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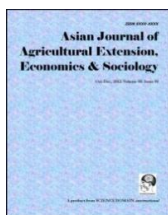
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Cost-Benefit Analysis for Agroforestry Systems in Vietnam

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Authors' contributions

This work was carried out in collaboration among all authors. Author HVT conducted data collection.

Authors TVD and OK performed the statistical analysis and wrote the manuscript. Author DCC managed the literature searches and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Agroforestry has been practiced for a long time in Vietnam. In this study, the cost-benefit was analyzed in four agroforestry systems, which have been widely established in north mountainous provinces with Star Anise (*Illicium verum*) + tea (IT), bead tree (*Melia azedarach*) + cassava (MC), *Acacia hybrid* + cassava (AC) and *Acacia mangium* + maize (AM). 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 results indicated that IT had the highest economic 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), respectively. However, even with such economic benefits, these agroforestry models could not be established across all mountainous regions because of site specific ecological requirements of tree species and crops. In addition, unstable market and fluctuating price of agroforestry products is a big concern leading to unsustainability of these agroforestry systems. It is recommended that

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farmers, the local government, business sector, researchers and other relevant sectors, collaborate and work together in developing an agroforestry development strategy for the northern mountainous region of Vietnam. Such a strategy must include selecting suitable species, employing improved management techniques, harvesting and processing techniques, financing, market and price security and environment protection.

Keywords: *Acacia mangium*; cassava; *Illicium verum*; maize; *Melia azedarach*.

1. INTRODUCTION

Agroforestry is a land-use system where woody perennial plants (trees, shrubs, palms, bamboos, etc.) are deliberately used 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 economical interactions between the different components [1]. Land degradation and declining crop yields in tropical uplands in general, and in Vietnam in particular, have been recognized as key issues arising from intensification of upland cultivation [2-5]. Mono-culture systems have led to rapid soil fertility decline through erosion, reduced cultivation time for crops to several years [6,7] and in one to two rotations in the case of Eucalyptus plantation. To sustainably manage the vast rural uplands in the tropics [8], various agroforestry systems have been introduced.

The Vietnam is located in the monsoon climate region with an annual precipitation of up to 3,500 mm. Upland areas have a very complicated geography characterized by rugged terrain, steep hills and rocky mountains [9]. Programs promoting sustainable land use practices in the uplands to achieve food security have been carried out for several decades [10,11]. A range of agroforestry practices have been adopted based on local agro-climatic conditions, capacity of local people and market availability, among others. However, due to unstable market for products, agroforestry systems and practices have been changed and/or adjusted to meet market requirements and some of them have expanded overtime. This work conducted cost-benefit analysis for four agroforestry systems in Northern, Vietnam and discussed challenges and opportunities for their sustainable development.

2. MATERIALS AND METHODS

We evaluated four agroforestry systems (AFS) in North Vietnam: (1) Star Anise (*Illicium verum*) + tea (IT), (2) Bead tree (*Melia azedarach*) +

cassava (MC), (3) *Acacia hybrid* + cassava (AC), and (4) *Acacia mangium* + maize (AM).

2.1 Tree Species Description

Star Anise (Illicium verum) is a native species of Lang Son province. Its fruits are main products and used to extract oil. The fruits has antibacterial, carminative, diuretic, odontalgic stimulant, and stomachic properties and usage. It is taken internally in the treatment of abdominal pain, digestive disturbances and complaints such as lumbago. The fruit is used as a flavoring in curries, teas, and pickles. It is an ingredient of spice powder used in Chinese and Vietnamese cuisines.

Bead tree (*Melia azedarach*), *Acacia mangium*, and *Acacia hybrid* are forest trees, which are widely planted in Vietnam. *M. azedarach* is a deciduous tree species, grows up to 20 m tall and 40 cm in diameter at 8-10 years old. It is softwood that becomes durable after traditional treatment, and widely used by local people for housing and furniture making. *A. mangium* and *A. hybrid* are evergreen trees growing up to 15 m tall and 35 cm diameter at 6-7 years old. Their wood is widely used for pulp in Vietnam and chips for exporting.

2.2 Description of Agroforestry Systems

Illicium verum + tea is a special agroforestry system, which can only be established in Lang Son province, since *I. verum* is a native species in the area. The system can be found in areas under 700 m above sea level and in secondary forests, where native forest tree species are still available for supporting the growth of *I. verum*. A planting density of 400 trees/ha; (5 m x 5 m) is most suitable for growing *I. verum*. The density of tea is 20,000 trees/ha spaced at 0.5 m x 1 m (Fig. 1). *I. verum* and tea are planted at the same time. Collecting tea leaves starts during the fourth year after establishment, while the first fruit collection of *I. verum* comes around the 12th year (Table 1).



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

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

Year	Input	Income	Benefit
1	676		
2	107		
3	107		
4	4,393	10,312	4,773
a5 ÷ 11	4,393	10,312	5,920
b12 ≈	4,548	11,074	6,527

Inputs include costs of labor, seedlings, fertilizer.

Income is from selling products as tea leaves and fruits of *I. verum*.^afrom 5th year to 11th year, ^bfrom 12th year onward

Melia azedarach +cassava can be established in most mountainous provinces in Northern Vietnam, because both *M. azedarach* and cassava are widely adopted in the area and the market for cassava is quite stable. The system is established in areas with elevations up to 500 m above sea level, and on less than 10° sloping lands. *M. azedarach* is planted at 3 m x 2 m spacing and have a density of 1,660 trees/ha from seedlings produced locally (Fig. 2). Three rows of cassava are planted at 1 m x 0.5 m spacing on every two rows of *M. azedarach*. Cassava is planted at the same time with the *M. azedarach* and replanted in the second and third years.

Acacia hybrid + cassava are widely adopted in the upland areas of Northern Vietnam since *A. hybrid* is well adopted and the wood market is available. The most suitable site for this system is below 500 m above sea level with slopes less than 15°. The rotation for the system is seven years. *A. hybrid* is planted at a density of 1,660 trees/ha with planting distance of (3 m x 2 m) from cuttings produced locally (Fig. 3). Cassava

is planted in the first and second years with a density of 3,330 stumps per hectare with a planting distance of (1.5 m x 2 m) and can be harvested in the second and third years.

Acacia mangium + maize is widely adopted in the uplands of north- central region of Vietnam since *A. mangium* is well adopted and the wood market is equally available. The most suitable site is below 200 m above sea level with slopes less than 15°. *A. mangium* is planted with a density of 1,660 trees/ha with a planting distance of (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 of seeds per hectare. The rotation for this model is six years.

2.3 Data Collection

The data sets were collected in 4 provinces in Northern Vietnam including Lang Son for *Illicium verum* + tea at 21°59'N, 106°23'E; Tuyen Quang for *Melia azedarach* + cassava at 22°22'N, 105°25'E; Bac Giang for *Acacia hybrid* + cassava at 106°36'N, 21°18'E; and Thanh Hoa for *Acacia mangium* + maize at 20°05'N, 105°45'E. Data collection was conducted as following. First, officers of Provincial Department of Forestry were interviewed to identify which system was the best AFS in that province in terms of high and stable income, market and price stability, easy application and environmental protection. Second, four best households based on the officer's records were invited for field interviews and survey. Generally, interviewed households must have applied traditional techniques in establishing AFS, and had sold their products at local markets. In four provinces (Lang Son,

Tuyen Quang, BacGiang, and ThanhHoa), 16 households (four households for each province) were interviewed and surveyed. A questionnaire was used to collect concerned information including (1) Establishing time, (2) Techniques for soil preparation, planting, tending, and harvesting, (3) Seed and seedling sources and prices, (4) Loans and interest rates, (5) Price of fertilizers, pesticides etc., (6) Harvesting time and price of products at selling, (7) Challenges and advantages for establishing, and (8) Requirements for establishing such AFS in the future.

2.4 Cost-Benefit Analysis

Inputs for establishing AFS included costs for buying seeds, seedlings, fertilizers, pesticides, labor costs for planting, tending, and harvesting. While, incomes from AFS included benefits from selling products as fruits, leaves, corns, and timber products. All values were measured in Vietnamese currency (VND), then were converted to the United States dollar (US\$) at the exchange rate of 20,000 VND: 1US\$ as mean rate in 2013.

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

$$PV = \sum_{i=1}^t \text{Past}V_i * (1 + IR_i)^t \quad (1)$$

where, Past V_i is past values of input or income and t is number of years from year 1 to present. IR is interest rate, which was fixed to 10% following local interest rate. All data were collected in 2013.



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

3. RESULTS

3.1 *Illicium verum* + Tea

The establishment and maintenance of the system in the first three years is nearly 900 US\$ ha^{-1} , and there is no income yet, during this period (Table 1). Depending on the economic status of the household and if the area being developed is only half or less than a hectare, farmers usually spend their own funds. Otherwise, they access financial support from the local government. In the fourth year, income from tea leaves is generated. After subtracting the establishment and maintenance cost during the first three years plus bank interest (if loaned), the net benefit to farmers from this system is 4,773 US\$ ha^{-1} . From year five to eleven, the economic benefit increases by up to 5,920 US\$ $\text{ha}^{-1} \text{y}^{-1}$. From year 12th onward, income from fruits of *I. verum* is generated, resulting in further increased income by as much as 6,527 US\$ $\text{ha}^{-1} \text{y}^{-1}$ (Table 1). Obviously, tea leaves play a much more important role (10,312 US\$ $\text{ha}^{-1} \text{y}^{-1}$) in the total income compared to the fruits of *I. verum* (762 US\$ $\text{ha}^{-1} \text{y}^{-1}$). However, tea yields are influenced by the shading effect of *I. verum*. Therefore, both components are benefiting from each other.

As mentioned above, this system is special since *I. verum* can only grow in Lang Son Province. However, even with lower establishment and maintenance cost in the first three years (890 US\$ ha^{-1}) and poor households can self-finance or access low-interest bank loans to establish the system, expansion of the system is hindered by two main reasons. First, *I. verum* fruits are mainly exported to China where the price is controlled and manipulated by Chinese business and middle men. This creates uncertainty of the market and price instability of the tree product. Second, the system can only be established in remote secondary forests with naturally regenerated native species, creating difficulties in accessing the fruits.

3.2 *Melia azedarach* + Cassava

The rotation of *M. azedarach* is seven years, providing income to farmers in fourth years, of which the first three years is from cassava (Table 2). The investment cost of the system could not be recovered by the income from cassava in the first initial 3 years, but it provides annual cash flow for farmers, which is an

important criterion for farmers when selecting a suitable agroforestry system. For seven years, the average annual income from this system is 2,905 US\$ ha⁻¹ y⁻¹ (Table 2).

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

Year	Input	Income	Benefit
1	1,380		
2	930		
3	740		
4	40		
5	40		
6	40		
7	240	21,316	21,076
Net present value			20,332

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

Cassava is the main agricultural product in the northern mountainous region of Vietnam. It is marketed and processed for animal feed, flour and other food items, as well as ethanol. However, the market is not stable because of instability of the livestock industry in Vietnam. As far as the timber from *M. azedarach* is concerned, the market has also declined as a result of the recent shift to using cement and concrete materials for housing construction.

3.3 *Acacia hybrid* + Cassava

With a rotation of seven years, income from cassava is therefore generated in the second and third years. The incomes from cassava are 1,714 US\$ ha⁻¹ in the second year and 1,714 US\$ ha⁻¹ in the third year (Table 3); whilst *A. hybrid* is logged in the 7th year (6,000 US\$ ha⁻¹). The total economic benefit from this system is 7,298 US\$ ha⁻¹ with annual average income of 1,043 US\$ ha⁻¹ y⁻¹.

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

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

Beside the market limitation of cassava as mentioned above, difficulty in selling timber from *A. hybrid* is a big concern to most farmers due to poor access to markets. Timber is usually transported by animal-drawn carts or by farmers themselves, making it laborious and physically demanding. In addition, the market is insecure because there is no contract created between farmers and timber companies. These are the main concerns for extending *Acacia hybrid* + cassava system in the area.

3.4 *Acacia mangium* + Maize

Incomes are generated in the first two years of the 6-year rotation (Table 4). Since *A. mangium* is still small and no competition occurred between *A. mangium* and maize in the first two years, the yield and income from maize amounts to 1,667 US\$ ha⁻¹ in the first year; however, it decreases to 405 US\$ ha⁻¹ in the second year (Table 4). Maize contributes 24% of the total income from the system. The average economic benefit of this model is 870 US\$ ha⁻¹ y⁻¹. Maize is widely used by the food and animal feed industry, and the market is generally stable. Similar to *A. hybrid*, the market for wood of *A. mangium* is unstable.

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		5,858
Net present value			5,224

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

4. DISCUSSION

Comparing it to the benefit of rice + cinnamon AFS as 1,800 US\$ ha⁻¹ y⁻¹ [12], the annual benefit of *A. hybrid* + cassava AFS and *A. mangium* + maize AFS in the present study is lower. However, rice + cinnamon AFS is native to Yen Bai and Lao Cai Provinces and the price for bark of cinnamon is not stable recently, leading to narrowing area of this AFS in Northern, Vietnam. In addition, it is clearly shown that any AFS applied in Vietnam has benefit much higher than that from rice + Swidden system, which has benefit of less than 500 US\$ ha⁻¹ y⁻¹ and

accompanied with soil erosion and environmental problems [12]. Meanwhile, the AFS of intercropping among coffee, pepper, durian, areca, and other fruits has much higher benefit of up to 17,000 US\$ ha⁻¹ y⁻¹. However, this AFS is native to Central Highland Vietnam, where coffee grows well and yields highly [13]. Therefore, it cannot be established in Northern provinces for higher benefit compared to the four studied AFSs in the present study. Other AFSs (e.g. forest trees + fruit trees + crops, forest trees + fruit trees, forest trees + crops) are native to Thua Thien Hue Province, Central Vietnam, and have benefits ranging from 1,500 to 2,500 US\$ ha⁻¹ y⁻¹ [14], which is higher than that of *A. hybrid*+cassava and *A. mangium* + maize, but lower than that of *M. azedarach* +cassava and *I. verum* + tea in the present study.

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 [15]. 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 [16].



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



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

Ecologically, not all agroforestry systems can be established throughout Vietnam since each species is adapted only in particular ecological region. Even though, 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 benefits are known, even if the system 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 illiterates and very poor, making it difficult for them to access extension services. Support for capacity building and financial support from local governments is essential; such support should include long and short-term loans with low interest rates [17]. Increasing the value of products with pre-processing and packing technologies are more potentially beneficial than directly selling the raw/fresh products, which is currently the common practice. For example, tea leaves are usually sold fresh from the garden, whilst the main product of tea, which is packed-dried leaves, would increase the value to more than 90%. Traditional drying method is still widely used by ethnic minorities on small-scales, leading to lower economic returns.

5. CONCLUSION

Cost-benefit analysis was conducted for four main agroforestry systems in Vietnam. Star Anise (*Illicium verum*) + Tea has highest benefit of 6,527 US\$ ha⁻¹ y⁻¹, followed by bead tree (*Melia azedarach*) + cassava of 2,905 US\$ ha⁻¹ y⁻¹, *Acacia hybrid* + cassava of 1,043 US\$ ha⁻¹ y⁻¹, and *Acacia mangium* + maize of 870 US\$ ha⁻¹ y⁻¹. Each agroforestry system is only suitable to establish in its ecological region, since each species cannot grow well outside its ecological region. Unstable market leads to unsustainability of these agroforestry systems. Therefore, it is recommended that farmers, the local government, business sector, and researchers collaborate and work together in developing an

agroforestry development strategy before establishment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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