

Cost-benefit analysis for agroforestry systems in Vietnam

Abstract

Agroforestry has been practiced for a long time in Vietnam. There are four agroforestry systems, which have been widely established in north mountainous provinces with *Illiciumverum* + Tea (IT), *Melia azedarach* + cassava (MC), *Acacia hybrid* + cassava (AC), and *Acacia mangium* + maize (AM). In this study, cost-benefit analysis was conducted. A questionnaire was used to obtain information on (1) inputs, which included costs for seeds/seedlings, fertilizers, pesticides, and labor costs, and (2) incomes, which included benefits from selling fruits, leaves, corns, and timbers. The result indicated that IT had highest benefit (6,527 US\$ ha⁻¹ y⁻¹), followed by MC (2,905 US\$ ha⁻¹ y⁻¹), AC (1,043 US\$ ha⁻¹ y⁻¹), and AM (870 US\$ ha⁻¹ y⁻¹). Even with high benefits, such models cannot be established in all mountainous areas because each perennial tree and/or crop can only grow well in its ecological regions. In addition, instability of market and price is a big concern leading to unsustainable development of these agroforestry systems in Vietnam. It is recommended that farmers, local government, business communities, and researchers should collaborate and work together for a sustainable agroforestry development strategy in each ecological region before it is established. The strategy must include selecting suitable species, techniques on establishing, harvesting and pre-processing, market and price stability, and environment protection.

Keywords: agroforestry, benefit, market instability, mountainous areas, property reduction.

Introduction

Agroforestry is a land-use system where woody perennial plants (trees, shrubs, palms, bamboos, etc.) are deliberately cultivated on the same land-management units as agricultural crops in form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic benefits between the different components [1].

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Comment [W3]: Suggestion of keywords: *Illiciumverum*, *Melia azedarach*, cassava, *Acacia hybrid*, *Acacia mangium*, maize.

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Land degradation and crop yield decrease in tropical uplands in general and in Vietnam in particular have been recognized as the main problems arising from intensification of upland cultivation [2-5]. Using mono-cultivation of crops or forest trees in the past had led to fast reducing soil fertility through erosion; reducing cultivation time for crops to several years [6,7]. For sustainable management and development for upland areas [8], many agroforestry systems have been developed in tropical areas; aiming at sustaining food supply, increasing soil fertility, and reducing agriculture land encroachment.

Vietnam is located in the monsoon climate region with annual precipitation up to 3500 mm and complicated geography in upland areas [9]. The development of sustainable practices in the upland for food security has been undertaken in Vietnam for several decades [10, 11]. Many agroforestry systems have been undertaken in local areas based on prevailing climate conditions, the capacity of indigenous markets, etc. However due to unstable market for products, agroforestry systems have been changing to meet markets' requirements.

This work conducted cost-benefit analysis for four agroforestry systems in Northern, Vietnam and discussed challenges and opportunities for their sustainable development.

Material and method

Main agroforestry systems in Vietnam

The characteristics of main agroforestry systems are (1) easily applied by indigenous with little support from technicians, (2) able to establish in large area for massive products, (3) having stable markets, (4) ensuring sustainable benefit for indigenous, and (5) contributing to environment protection especially in terms of maintaining soil fertility. There are four main agroforestry systems (AFS) in Northern Vietnam including (1) *Illicium verum* + tea (IT), (2) *Melia azedarach* + cassava (MC), (3) *Acacia hybrid* + cassava (AC), and (4) *Acacia mangium* + maize (AM).

Tree species description

Fruits of *I. verum* are the main products and they are used to extract oil. The fruit has antibacterial, carminative, diuretic, odontalgic, stimulative, and takes care of stomachache. It is taken orally in the treatment of abdominal pain, digestive disturbances and complaints

such as lumbago. Again, the fruit is used as a flavoring in curries, teas, and pickles. It is an important ingredient of spice powder used in Chinese and Vietnamese cuisine.

Melia azedarach, *Acacia mangium*, and *Acacia hybrid* are forest trees, which are widely planted in Vietnam. *M. azedarach* is a deciduous tree species, up to 20 m tall and 40 cm in diameter at 8-10 years old. Its wood is soft, durable after traditional treatment, and widely used by indigenes for housing and furniture making. *A. mangium* and *A. hybrid* are evergreen trees, up to 15 m tall and 35 cm at 6-7 years old. Their wood is widely used for pulp in Vietnam and woodchips for exporting.

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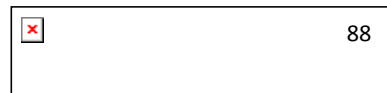
Data collection

For each AFS, we selected three representative models from three different households based on their cultivate areas, which ranges from 0.1 to 4 ha. The selected households must apply traditional techniques in establishing AFS, and sell products at local markets. A questionnaire was used to collect concerned information including (1) time when AFS was established, (2) techniques for soil preparation, planting, tending, and harvesting, (3) seed and seedling sources (producing themselves or purchasing from local companies) and prices, (4) loans and interest rates, (5) where they bought other materials as fertilizers, pesticides etc., and prices, (6) when they harvested products and price at selling, (7) what are challenges and advantages for establishing such AFS, and (8) what are their requirements for establishing such AFS in future.

Inputs for establishing AFS included costs for buying seeds, seedlings, fertilizers, pesticides, labor's cost for planting, tending, and harvesting. While, incomes from AFS included benefits from selling products as fruits, leaves, corns, and timbers. All values were in Vietnamese currency (VND), then were exchanged to US\$ with exchange rate of 20,000 VND/1 US\$ as mean rate in 2013.

Cost-benefit analysis

Cost-benefit analysis (PV) was conducted following Eq. 1.



where, $PastV_i$ is past values of input or income and t is number of years from year i to present. IR is interest rate, which was fixed to 10% following local interest rate. All data were collected in 2013.

Results

Illicium verum + tea

Illicium verum + tea is a special AFS, which can only be established in Lang Son Province, since *I. verum* is native species there. The AFS should be established in elevation < 700 above sea level and on secondary forest, where native forest tree species are still available for supporting growth of *I. verum*. A planting density of 400 trees/ha; (5 x 5 m) planting distance is most suitable for growing *I. verum*. While, planting density of tea is 20,000 trees/ha with (0.5 m x 1 m) as planting distance. *I. verum* and tea are planted at the same time. Collecting tea leaves starts in the fourth year after establishment, while collection of fruits of *I. verum* is conducted in the 12th year (Table 1).

There is no income in the first three years, resulting no benefit for growers (Table 1). While, total input in the first three years is nearly 900 US\$ ha⁻¹. Depending on the economic status of each household, if the area is less than 0.5 ha, they can afford the cost themselves. Otherwise, they can get support from local government. The fourth year income is generated from tea leaves, after subtracting inputs of the first three years with adding interest, the benefit is 4,773 US\$ ha⁻¹. From year five to year eleven, benefit is 5,920 US\$ ha⁻¹ y⁻¹. From year 12th afterward, income is added from fruits of *I. verum* leading to higher benefit as 6,527 US\$ ha⁻¹ y⁻¹ (Table 1). Obviously, tea plays a much more important role (10,312 US\$ ha⁻¹ y⁻¹) in total income compared to that from fruits of *I. verum* (762 US\$ ha⁻¹ y⁻¹). However, tea cannot yield highly without benefit from shading of *I. verum*. Therefore both are ecologically important in *I. verum* + tea AFS.

This is, so called, native AFS of Lang Son Province, since *I. verum* can only grow there. Input in the first three years is not so high (890 US\$ ha⁻¹), which poor households can afford themselves or get loans from local banks with low interest rates. There are some

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disadvantages in developing this model as: (1) fruit of *I. verum* is mainly exported to China, leading to market instability; (2) only remote areas, which are covered by secondary forest with naturally regenerated native species available, are suitable for establishing, leading to access difficulty. These two main barriers restrict the extension of *I. verum* + tea AFS in Lang Son Province.

***Melia azedarach* + cassava**

Melia azedarach + cassava can be established in most mountainous provinces in Northern Vietnam, because both *M. azedarach* and cassava can grow well and there is a wide market for cassava in that ecological zone. The AFS should be established on elevation below 500 m above sea level in less than 10° sloping areas. *M. azedarach* is planted in a density of 1,660 trees/ha in a (3 m x 2 m) planting distance using seedlings produced locally (Fig. 2). Between two rows of *M. azedarach*, three lines of cassava are planted in the spacing of 1 m x 0.5 m by using hybrid cassava. Both species are planted at the same time.

With a rotation of seven years for *M. azedarach* and mixing cassava in the first three years, the AFS has income in four years of a 7-year rotation (Table 2). In the first three years, even incomes cannot compensate the input, however such kind of model can sustain livelihood of indigenous people from cassava's income. Regular income has become first priority for indigenous people when selecting AFS. Average annual benefit of this model is 2,905 US\$ ha⁻¹ y⁻¹ (Table 2).

Cassava is the main agricultural product of mountainous areas in Vietnam, which is widely used by the food industry for animal feed production as well as ethanol. However, the market is not stable because of instability of animal husbandry. In addition, recently housing is made concretely other than using traditional style from wood even for remote areas, leading to narrowing wood market for *M. azedarach*.

***Acacia hybrid* + cassava**

Acacia hybrid + cassava is widely established in upland areas of North Vietnam, since *A. hybrid* grows well there and the timber market is available. The most suitable site is below 500 m above sea level with slope of less than 15°. *A. hybrid* is planted in a density of 1,660 trees/ha (3 m x 2 m) from cuttings produced locally (Fig. 3). Cassava is grown in the first

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and second years in a density of 3,330 stumps per ha (1.5 m x 2 m) for harvesting in the second and third years. The rotation for this model is seven years.

With a rotation of seven years, income is generated in three years. Cassava is planted in the first and second years and is harvested in the second (1,714 US\$ ha⁻¹) and third (1,714 US\$ ha⁻¹) years (Table 3). While, *A. hybrid* is logged in 7th year (6,000 US\$ ha⁻¹). Total benefit of this AFS is 7,298 US\$ ha⁻¹ (annual benefit of 1,043 US\$ ha⁻¹ y⁻¹).

Beside the limitation of market for cassava as mentioned above, difficulty for selling wood products of *A. hybrid* is a big concern for most mountainous areas planting Acacia. Generally, this AFS system is established by indigenes themselves, which is in remote areas with difficult access. Transporting logged timbers is usually conducted by traditional manner as using buffalos and human labor. In addition, the market is not stable because of no contract for selling product between growers and companies. These are the main concerns for extending *Acacia hybrid* + cassava AFS.

Acacia mangium + maize

Acacia mangium + maize is widely established in upland areas of the north central regions, since *A. mangium* grows well there and the timber market is available. The most suitable site is below 200 m above sea level with slope of less than 15°. *A. mangium* is planted in a density of 1,660 trees/ha (3 m x 2 m) from seedlings produced locally (Fig. 4). Maize is sown in the first two years in two seasons per year (spring and autumn) with a density of 14 kg seeds per ha. The rotation for this model is six years.

Incomes are generated in three years of a 6-year rotation (Table 4). Since *A. mangium* is still small and no competition occurs between *A. mangium* and maize in the first year, it leads to high productivity and income from maize (1,667 US\$ ha⁻¹) compared to that (405 US\$ ha⁻¹) in the second year (Table 4). Maize contributes 24% to total income and average benefit of this model is 870 US\$ ha⁻¹ y⁻¹.

Maize is widely used by food industry for animal feed and the market is generally stable for this product. However, market for timber of *A. mangium* is not stable the same as mentioned above for *A. hybrid* wood.

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Discussion

The prerequisites for the success of establishing or venturing into agroforestry are stability of market and price of products; the challenge however, is that these agroforestry systems are often established and expanded through farmers' own efforts without directive or government support, leading to no clear market strategy for agroforestry products (Nguyen, 2013). During the establishment, the price of products is high, but usually decreases as a result of oversupply, and also because farmers do not have marketing contracts with buyers. In some cases, farmers are not able to sell their products, which led them to abandon or shift their practices. Clearly, agroforestry investment is constrained by lack of stable markets. This issue calls for three important actions by local governments as follows: (i) mediating between farmers and companies/exporters to develop a clear marketing strategy or agreement; (ii) facilitating planning with farmers as to the areas that can be legally planted to or converted to agroforestry; and (iii) providing technical and financial support to farmers (Hoang et al., 2014).

Ecologically, not all agroforestry systems can be established throughout Vietnam since each species is adapted only in particular ecological region. But even where one agroforestry system is ecologically suitable to a particular region, farmers' ability to finance, as well as availability and stability of markets are crucially important considerations. However, farmers spontaneously adopt agroforestry once its benefit is known even if it is outside of their ecological region. Often, this creates not only technological but also marketing problems, which ultimately lead to failure of the investment. This issue could be avoided or addressed by a clear agroforestry strategy that can be developed through the collaboration amongst farmers, researchers, business communities and the local government.

An important aspect that needs consideration is the low educational level of ethnic minorities who form the majority of agroforestry. Many ethnic minority people are illiterate and very poor, making it difficult for them to access extension services. Support for capacity building and financing support from local governments is essential; such support would include long and short-term loans with low interest rate (Nguyen and Tran, 2013).

Increasing the value of products with pre-processing and packing technologies is potentially beneficial than directly selling raw/fresh products, which is currently commonly practiced. For example, tea leaves are usually sold fresh from the garden, whilst the main product of tea, which is packed-dry leaves would increase the value to more than 90%. Traditional

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drying method is still widely used by ethnic minorities on small-scale, leading to lower economic returns.

Conclusion

There are four agroforestry systems, which have been widely established in Northern, Vietnam. With their components of crop and tree, each agroforestry system can only be established in the particular ecological region. *Illicium verum* + Tea had highest benefit (6,527 US\$ ha⁻¹ y⁻¹), followed by *Melia azedarach* + cassava (2,905 US\$ ha⁻¹ y⁻¹), *Acacia hybrid* + cassava (1,043 US\$ ha⁻¹ y⁻¹), and the lowest benefit belonged to *Acacia mangium* + maize (870 US\$ ha⁻¹ y⁻¹). The most challenging for enlarging such agroforestry systems in their particular ecological regions is instability of markets and prices for their products. Such challenging can only be solved by a collaboration and agreement among farmers, researchers, business communities, and local government.

Acknowledgements

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273 **Table 1.** Cost-benefit analysis for *Illiciumverum* +tea AFS (US\$ ha⁻¹).

Year	Input	Income	Benefit
1	676		
2	107		
3	107		
4	4,393	10,312	4,773
^a 5 ÷ 11	4,393	10,312	5,920
^b 12 ≈	4,548	11,074	6,527

274 **Inputs include costs of labor**, seedlings, fertilizer. Income is from selling products as tea
 275 leaves and fruits of *I. verum*. ^afrom 5th year to 11th year, ^bfrom 12th year afterward.

276

277 **Table 2.** Cost-benefit analysis for *Melia azedarach* +cassava AFS (US\$ ha⁻¹).

Year	Input	Income	Benefit
1	1,380	655	
2	930	524	
3	740	393	
4	40		
5	40		
6	40		
7	240	21,316	21,076
Net Present Value			20,332

278 **Inputs include costs of labor**, seedlings, fertilizer. Income is from selling products.

279

280 **Table 3.** Cost-benefit analysis for *Acacia hybrid* + cassava AFS (US\$ ha⁻¹).

Year	Input	Income	Benefit
1	1,024		
2	966	1,714	148
3	707	1,714	1,007

4	50		
5	50		
6	50		
7	50	6,000	5,550
Net Present Value			7,298

281 **Inputs include costs of labor**, seedlings, fertilizer. Income is from selling products.

282 **Table 4.** Cost-benefit analysis for *Acacia mangium* + maize AFS (US\$ ha⁻¹).

Year	Input	Income	Benefit
1	1,642	1,667	15
2	731	405	
3	446		
4	33		
5	33		
6	571	6,429	5,858
Net Present Value			5,224

283 **Inputs include costs of labor**, seedlings, fertilizer. Income is from selling products.

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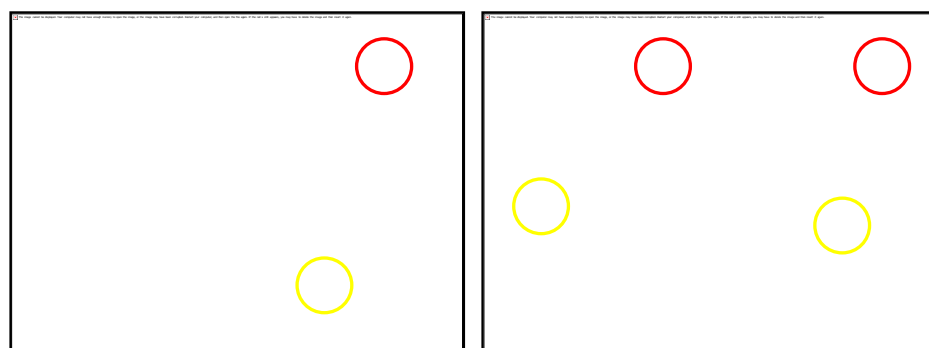


Fig. 1. *Illicium verum* + tea agroforestry system. Yellow circles indicate teas and red circles indicate *I. verum* trees.

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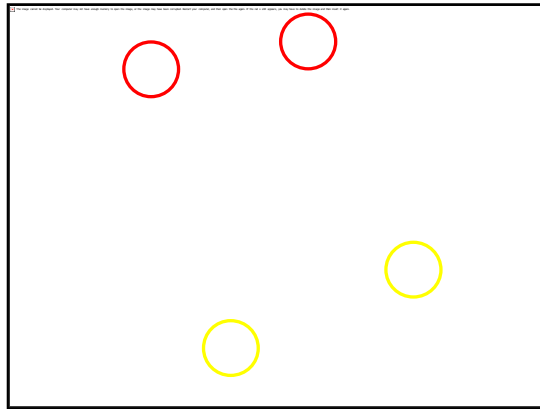


Fig. 2. *Melia azedarach* + cassava agroforestry system. Yellow circles indicate cassavas and red circles indicate *M. azedarach* trees.

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Fig. 3. *Acacia hybrid* + cassava agroforestry system. Yellow circles indicate cassavas and red circles indicate *A. hybrid* trees.

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Fig. 4. *Acacia mangium* + maize agroforestry system. Yellow circles indicate maize and red circles indicate *A. mangium* trees.