-3*); Upland rice (*LUYIN46, CIRAD141, IR74371-3-1-1, IR74371-54-1-1*); fodder grass (*Elephant grass Pennisetum purpureum, Brizantha, Panicum maximum, Panicum astratum, VA06*).

Research design

Short-growth duration associated species: The field experiment method developed by Pham Chi Thanh (1986) was used. The experiment was a Randomized Complete Block Design (RCBD).

Main crop (rubber trees): The data collection protocol suggested by the Rubber Research Institute of Vietnam was employed in this study.

Literature review on intercopping associated plants in rubber plantations during the 1st, 2nd year after planting, in slopes ranging 10-20 degrees.

Soil erosion measurement: A soil trap with dimensions 60cmx60cmx5m was established at the bottom of the research plot. Soils are collected once a month and sampled for processing and analysis.

Results

Associated crops

Short growth duration crops found to be appropriate for intercropping with rubber trees are: (i) 2 peanut varieties (*LH5 and MD7*); (ii) 2 maize varieties (*LVN184 and LVN 14*); (iii) 1 soy bean (*DT12*); (iv) 2 mung bean (*V123 and VN99 – 3*); (v) 2 upland rice varieties *Luyin 46* and *IR 74371-3-1-1*; and (vi) 1 grass variety (*VA06*).

The density of short-term associated plants has obvious impacts on productivity. The recommended density levels are: (i) peanut variety *MD7* 30 - 35 units/m2; (ii) maize variety *LVN14* 65,000 units/ha; and (iii) mung bean variety *VN99-3* 26 units/m2.

Spring-Summer is the best season for sowing maize LVN 14, for intercropping with rubber trees in the Northwest. Sowing can be done between April 10 and May 10, while soya bean can be sown in between April and August, and upland rice within the first week of May.

The amount of fertilizer for short-growth duration crops needs to be increased by 25%

Hybrid cotton VN01-2 intercropped with rubber trees in the establishment phase at Chieng Pan, Yen Chau, Son La.

Photo by NOMAFSI

from the recommended maximum level of fertilization for high-yielding crops.

Furthermore, five suitable structures of associated crops for intercropping with rubber trees were found:

- Structure 1: Planting pasture all year round during the establishment phase.
- Structure 2: Bi-annual associated crops, which are spring season bean (season 1) and summer autumn bean (season 2)
- Spring season soya bean *DT12* and summer autumn soya bean *DT12* (season 2):
- Spring season mung bean *VN99-3* (season 1) and summer autumn mung bean *VN99-3* (season 2)
- Structure 3: Bi-annual associated crops: spring summer bean (season 1) and summer autumn upland rice (season 2)
- Spring season soya bean *DT12* and summer autumn upland rice *IR74371-3-1-1*
- Spring season mung bean *VN99-3* and summer autumn upland rice *IR74371-3-1-1*
- Structure 4: spring summer upland rice *IR74371-3-1-1* (season 1) and autumn winter bean (season 2)
- Spring summer upland rice *IR74371-3-1-1* and autumn winter soya bean *DT12*
- Spring summer upland rice *IR74371-3-1-1* – and autumn winter mung bean *VN99-3*
- Structure 5: spring summer maize (season 1) and autumn winter bean (season 2)
- Spring summer maize *LVN14* (season 1) and autumn winter soya bean *DT12* (season2)
- Spring summer maize *LVN14* (season 1) and autumn winter mung bean *VN99-3* (season 2)

Evaluation of the structures show that the three most appropriate structures of associated crops are: (i) Planting all-year-round pasture *VA06;* (ii) Spring bean – Summer autumn upland rice; and (iii) Spring summer maize – autumn winter bean.

Impacts of associated crops on the growth of rubber trees

- Associated crops have positive impacts on the growth of rubber trees. Tree height and diameter increased by 2.26%- 6.17% compared to monocropped rubber.
- Pests: Rubber trees in all intercropping, rotation and monocropping models have Powdery Mildew Fungus (E*rysiphe cichoracearum*) but infections were not serious and did not prevent growth.
- Bacterial leaf blight disease is observed in rubber trees that are monocropped and intercropped with spring summer maize – winter bean, but the damage was minimal. Red spiders are observed in monocropped rubber plantations.
- It can be concluded that intercropped rubber trees are more resistant to pests.

Influence of associated crops on soil protection, erosion prevention and fertility improvement

- Associated crops help reduce annual soil erosion by 33.65%-76.99%. The following soil erosion control levels of intercropping structures are arranged in a descending order: intercropping with pasture> with rice > with maize > with peanut > with soya bean > with mung bean > monocropped rubber trees (control).
- Intercropping short-day plants with rubber trees during the establishment phase was found to increase cover, protect soil and significantly reduce soil depletion.
- Soil protection capacities of associated crops vary. Intercropped pasture can best protect soil, reducing the amount of soil erosion by 52.17% to 76.99% compared to monocropped rubber trees (control).
- Rotation of associated crops differ significantly in terms of soil protection. Intercropping with all-year-round livestock pasture was found to be superior, followed by intercropping spring summer maize-winter bean and spring bean – summer autumn upland rice. Monocropping rubber trees has the highest soil erosion (control).
- Influence of associated crops on soil fertility improvement was also observed. Eight months after intercropping short-term species with rubber trees, the amount of nutrients measured in intercropping and monocropping models show no significant differences. However, from 20 months after intercropping, the amounts of humus (OM%), nitrogen fertilizer (N%), phosphate and potassium (P_2O_5 and K_2O) in intercropped plantations increase compared to those measured in monocropped plantations. Crop residues in the intercropping model reduced soil erosion, added soil organic matter, maintained nitrogen fertilizer and improve trees' ability to absorb hardly soluble minerals stored in sub-soil layers, particularly phosphate and potassium of bean plants.

Impacts of short-day associated crops on rubber plantations during the establishment phase

- Environmental impacts: Intercropping reduces slash-and-burn farming activities of ethnic minority groups. Maize leaves and stalks, bean and hay, etc. were plowed into the soil, providing significant amount of organic mulch. This helps retain moisture, increase soil aeration, and improve soil physical properties. Soil erosion was also significantly reduced by up to 80%.
- Economic impacts: Intercropping provided an extra income source. Local farmers had an annual average income of 10-12 million VND per ha before rubber trees can be tapped. With intercropping, the net profit were as follows: maize 13.38- 15.66 million VND/ha; peanut 5.82- 9.02 million VND/ha; bean 14.427- 18.177 million/ha; upland rice 2.4- 3.45 million/ha; grass 12.4- 14.02 million/ha.
- Social impacts: The model created more jobs, provided an extra income of 450,000 VND/month/person for four months/season/year. The intercropping technique is easy to adopt, and adapted to the current farming practice of the northwestern people.

Conclusion & recommendations

- A number of short-day species for intercropping with rubber trees during the establishment phase were found including: Maize varieties *LVN14* and *LVN 184*; soya bean varieties *DT12*; mung bean *VN 99-3*; upland rice species *Luyin 46*, *IR 74371-3-1-1*; and grass species *VA06*.
- 3 proper structures/models of associated crops were selected: (1) Planting all-year-round pasture VA06; (2) Spring bean – Summer autumn upland rice; (3) Spring summer maize – autumn winter bean.
- Intercropping short-growth duration crops with rubber has brought additional income between 24,304,000 and 37,340,000 VND.
- Intercropped rubber trees during the establishment phase grew by 2.26- 6.17%

faster than monocropped trees.
- Soils were better protected and preserved in intercropping models, particularly after 20 months.

In conclusion, the study recommends to provincial authorities of the Northwest and rubber enterprises in Son La, Dien Bien and Lai Chau, to create policies and strategies that support farmers and workers to intercrop short-day plants like maize, bean, upland rice, and cattle grass, among others with rubber trees during the first 3-4 years of establishment, to optimise income and environmental benefits of rubber plantations.

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Rubber-cassava agroforestry in Thua Thien – Hue province, central Vietnam

Tran Nam Thang

Abstract

Rubber-cassava intercropping system is widely adopted by farmers in the northern central province of Thua Thien Hue. Farmers usually plant cassava during the first three years of rubber plantation to save space and soil nutrients, increase soil cover, and prevent soil erosion. Income from cassava helps maintain farmers' cash flow while waiting to tap the rubber trees. This paper presents initial findings of a study that uses the WaNuLCAS model (Water Nutrient Light Capture in Agroforestry Systems) to simulate management scenarios that bring about optimum benefits of rubber+cassava+peanuts system in terms of carbon stocks, income and greenhouse gas emission reductions. It was found that increasing the density of rubber trees from current practice brings higher output in terms of carbon sequestration, carbon stocks, and latex production. While the study is only half-way, long term economic return is expected to be higher compared to current practice.

Keywords: agroforestry system, WaNuLCAS, rubber-cassava intercropping, carbon stocks

Introduction

Rubber-cassava intercropping system is popularly applied in Thua Thien Hue province. Most of the upland areas in the province are populated by ethnic minority groups of Katu, Paco-Van Kieu who are used to shifting cultivation on slopes with cassava as the main food crop. However, shifting cultivation gradually phased out due to:

- state and provincial policies restricting shifting cultivation;
- degraded soils due to unsustainable farming practices;
- decreasing crop productivity and emergence of economically lucrative systems such as rubber plantation; and
- the development of smallholder rubber plantations under the government's reforestation program 327 (since 1993).

As a result, vast areas of sloping farmlands have been converted into forestland and rubber since 2000. However, it was observed that rubber trees are not monocultured but intercropped with an indigineous cassava variety. Eventually, indigenous cassava has been replaced with high-yielding varieties to meet market demands.

There are many reasons for improving rubber-cassava system. First, cassava is intercropped in most of rubber-planted areas in Hue province; however, local people rarely apply fertilizer on cassava, which decreases the productivity of rubber trees since cassava requires huge amounts of soil nutrients and fertilizers. Second, farmers plant rubber trees with a 6x3 meter density (6 meter inter-row spacing and 3 meter inter-tree distance).

In collaboration with World Agroforestry Centre (ICRAF) scientists, we used WaNuLCAS primarily to determine the optimum benefits of rubber+cassava system in terms of economic returns, carbon stocks and reduction of greenhouse gas emisions. Specifically, the study aimed to: (1) ascertain where rubber trees can be intercropped with other species (such as peanut or bean) to improve soil fertility and increase long-term productivity of rubber trees; (2) determine the impacts of intercropping cassava on the yield of rubber trees; (3) determine if changes in planting density will have any impact on productivity and yield; (4) explore different alley crop rotations and rubber tree density (e.g., planting cassava in 3 consecutive years, cassava - bean/peanut – cassava, bean/peanut -cassava - bean/peanut, planting bean/peanut in 3 consecutive years, and double the density of rubber trees); and (5) examine the interaction among growth factors to be able to recommend improved management practices of current agroforestry model.

Method

WaNuLCAS Model

WaNulCAS model is used to simulate tree-crop-soil-climate interaction in agroforestry systems (van Noordwijk and Lusiana 1999; van Noordwijk et al. 2004). The model was developed by scientists from the World Agroforestry Centre (ICRAF) using the STELLA modeling frame. WaNuLCAS model has a plot scale spatial and daily time resolution. It has been used for different objectives such as to model fallow rotational systems (Walker 2007), sugarcane–rubber systems (Pinto 2005), agroforestry systems in semi-arid region (Muthuri 2003) and trade-offs analysis for possible timber-based agroforestry (Martin and van Noordwijk, 2009). The spatial configuration of simulated plot in the model consists of four-layer soil profiles and four spatial zones (Figure 1A) and tree or crop can be planted in any zone. The model takes into account three main component resources: light availability (for aboveground resource), water and nutrient availability (for belowground resources) in which tree and crop share, and these are interpreted into different modules.

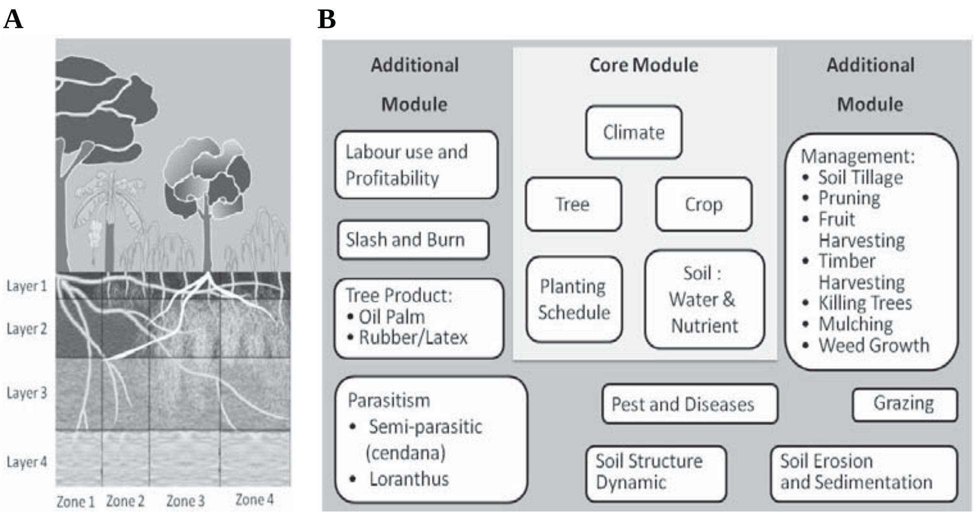

Figure 1: A. General lay out of zones and soil layers in the WaNuLCAS model. B. The main components of the model, their interaction, and modules that represent tree and crop in sharing light, water and nutrient resources.

Secondary Data Collection

Secondary data were collected and purchased from relevant sources:

- Temperature, rainfall and evaporation data in Nam Dong district (Thuong Nhat meteorological station).
- Related information about the models and land use changes from the Department of Agriculture and Rural Development.

Primary Data Collection

- Soil profiles for soil sample collection: the soil profiles were taken from existing Rubber – Cassava plantations. The samples of each soil layer were taken, preserved and analyzed, following the suggested criteria in the WaNulCAS model.
- Information about land use and management practices (labour, fertilizer) was collected through direct interviews with farmer cooperators. Additional information about their incomes was also collected.

Data Analysis

Both secondary and primary data were parameterized inputted into the WaNuLCAS model. We proposed four scenarios or models to compare with current practice both in terms of income, carbon stocks and greenhouse gas emission reductions (Table 1). Figure 2 presents the lay out of current practice in the WaNuLCAS model.

Table 1: Simulated scenarios/models

Current practice (0)	Rubber+cassava (Cassava is planted in the 3 first years; 6x3m rubber trees)
Model 1	Rubber+cassava+peanut (Cassava is planted in the first and third years, while peanut is planted in the second year)
Model 2	Rubber+peanut+cassava (Peanut is planted in the first and third years, while cassava is planted in the second year)
Model 3	Rubber+Peanut (Peanut is planted in the 3 first years)
Model 4	Rubber+cassava (change the density of rubber trees from 6 x 3 to 4 x 2)

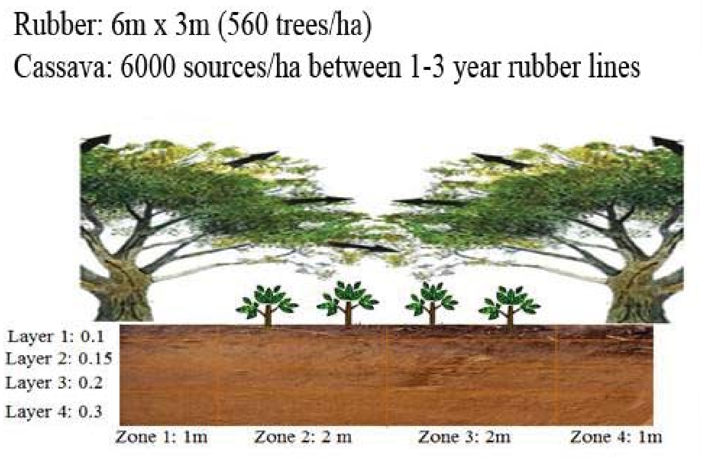

Figure 2: Rubber+ cassava system lay out under WaNuLCAS model

Results

As mentioned above, the study is still on-going; hence, we present partial results of our analysis only in terms of carbon sequestration, carbon stocks and latex production. Except for model 4, simulation results showed that the models have a relatively equal level of carbon sequestration, which can be attributed to the increased number of rubber trees in the simulated models compared to the current model.

Besides carbon sequestration, other relevant parameters were calculated and presented as shown in Table 2.

The results show that the current and first three models have relatively similar values for each parameter. Model 4 has remarkably higher latex yield and carbon sequestration since the density of rubber trees in this model was doubled (1,120 trees). However, the diameter of rubber trees of this model are smaller compared to current model.

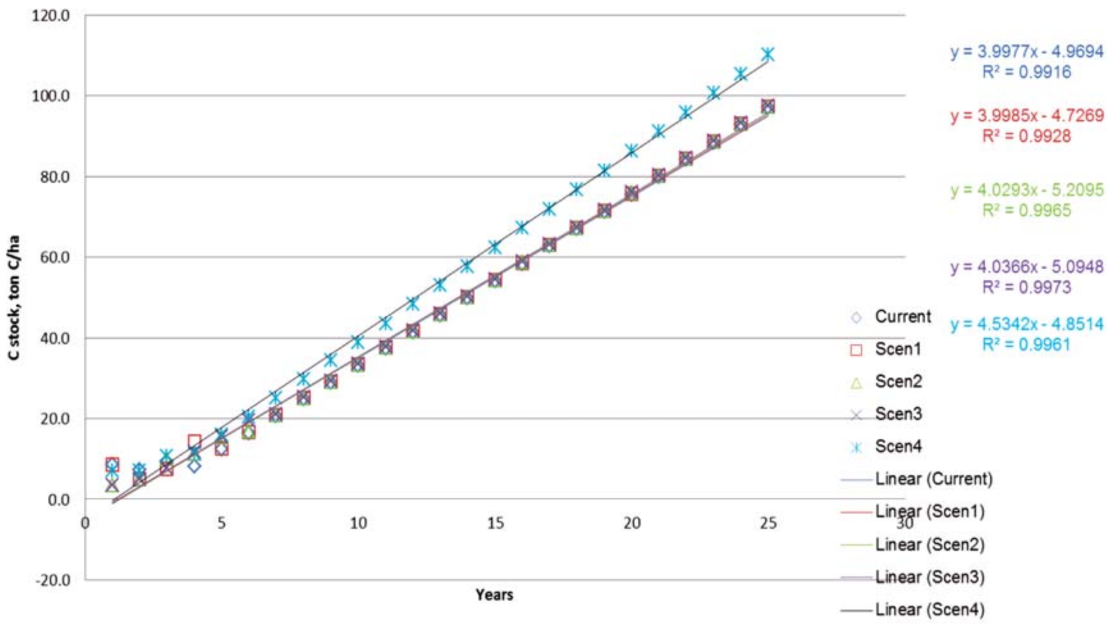

Figure 3: Changes in carbon sequesteredration in different models (tons/ha)

Table 2: Outputs of simulated models/scenarios

Model	Tree diameter (cm)	Latex output (ton/ha/year)	Carbon stock (ton/ha)
Current model (0)	18.73	0.44	47.0
Model 1	18.78	0.42	47.3
Model 2	18.78	0.40	47.2
Model 3	18.82	0.42	47.4
Model 4	14.67	0.64	54.1

The results show that the current and first three models have relatively similar values for each parameter. Model 4 has remarkably higher latex yield and carbon sequestration since the density of rubber trees in this model was doubled (1,120 trees). However, the diameter of rubber trees of this model are smaller compared to current model.

Some key study findings are herein summarized:

- It is economically and environmentally beneficial to convert from monoculture of short-growth duration crops to agroforestry to achieve long-term, sustainable development goals.
- Agroforestry helps reduce soil vulnerability during the initial years and create short-term income to compensate investments in long-term cash crops.
- Rubber-peanut intercropping facilitates the growth of rubber trees and increase latex reserves in the future. More in-depth studies on this should receive due attention.
- Rubber-casava model has the highest economic value while minimizing greenhouse emissions (N_2O, NH_4) compared to other models.
- Changing rubber tree density might be a solution, yet it should be studied and tested more thoroughly. High density planting has been implemented in China and the Philipines, so learning their techniques and lessons is necessitated for scaling up the models.

- Low or zero fertilization of cassava will affect the quality and productivity of rubber trees in the long term.

Recommendations for future research

- Management for intercropping peanuts to support the long-term growth of rubber
- On-farm trials on latex measurement
- Suitable shade tolerant trees for planting under the canopy of rubber trees (e.g., non-timber forest species, medicinal plants, coffee, tea, etc.) after the third year, to effectively and sustainably utilize below canopy resources such as space.

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Integrated agri-aqua-forestry systems in Vietnam's Mekong Delta: Current status and issues for future development

Dang Kieu Nhan

Abstract

Integrated agri-aqua-forestry (IAAF) is a farming system that is commonly practiced by farmers in acid sulphate wetlands and mangrove ecosystems of Vietnam's Mekong delta. The system is low-input that satisfies multiple objectives of food production, socio-economic benefits, and environmental management, but it is also vulnerable to climatic and socio-economic changes and forest resources degradation. Integrated solutions that include policies, institutions and technologies for sustainable natural resources management at household, community and regional scales, are needed to make IAAF systems more resilient to harsh environmental and rapid economic change.

Keywords: integrated agri-aqua-forestry system, Mekong delta, integrated farming system, wetlands

Introduction

A type of agroforestry that is commonly known and widely practiced in the Mekog delta is 'integrated agri-aqua-forestry system' or IAAF. In this system, farmers integrate crops with livestock and aquaculture and/or forestry on the same farm in order to optimize resource use (Prein, 2002; Nhan et al., 2007). The key principle of integrated farming systems is the cycling of water, nutrients and energy among farm enterprises within a system, which helps reduce external production costs and economic risks (Prein, 2002). Such integrated farming systems would contribute significantly to food production, adaptation to changes in living environment and environmental protection under the context of population growth, limited land and water resources and climate change (Fedoroff et al., 2010).

In the Mekong delta, where wetland is a dominant ecosystem, aquaculture becomes an integral component to agroforestry. Farmers in the delta have been practicing IAAF for over 30 years (Sanh et al., 1998), where two main types are distinguished by their environmental characteristics: (1) Integrated agriculture-aquaculture-forestry farming systems in back swamp acid sulphate soil areas (Sanh et al., 1998); and (2) Integrated shrimp-mangrove farming system in coastal areas (Binh et al., 1997). These systems are suitable and common in unfavourable areas in terms of land and water resources, and their vulnerability to socio-economic and environmental changes.

A number of studies have tried to describe system components and their interactions and focused on options to improve crop and/or aquaculture yields and economic profitability (Binh et al., 1997; Johnston et al., 2002; Au et al., 2009). However, economic and environmental trade-offs usually exist in these systems (Dang et al., 2009). To promote IAAF systems, their environmental and social benefits need to be identified, as socio-economic constraints at community and at a larger scale appear to be more important than technological problems at household scale. These issues have not been studied sufficiently.

Information on these issues would support policy and institutional improvements aimed at enhancing multiple objectives than economic viability only. This report analyses trends and drivers of agricultural land use evolution in the Mekong delta and describes two case studies as illustrations for suggesting solutions to further develop IAAF systems in the Mekong delta in particular, and in Vietnam in general.

Evolution of agricultural land use

The evolution of agricultural land use in the Mekong Delta is strongly related to irrigation development, agriculture and market development policies, agricultural technology advancement, and urban-rural labour migration, and can be summarized into three periods: (1) 1975-1990– expansion and intensification of rice production to achieve national food security; (2) 1991-1999 – intensification of rice production and expansion of aquaculture; (3) 2000-2012 – agricultural diversification towards development of aquaculture, fruit and vegetable production (Figure 1). In 1975-1990, the development of irrigation and flood and salinity control systems facilitated the expansion of high-yield rice production, which gradually replaced traditional rice, in acid sulphate and saline soil areas, during which, the rice annual growth rate was 37% in area and 62% in production for the dry season crop. The corresponding figures were 18% and 25% for the wet season rice crop. Between 1991 and 1999, economic policy reforms for agricultural exports enabled the expansion and intensification of rice production, which led to the shift from self-sufficiency to market-oriented rice production. As a result, rice production grew 11% for the dry season crop and 14% for the wet season crop (calculation from GSO, 2000). 2000-2012 marked the implementation of agricultural shifting policy (under Directive No. 09/2000/NQ-CP, dated 15/6/2000) as farmers shifted from single rice crop to more diverse farming systems. In alluvial soil areas, farmers replaced rice monoculture with rotational or integrated rice and aquaculture or upland crops, or with fruit crops. In saline areas, farmers shifted from rice monoculture to rice rotated with shrimp (Penaeus monodon) or mangrove-shrimp farming.

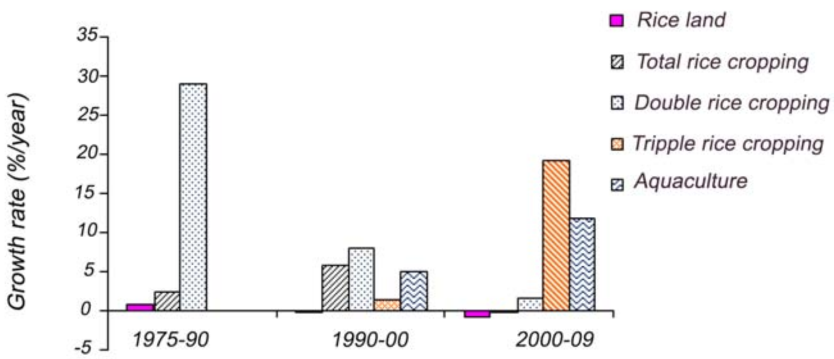

Figure 1: Annual growth rate in area of farming patterns in the Mekong Delta by period (calculated from statistical data of GSO)

Rice and aquaculture development contributed significantly to deforestation in back-swamp acidic soil and coastal areas. Statistics show that the forest area around the Delta was reduced by about 300,000 ha between 1995 and 2002 and about 30,000 ha between 2003 and 2010 (GSO, 1995-2011). By using aerial photos, Binh et al. (2005) estimated the decline in the forest area of Ca Mau province in 1968-2003. It was found that rice expansion contributed to about 60% and aquaculture expansion to 40% of the decline in forest areas.

In the Mekong delta, farmers' decisions on what to crop are largely driven by biophysical and socio-economic factors. On this premise, they applied two strategies: (1) market-oriented specialisation and intensification; and (2) risk spreading-oriented diversification through crop rotation or integration (Figure 2). Crop specialization and intensification require higher external inputs, but reduces economic risks, thereby farmers are able to diversify farming systems through crop rotation or integration. In contrast, farmers who practice integrated farming systems with sufficient resources were more incline to market-oriented farm intensification and specialization. In both strategies, optimization is a goal, where the output of agricultural production is multiple – food, economic, social and environmental.

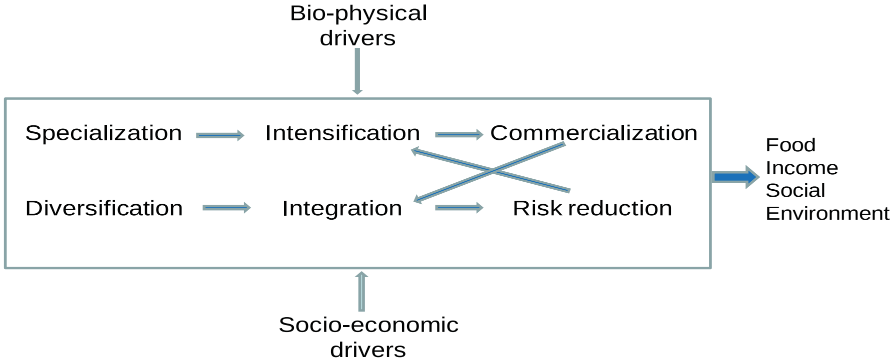

Figure 2: Options and expected outputs of farming systems in the Mekong Delta

Key IAAF systems in the Mekong delta

Integrated farming systems in back-swamp acid sulphate soils.

This system has been commonly practiced in back-swamp acid sulphate soils in the Plain of Reed and U Minh Thượng, forming buffer areas for the core area of National Parks. Specific systems include (a) Fish – *Melaleuca/Eucalyptus*; (b) Rice – fish – *Melaleuca/Eucalyptus*; and (c) Sugar cane/pineapple/banana – fish – *Melaleuca/Eucalyptus* (Figure 3).

The systems are considered low-input and low-output. The farm consists of raised beds and ditches (30-40% of the total area). Rice yields are 3-4 tons/ha per cropping season and fish yields are only 50-150 kg/ha per year. Low yields are due to acidic soils and water, making the system less favourable compared to those in alluvial areas. The systems have lower economic returns than double rice cropping or rotational rice and shrimp farming systems, but with significant environmental protection benefits due to enhanced ecological functions of the back-swamp ecosystem. The performance of the systems is constrained by poor infrastructure and limited livelihood resources of local farmers. Intensive use of upstream water had also been a limiting factor. Promotion and development of these farming systems need integrated support including rural infrastructure, additional livelihood options, and value addition to farm products.

(a) (b) (c)

Figure 3: IAFF systems in back-swamp acid sulphate soil areas in the Mekong Delta: (a) rice-fish-Melaleuca and Eucalyptus, (b) pineapple-fish-Melaleuca, and (c) fish- Melaleuca. Photos by Dang Kieu Nhan

Integrated shrimp-mangrove in coastal areas

Shrimp culture integrated with mangrove has been practiced for 30 years and it has been much developed for 20 years. In this farming system, farmers grow shrimp with low inputs by capturing wild shrimp (*Penaeus indicus*), crabs and fish and/or stocking hatchery-produced shrimp seed (*Penaeus monodon*) at a low density (Figure 4). Shrimp culture is mainly based on natural feed resources available in the system and no supplement feeding is done. A common ratio of shrimp to mangrove is 4:6. Shrimp yields 100-200 kg/ha/year compared to 400-1000 kg/ha/year in improved extensive or semi-intensive system (Joffre and Bosma, 2009). Shrimp yields are low due to shading by mangrove species and primary productivity of ditches is low (Johnston et al., 2002).

The major benefit of this system is enhanced resilience of socio-economic and ecological systems. Shrimp culture in mangrove improves farmers' income, protects coastal mangrove, maintains coastal living aquatic resources, minimize erosion of sea dikes, reduces impacts of typhoons, and captures coastal sediments, etc. In addition, the farming system helps filter pollutants discharged from rivers. Better integration between mangrove management and shrimp farming is of great importance to sustainable livelihoods of farmers in coastal areas. However, major challenges in the development of this farming system remain such as the following:

- Conflict occurs between economic (shrimp) and environment factors (mangrove) in the system due to mangrove shading and the resultant low primary productivity in shrimp ditches. Successes of earlier shrimp crops enticed farmers to increase the density level of shrimp production by stocking more juvenile shrimps and expanding shrimp ditch area, posing risks to production. In areas inside sea dikes, combined with gradual intensification of shrimp production, limited water exchange and sedimentation by sea dikes constrain maintenance and development of mangrove (Figure 4b).
- Land use ownership, rights and obligations of land users, and regulations have not been clarified for proper mangrove resources management. Roles of mangrove, livelihoods of local communities, and institutions have not been adequately elaborated.
- Farm input and output services are poor. Value chains of aquaculture commodities are poorly developed, even though the system produces ecological products. Hence, the economic values of aquaculture products are low.

(a)

(b)

Figure 4: Integrated shrimp-mangrove system in the Mekong Delta: (a) the system outside sea dikes; and (b) inside sea dikes. Photos by Dang Kieu Nhan

Conclusion

IAAF systems in the Mekong delta have well served multi-purposes – food, socio-economic and environment. These systems are considered superior not only by poor, but also rich farmers in the delta who are aiming at low input, low risk, and market-oriented production. Reducing socio-economic and environmental trade-offs are the main challenge for development of the systems. As the systems are practiced in fragile and vulnerable ecosystems leading to biophysical and socio-economic changes, social and environmental benefits of the systems at household, community and regional scale need serious and urgent attention by the government. Appropriate policies and institutions for sustainable management of natural resources are needed, and ecosystem services from these farming systems need to be assessed and quantified so that farmers can participate in the ecosystems marketplace.

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Agroforestry landscape in Yen Bai, northern Vietnam
Photo by: Pham Huu Thuong

SOCIO-ECONOMIC & POLICY ASPECTS OF AGROFORESTRY

Integrating socioeconomic issues into agroforestry research: The case of cacao-cashew and vegetable agroforestry systems in Vietnam

Dang Thanh Ha

Abstract

This paper discusses the socio-economic aspects of agroforestry systems and highlights the need for a multidisciplinary and integrated approach to ensure the success of agroforestry research and development. Our study on cacao-cashew and vegetable agroforestry systems provides an example of using agroforestry to improve income and reduce poverty. The integration of vegetables or cacao under cashew together with resource conservation technologies could help farmers increase incomes, protect farmers' health and reduce other environmental costs. Incorporating socioeconomic issues into biophysical agroforestry research through a participatory and multidisciplinary approach results in innovative agroforestry practices that are technologically sound, socio-economically acceptable and feasible, as well as environmentally sustainable, making it attractive especially to smallholders.

Keywords: vegetable-agroforestry system, cacao-cashew system, integrated research approach, environmental services

Introduction

Agroforestry is defined as the deliberate integration of trees with agricultural crops and/or livestock either simultaneously or sequentially on the same unit of land. This sustainable land-use management practice has gained increasing interest from scientific and development communities and policy makers because of its potential to provide environmental and socioeconomic benefits. Through more than a decade of research and pilot projects, The World Agroforestry Centre (ICRAF) has clearly shown that agroforestry can reduce poverty, improve food security, and protect the natural environment.

In the last decades, most agroforestry research focused on the biophysical and ecological aspects of agroforestry. However the adoption of agroforestry is also influenced by various socioeconomic and policy issues that need to be settled. Concerns over adoption rates and impacts of agroforestry systems have highlighted the importance of integrating socioeconomic elements into traditional biophysical agroforestry research (Nair, 1998).

This paper discusses the socio-economic aspects of agroforestry systems and highlights the need for a multidisciplinary and integrated approach in agroforestry research. It presents the results of the research project on cacao-cashew and vegetable agroforestry systems conducted by a research team from University of Agriculture and Forestry, Ho Chi Minh City.

Socioeconomic aspects of agroforestry

Farmers in tropical regions are adopting a range of agroforestry practices such as the taungya, home gardens, improved fallows, multipurpose trees, plantation-crop combinations, silvo-pasture, shelterbelts and windbreaks, and alley cropping. These agroforestry systems supply local farmers with important products such as food, fodder, fuel wood, poles, timber and medicines for home consumption and for the market. They also provide environmental services including soil conservation, water and air quality improvement, carbon sequestration, biodiversity conservation, and landscape beauty.

Researchers and policy makers in developing countries have paid more attention to agroforestry as a sustainable land-use management practice that holds promising solutions that help secure food production and reduce rural poverty while protecting the natural resource base and the environment.

Over the past decades, researchers have focused on exploring the biophysical and ecological aspects of agroforestry with a limited emphasis on socioeconomic aspects of agroforestry (Mercer & Miller, 1998; Janaki and Mercer, 2004). But there are various socioeconomic issues such as profitability, household benefits, equity, sustainability, soil conservation, environmental services, markets for inputs and outputs, gender, and institutions that influence the nature and magnitude of agroforestry adoption.

The economic benefits of agroforestry determine the ultimate value and feasibility of agroforestry to the land user (Nair, 1993). Participants at the first World Agroforestry Congress held in June 2004 in Orlando, Florida identified economics and policies as important areas that need significant attention if agroforestry impacts are to be achieved rapidly. However, analyzing the economic aspects of agroforestry is usually more complicated than annual crops alone or monoculture systems. Agroforestry produces not only products such as food, fodder, fuel wood, poles, timber and medicines but also environmental services called positive externalities including soil conservation, water and air quality improvement, carbon sequestration, biodiversity conservation, and landscape beauty, which makes it more complex and complicated to measure in terms of overall system value. Marketing is another important aspect of agroforestry research and development. Marketing agroforestry products is necessary to improve farmers' income and increase adoption of agroforestry systems. Farmers are encouraged to adopt new agroforestry systems when they earn income from the crops and products generated by the trees.

Farmers are also motivated to adopt agroforestry when they capture the positive values from environmental services that trees from agroforestry systems generate. Over the last decade, there has been increasing interest in mechanisms such as PES (Payments for Environmental Services) and REDD+ (Reducing Emissions from Deforestation and Forest Degradation "plus" conservation, the sustainable management of forests and enhancement of forest carbon stocks) for linking the supply and demand of environmental services such as carbon sequestration, watershed protection and biodiversity conservation. These mechanisms, if realized, will provide new and promising financial sources for promoting agroforestry adoption.

The rural poor are commonly considered as the primary beneficiaries of agroforestry. At the household level, household members manage agroforestry systems and their products and services for their own purposes. Agroforestry also offers opportunities to improve health and nutrition of women and children. The expansion of fruit tree cultivation on farms can greatly increase the quality of children's nutrition (Garity, 2006).

Other issues critical to the adoption of agroforestry include land tenure, labor, capital, local use and knowledge, local organization and participation in tree management, off-farm and on-farm income, food security, and gender and age of farmers. The concern over adoption rates has highlighted the importance of integrating socioeconomic elements into biophysical agroforestry research. Given the socioeconomic and ecological complexity of agroforestry systems, a multidisciplinary and participatory approach is required in agroforestry research and development.

Integrating socioeconomic aspects in agroforestry research: The case of cacao-cashew and vegetable agroforestry systems in Vietnam

The research project

The study on vegetable agroforestry and cacao-cashew systems in Vietnam is part of the SANREM CRSP project on "Agroforestry and Sustainable Vegetable Production in Southeast Asia Watersheds" that aims to develop sustainable agroforestry-based vegetable production systems in steeply-sloping hillsides of Southeast Asia, to alleviate poverty and food scarcity and reduce environmental degradation. In Vietnam, the research was implemented from 2006 to 2010 by the research team of the University of Agriculture and Forestry, Ho Chi Minh City in Nghia Trung commune in Bu Dang District, Binh Phuoc Province.

The research project has six objectives formulated around technology, market, policy, environmental and socioeconomic impacts, gender, and scaling-up.

The technology objective was aimed to understand complementarities between vegetables and trees, and trees with trees. The marketing objective identified opportunities for greater profit along the value chain, extending from production inputs to handling and sale of vegetables and tree products. The policy objective aimed to identify incentives that promote investments in vegetable-agroforestry systems or VAF. This element sought to answer the question: "What policy incentives promote wider adoption of VAF systems by small-scale male and female farmers?" The environmental and socioeconomic impact objective sought answers to the questions: "Can VAF improve the quality of life of small-scale farmers? Will small-scale farmer incomes increase with VAF? Can VAF reduce the non-sustainable destructive hydrologic impacts of current practices?" Finally, the gender study addressed equity issues around the VAF value chain, while scaling-up sought to understand the potential of VAF to be adopted at wider scale.

The research approach

The research team adopted a participatory and multidisciplinary research approach in identifying the research agenda, and in planning and implementation of research activities with special focus on cashew-cacao and vegetable agroforestry systems. At the beginning of the project, baseline survey and rapid market assessment survey were conducted to provide the basis for designing the technology, and understanding the marketing, policy, environmental, socioeconomic, gender, and scaling-up aspects of agroforestry. The initial baseline study helped to set technology development priorities, whereas the marketing baseline study identified marketable vegetables and trees, which became the focus of technology research.

The major research activities of the research team related to the technology objective included studies on vegetables under different cashew shading conditions; vegetable cultivation with Arachis pintoi as a cover crop; vegetables in home garden cultivated with and without drip irrigation; cacao-cashew complementarity; drip irrigation on young cacao plantings; effect of cashew weed-management practices on soil quality; and termite control on cacao seedling using vetiver grass (Figure 1).

In conducting cost-benefit analysis of the studied systems, the socioeconomic research team used yield, input and cost data from on-farm experiments. Data from experiments on vegetable-tree or tree-tree combination and management practices provided inputs for further socioeconomic analysis and environmental impact analysis using the Soil and Water Assessment Tool (SWAT) computer model. The SWAT simulation results were used to quantify soil conservation and water quality benefits of alternative land uses and agroforestry management practices. Gender division of labor in agricultural activities among farm households was investigated using data from the baseline survey. A case study on gendered networks was also carried out to investigate how women made use of informal gendered networks as an alternative means of access to markets and other social, economic resources.

Figure 1: Technology research of VAF

Key findings

In the cacao-cashew complementarity study, financial analysis shows that the planting of cacao under cashew canopy increases income, in-terms of NPV per hectare, by about 159% compared to pure cashew system (Ha, et al, 2011). With a large cashew area in Binh Phuoc Province and in other provinces in the Southeast region and Central Highlands of Vietnam, there is therefore, a high potential to expand the cacao-cashew system. Adoption of this system will help improve incomes of small-scale cashew farmers.

Results from the study on vegetable-tree complementarity showed that the shading level created by the tree canopy markedly affected the growth and yield of all vegetables. Generally, the higher the light intensity, the higher the yield of vegetables during rainy season, while during dry season, the yield of most vegetables, especially the leafy ones was higher in partial shade than in the other treatments. It was observed that cashew yield increased when vegetables were planted between the trees.

The crop budgeting conducted using data from on-farm experiments showed that the yield and income from growing vegetable in farmer's home garden increased only slightly when low-cost drip system is applied compared to farmer's current irrigation practice. However in terms of resource use, drip system has significantly greater water and labor productivity in home garden vegetable cultivation. Water saving was identified by farmers as the major benefit from using a drip system, particularly in areas experiencing water shortage. To encourage farmers to adopt the drip system, support from extension services and access to the supply of drip kits are needed. The drip irrigation study on young cacao plantings showed that with drip irrigation, there was a 24 percent saving in irrigation cost and about 60 percent of total water used for young cacao planting compared with current farmers' irrigation practices (Ha, et al, 2011).

Using focus group discussions, in-depth interviews and weight scoring method, the marketing study helped in identifying the most profitable and marketable crops that create opportunities for market-driven development of existing farming systems, as well as strategies and interventions to improve small-scale farmer's market access in the study area. Furthermore, the review of policy incentives for Vegetable-Agroforestry (VAF) has revealed that in general, the policy environment is encouraging the development of VAF system but not able to fully address the complex, diverse and unique conditions of smallholders. The benefits of these policy incentives have not yet fully trickled down to the local level. The incentives provided were therefore not sufficient to stimulate smallholder investment in VAF system. Targeted policy incentives are needed if smallholders are to invest in VAF. Furthermore, the study found a need to strengthen the linkages between policymakers, researchers and educators, traders and producers towards promoting smallholders' investment in VAF.

Results from the study on the effect of cashew weed-management practices on soil quality showed that permanently maintaining grass cover and applying organic fertilizer improves soil physical properties (infiltration rate, water-holding capacity, organic carbon) and increased biological activity (respiration rate, earthworm) better than weeding through herbicide. The grass cutting and covering practice also maintained a higher concentration of essential minerals in the topsoil. The SWAT model was applied to evaluate the effects of land use on soil loss and water quality in Nghia Trung sub-watershed. Results have shown that by not weeding cashew, the average sedimentation load per ha of cashew would be reduced by about 10 percent.

The study on pesticide use on cashew cultivation was conducted to examine the impact of pesticide application on cashew yields and farmers' health. The study used the Cobb-Douglas production function analysis to examine pesticide productivity on cashew production. A health cost model was also employed to quantify the health impairments of the farmers. Results from this study showed that prophylactic use of pesticide, the common pest management method applied by cashew farmers, did not help improve cashew yield as much as it was expected. The misuse of pesticides, however, caused higher production and health costs to the farmers. The study provides an important basis for the development of policies and measures to promote sustainable pest management practices in a cashew-based production system.

The field study on gender division of labor and gendered network revealed that women farmers undertake marketing activities and seek to improve their economic status for the sake of family, especially children's welfare. Family-oriented goals rather than desire for personal empowerment motivated them to become market players and to advance in this role. The informal gender networks provided valuable links to suppliers of farm inputs or goods for trading, buyers of farm products, sources of capital or credit, and market-related information such as which products were currently in great or short supply, price fluctuations, buyers' preferences, and demand for new crops. The government and other agencies are recommended to considering informal gender networks when developing their programs in the future.

The research results indicate that integrating vegetables and/or cacao under cashew can help farmers increase their incomes. It was also found that resource conservation technologies would help farmers reduce production costs as well as protect their health and the environment. In general, there is high potential for expanding cashew-cacao-vegetable agroforestry systems, particularly the cacao-cashew system in Vietnam. However the viability of the cashew-cacao-vegetable agroforestry systems is constrained by various factors including farmers' inability to invest in the system, inadequate institutional structures for facilitating information flow and lack of market incentives. Targeted policy incentives are needed if smallholders are to invest in these agroforestry systems.

Conclusion

Agroforestry is a sustainable land-use management practice with potential environmental and socioeconomic benefits. Our study on cacao-cashew and vegetable agroforestry systems has shown that agroforestry can help improve farmers' income. The integration of vegetables or cacao under cashew together with resource conservation technologies could help farmers increase their income, protect farmers' health and reduce other environmental costs. Ultimately, there is a high potential for expanding VAF system in Vietnam.

The research highlights the need to integrate socioeconomic and ecological aspects of agroforestry systems into agroforestry research, using multidisciplinary and participatory approaches. For future agroforestry research and development efforts in Vietnam to be effective, they need to be designed in ways that take account biophysical, socioeconomic, policy and institutional aspects of agroforestry.

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Policies and mechanisms for agroforestry development in Yen Bai province, Northwest Vietnam

Vu Thi Luu

Abstract

Agroforestry practices have been adopted in different mountainous and remote areas in Vietnam, mainly for self-subsistence for the local people. In recent years, the Government has issued different policies to promote the development of agricultural and forestry production as well as agroforestry. Yen Bai is an upland province, inhabited by 30 different ethic minority groups. The provincial government has recently focused its resources on agricultural and forestry production, encouraging the adoption of many agroforestry models among local farmers, which brought about significant achievements in terms of poverty reduction and environmental protection.

Keywords: Agroforestry policies, Yen Bai province, agroforestry capacity building

Introduction

In mountainous areas, agroforestry products have become prime commodities that are processed and sold for people to earn income. However, further development of agroforestry depends on sound government policies.

In recent past, the Government of Vietnam has issued various codes, decrees and decisions regarding agriculture and forest lands, which are aimed at accelerating production in general and (directly or indirectly) promote agroforestry, in particular. Some policies particularly target pro-development investments in the uplands. Three major laws have promoted the use of land for agriculture and agroforestry namely, the Land Law (2003), Law on Protection and Development of Forest (2004) and the Law on Environmental Protection (2005). The Land Law defines the obligations of the landowner to "carry out measures to protect the land." The Law on Protection and Development of Forest also allows integrated production of agriculture, forestry and fishery in forestlands, except for special use forest, which is under forest management regulations. The Law on Environmental Protection defines responsibilities of organizations and individuals in production, business and services to protect the environment.

A typical landscape in the Northwest of Vietnam where maize is planted in rolling to steeping hills

Photo by Yasmi Yurdi

Key policies that are pro-agroforestry

- Decision No.327/HDBT of the Council of Ministers was issued on 15 September 1992. It promulgates the use of bare land, degraded hills, forest, coastal plains, and water bodies and demands the formulation of an appropriate production mechanism that facilitates the combination of forestry, agriculture, industrial, services, and commodity production. It must combine the processing industry with consumption markets within and outside Vietnam, and develop tree species and livestock breeds for intercropping.

- Decree No. 01-CP of the Government was issued on 04 January 1995. It regulates allocation of land to State-owned businesses for agricultural production, forestry and aquaculture. It clearly spells out the rights and obligations of the contracted farming households and individuals, including the following: 1) carry out production activities in allocated lands; 2) raise cattle and intercrop and be entitled to all products; 3) allocated with lands for planting perennial and annual tree crops; and 4) allocated with forest lands within targeted protection, special use and industrial forests.

- Decision No. 661/QD-TTg by the Prime Minister on Objectives, Tasks, Policies and Organization for the Establishment of Five Million Hectares of New Forest was issued on 29 July1998. It includes a variety of policies put forward to stimulate the development of agroforestry. For example, Policy on land, policy on investment and credit, policy on rights and benefits and marketing, policies on science and technology.

- Decree No.163/1999/ND-CP of the Government was issued on 16 November 1999, covering the allocation and leasing of forestlands to organizations, households and individuals for long-term forestry purposes. The State allocates forestry lands without taking fee for land use and the recipients are allowed to engage in agroforestry production.

- Decision No. 178/2001/QD-TTg of the Prime Minister issued on 12 November 2001 stipulated the benefits and obligations of households, individuals, leased or contracted forests and forest land. According to this Decision, households and individuals assigned, leased or contracted forests and forestry land by the State for forest protection, regeneration zoning off and planting are entitled to harvest secondary forest products, flowers, fruits, oil, rubber, etc. in the course of protecting and zoning off forests for regeneration under the guidance of the contracting party. Those assigned with forestry land without forests but falling under the protection forest planning are allowed to use perennial agricultural plants as major trees for planting in the protection forests or inter-cropping with perennial native forest trees according to afforestation designs approved by the provincial/municipal Agriculture and Rural Development Services. They are also entitled to enjoy 100% of the products exploited from supporting trees, inter-cropped trees and forest thinning products according to the design approved by the provincial/municipal Agriculture and Rural Development Services, and to ensure the forest coverage degree of over 0.6 after thinning. Furthermore, they are allowed to use a maximum of 20% of forestry land area without forests for agricultural production and aquaculture. Households and individuals assigned with natural forests that are subject to production forest planning are to intercrop agricultural and medicinal plants, graze cattle and exploit other resources according to regulations on production forest management.

- Decree No. 135/2005/ND-CP of the Government was issued on 08 November 2005 on contractual assignment of agricultural land, production forest and land with water surface for aquaculture in state-run agricultural and forestry farms.

- Decree No. 23/2006/ND-CP on the Implementation of the Law on Forest Protection and Development was issued on 03 March 2006.

- Decision No. 178/QD-TTg of the Prime Minister on the rights and obligations of households and individuals assigned, leased and contracted forests and forestland.

- Prime Minister's Decision No. 07/2006/QD-TTg approving the socio-economic development plan in difficult communes in ethnic minority and mountainous areas in 2006-2010. Program 135 was issued on 10 January 2006.

- MARD's Decision No.2740/QD/BNN-KL approving the project on forest allocation and lease during 2007 – 2010.

- Government's Resolution No.30a/CP on rapid and sustainable poverty reduction in 61 poverty-stricken districts was issued on 27 December 2008.

- Government Decree No. 56/2005/ND-CP on agricultural and fishery promotion stipulates that each commune, ward and communal district must have at least one agriculture and fishery promotion worker. Through the network of local-based promotion workers, advanced techniques of farming on sloping lands and of sustainable forest management have been distributed to farmers and widely adopted.

Science and technology

Research studies on agroforestry production in the uplands have focused primarily on sustainable agricultural cultivation on sloping lands, design of agroforestry models to reduce soil erosion, maintain biodiversity and protect the environment.

Furthermore, the Government has created favorable conditions for non-government organizations (NGOs) and ODAs (Overseas Development Agencies) to conduct research on sustainable agroforestry in hilly lands, such as SALT1, SALT2, SALT3 (Sloping Agricultural Land Technology) in mountainous areas.

Agroforestry projects/activities in Yen Bai province

As over 80% of land in Yen Bai is hilly and mountainous. The provincial authorities have given due attention to the development of forest economy and sustainable upland farming, considering them as pivotal to the province's socio-economic development. Since planting and preserving protection forests is important for the uplands, it is necessary to improve people's livelihoods from forest. Given the above guidelines from the provincial authorities, relevant agencies at provincial, district and commune levels have encouraged local people to create integrated production models such as:

- Forest-garden-fish pond-livestock (RVAC) model: ecologically and economically sustainable and resilient, contributing to the maintenance and protection of biodiversity, maintaining ecological balance for long-term sustainable development.

- Sustainable agroforestry farming models - SALT1, 2, 3

- Establishing intercropping models of various crops (bean, cassava, maize and vegies) with industrial tree species (acacia, Eucalyptus sp, camaldulensis Dehn.) during the establishment years.

- Intercropping food crops with Shan tea during the establishment phase of Shan tea plantation. For example, Colocasia esculenta-tea; tea-fruit trees models created by farmers provided initial economic benefits.

- Sustainable upland farming model in Van Chan, Mu Cang Chai, Tran Yen, Luc Yen, Van Yen. Slope < 30^0 : integrated model of agricultural crops fruits, tea and livestock farming; Slope >30^0: forest plants are grown to maintain humidity, soil and nutrients, and protect ecological environment.

- Some agroforestry systems adopted by farmers include the following: Bean + livestock grass intercropped with tea; Forest + Garden + terrace field; Ginger under forest canopy; Amomum tsaoko under forest canopy; and *Mangletia conifera Dandy* on tea plantations.

- Intercropping protection forest and fruit trees (Pinet + Schima wallichii + Crataegus) to cover bare hills and mountains, protect ecological environment and provide people with additional incomes.

- Research on planting medicinal plants under forest canopy (from science research funding) to provide scientific basis for expanding the model in contracted production forest area.

Pro-agroforestry policies and mechanisms in Yen Bai

The land allocation policy in Yen Bai was adopted in 1993 but was not fully implemented until 1999. By 2010, Yen Bai province has allocated over 251,197 hectares of forest and forestry land and issued 48,179 land use right certificates to enterprises, households and individuals. The province continues to implement policies on allocation and leasing of forest, invest in protection forest and provide incentives to production forest planters. It also distributes seedlings and fertilizers to farmers in support of upland farming. Over the recent past, Yen Bai province has issued several policies as follows:

- Resolution No.06-NQ/TU on 14/4/2003 on planning and developing forest hill economy (2003- 2005) with a vision towards 2010

- Decision No. 96/QD-UBND on 6/7/2001 approving the Afforestation Planning of Yen Bai province (2000 – 2010)

- Decision No.325/QD-UBND on 15/3/2007 approving the planning project of three forest types

- Decision No.339/2003/QD-UBND on 17/11/2003 on the issuance of some policies on agroforestry production (2004 – 2006)

Farmers are digging holes to plant Mulato grass in Longan-maize trial in Chieng Chan, Mai Son district, Son La province
Photo by Pham Huu Thuong ICRAF Vietnam

- Decision No. 469/QD-UBND on 04/12/2007 of Yen Bai Provincial People's Committee on issuing policies that facilitate the development of agricultural production, forestry and aquaculture (2007 – 2010)

- Resolution No.09/2008/NQ-HDND on 2/4/2008 by the Yen Bai Provincial People's council on investment and incentive policies to support agroforestry and aquaculture production in Yen Bai (2008 – 2010)

- Decision No. 21/QD-UBND on 9/5/2008 by the Yen Bai Provincial People's Committee stipulating specialized policies in support of socio-economic development in two districts of Tram Tau and Mu Cang Chai, Yen Bai (2008 – 2010)

- Decision No.09/QD-UBND on 20/5/2008 by the Yen Bai provincial People's Committee on stipulating policies on investment for and development of agricultural and forestry production, and aquaculture (2008 – 2010)

- Resolution No. 11/2012/NQ-HDND by the People's Council of Yen Bai on allocating and contracting, leasing forest in line with allocating and leasing land as well as distributing land use right certificates of forestry production land in Yen Bai (2012 – 2015)

Lessons learnt

- There is a need for coordination among local authorities and scientific research organizations, domestic and international alike, from the beginning when ideas are formed until the pilot and implementation phase. This is to reach a consensus in assessment of supportive policies and measures needed to scale up adoption of advanced techniques among local people.

- There is a need to promote cooperation with international partners to attract more technology investments.

- There is a need for a mechanism to promote the "farmer- state- scientist- enterprise" linkages in the production, processing and marketing of farm products. Especially, a favorable "legal corridor" to encourage enterprises' direct investments in production.

- The role of farmers in the production process needs to be emphasized. More training and dialogues should be held to improve farmers' involvement in designing and implementing research as well as application of technologies.

- Agroforestry models have brought economic benefits to the local people, ensuring food security for the province, particularly for poverty-stricken mountainous areas, reducing soil erosion, protecting the environment and increasing tree cover.

- Studies on agroforestry trials are a foundation for policy making and dissemination of advanced models among local people.

Rice terraces in the Northwest
Photo by ICRAF Vietnam

Recommendations

- Land use planning should be conducted at commune level. Criteria for land categorization based on land use purposes must be clarified to facilitate forest and forestland allocation.
- More studies are needed in the following areas: i) integrated techniques in agroforestry systems that are adjusted to local ecological conditions; ii) impacts of new techniques on the environment; and iii) economic benefits for smallholders in the uplands.
- Develop and expand the adoption of agroforestry models that best suit the agro-ecological areas with the involvement of local people; promote effective marketing approaches to improve livelihoods; and design appropriate pro-agroforestry policies for each area.
- Support local farmers to market their products and increase their values through advanced processing techniques. Identify potential markets and develop an effective market chain for agroforestry products.
- Open dialogues with policy makers to review current policies and promote the adoption of agroforestry models.
- Develop agroforestry extension guides.
- Create more policies that 1) support research on sustainable agroforestry techniques in sloping lands for micro ecological areas; selection and preservation of quality seeds and livestock breeds; assist experiments of improved seeds and breeds in agroforestry systems; and 2) support the development of agroforestry models, including providing seeds, breeds for livestock and aquaculture, fertilizers; training workshops for agroforestry extension workers; training workshops on agroforestry technology transfer; implementation of agroforestry models; marketing and advertising agroforestry products.

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