

1 Main agroforestry systems and their contribution to property 2 reduction in mountainous areas, Vietnam

3 4 Abstract

5 Agroforestry is a land-use system where both woody perennial trees and crops are grown on
6 the same land-management units. Agroforestry is known as one of the best land-use systems
7 in tropical region to sustain livelihood of local people and reduce soil erosion. In Vietnam,
8 agroforestry has been practiced for a long history and contributed to property reduction in
9 mountainous areas. Depending on ecological regions and local markets there are four main
10 agroforestry systems, which have been widely established in north mountainous provinces
11 of Vietnam as *Illiciumverum* + Tea (IT), *Melia azedarach* + cassava (MC), *Acacia hybrid* +
12 cassava (AC), and *Acacia mangium* + maize (AM). Cost-benefit analysis indicated that IT
13 has highest benefit (6,527 US\$ ha⁻¹ y⁻¹), following MC (2,905 US\$ ha⁻¹ y⁻¹), AC (1,043
14 US\$ ha⁻¹ y⁻¹), and AM (870 US\$ ha⁻¹ y⁻¹). Even high benefit, such models cannot be
15 established in all mountainous areas because each perennial tree and/or crop can only grow
16 well in its ecological regions. In addition, instability of market and price is a big concern
17 leading to unsustainable development of these agroforestry systems in Vietnam. It is
18 recommended that farmer, local government, businessman, and researcher should
19 collaborate and work together for a sustainable agroforestry development strategy in each
20 ecological region before it is established. The strategy must include selecting suitable
21 species, techniques on establishing, harvesting and pre-processing, market and price
22 stability, and environment protection.

23 **Keywords:** agroforestry, benefit, market instability, mountainous areas, property reduction

24 25 Introduction

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

30 Land degradation and crop yield decrease in tropical uplands in general and in Vietnam
31 have been recognized as the main problems arising from intensification of upland
32 cultivation[2-5]. Using mono-cultivation of crop or forest tree in the past had led to fast
33 reduce of soil fertility through erosion; reducing cultivation time for crops to several years
34 [6,7] or to 1-2 rotations for Eucalyptus plantation. For sustainable management and
35 development for upland areas [8], many agroforestry systems have been developed in
36 tropical area; aiming at sustaining food supply, remaining soil fertility, and reducing
37 agriculture land encroachment.

38 Vietnam is located in monsoon climate region with annual precipitation up to 3500 mm and
39 complicated geography in upland areas [9]. The development of sustainable use practices in
40 the upland for food security has been carried out in Vietnam for several decades [10, 11].
41 Many agroforestry systems have been applied in local areas basing on climate conditions,
42 capacity of local people, markets, etc. Because of unstable market for products, agroforestry
43 systems have been changing to meet markets' requirements. However, there are several
44 agroforestry systems which have been growing overtime. These are identified as main
45 agroforestry systems. The characteristics of main agroforestry systems are (1) easily applied
46 by local people with litter support from technicians, (2) able to establish in large area for
47 massive products, (3) having stable markets, (4) ensuring sustainable benefit for local
48 people, and (5) contributing to environment protection especially in term of maintaining soil
49 fertility.

50 This work described main agroforestry systems in North Vietnam, conducted cost-benefit
51 analysis, and discussed challenges and opportunities for sustainable development.

52

53 **Main agroforestry systems in North, Vietnam**

54 There are four main agroforestry systems (AFS) in North Vietnam including
55 (1)*Illiciumverum* + tea (IT), (2) *Melia azedarach* + cassava (MC), (3) *Acacia hybrid* +
56 cassava (AC), and (4)*Acacia mangium* + maize (AM).

57

58 ***Tree species description***

59 *I. verum* is a native species of Lang Son province. Fruits are main product and used to

extract oil. The fruit is antibacterial, carminative, diuretic, odontalgic, stimulant, and stomachic. 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 cuisine.

M. azedarach, *A. mangium*, and *A. 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 local people 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 chips for exporting.

Data collection and cost-benefit analysis

Field survey was conducted to collect data for cost-benefit analysis. Three representative models for each AFS were selected based on areas which ranged from 0.1 to 4 ha. These models applied local techniques in establishing, and sold products at local. Collected data included techniques for establishing AFS, total cost (e.g. seeds, seedlings, fertilizers, labor's cost), productivity (e.g. fruits, leaves, corns, and wood), and price at local markets. Interest rate (IR) of 10% was used for cost-benefit analysis in Eq. 1.

$$PV = \sum_{i=1}^t \frac{PastV_i}{(1 + IR_i)^t} \quad (1)$$

where, V_i is past values of input or income and t is number of years from year i to present. All data were collected in 2013.

***Illicium verum* + tea**

I. 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 a.s.l 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) is most suitable for growing *I. verum*. While, density of tea is 20,000 trees/ha (0.5 m x 1 m; Fig. 1). *I. verum* and tea are planted at

88 the same time. Collecting tea leaves starts in the fourth year after establishment, while the
89 first collecting fruits of *I. verum* conducted in the 12th year (Table 1).

90 There is no income in the first three years, resulting no benefit for growers (Table 1). While,
91 total input in the first three years is nearly 900 US\$ ha⁻¹. Depending on economic status of
92 each household, if the area is less than 0.5 ha they can afford themselves. Otherwise, they
93 can get support from local government. In the fourth year income is generated from tea
94 leaves, after subtracting inputs of the first three years with adding interest, the benefit is
95 4,773 US\$ ha⁻¹. From year five to year eleven, benefit is 5,920 US\$ ha⁻¹ y⁻¹. From year
96 12th afterward, income is added from fruits of *I. verum* leading to higher benefit as 6,527
97 US\$ ha⁻¹ y⁻¹ (Table 1). Obviously, tea plays a much more important role (10,312 US\$ ha⁻¹
98 y⁻¹) in total income compared to that from fruits of *I. verum* (762 US\$ ha⁻¹ y⁻¹). However,
99 tea cannot yield highly without shading of *I. verum*. Therefore both are ecologically
100 important in *I. verum* +tea AFS.

101 This is, so called, native AFS of Lang Son province, since *I. verum* can only grow there.
102 Even input in the first three years is not so high (890 US\$ ha⁻¹), which poor households can
103 afford themselves or get loans from local banks with low interest rate. There are some
104 disadvantages in developing this model as: firstly fruit of *I. verum* is mainly exported to
105 China, leading to market instability; secondly only remote areas, which are covered by
106 secondary forests with naturally regenerated native species available, are suitable for
107 establishing, leading to access difficulty. These two main barriers restrict the extension of
108 *I. verum* +tea AFS in Lang Son province.

109

110 ***Melia azedarach* + cassava**

111 *M. azedarach* +cassava can be established in most mountainous provinces in North Vietnam,
112 because both *M. azedarach* and cassava can grow and there is a wide market for cassava.
113 The AFS should be established on elevation below 500 m a.s.l in less than 10° slopping
114 areas. *M. azedarach* is planted in a density of 1,660 trees/ha (3 m x 2 m) from seedlings
115 produced locally (Fig. 2). Between two lines of *M. azedarach*, three lines of cassava are
116 planted in spacing of 1 m x 0.5 m by using hybrid cassava. Both species are planted at the
117 same time.

118 With a rotation of seven years for *M. azedarach* and mixing cassava in the first three years,

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

124 Cassava is main agricultural product of mountainous areas in Vietnam, which is widely used
125 for food industry for animal husbandry and some is used for ethanol making. However, the
126 market is not stable because of instability of animal husbandry. In addition, recently housing
127 is made concretely using cement and ceramic other than using traditional style from wood
128 even for remote areas, leading to narrowing wood market for *M. azedarach*.

129

130 *Acacia hybrid + cassava*

131 *A. hybrid + cassava* is widely established in upland areas of North Vietnam, since *A. hybrid*
132 is growing well there and wood market is available. The most suitable site is below 500 m
133 a.s.l with slope of less than 15°. *A. hybrid* is planted in a density of 1,660 trees/ha (3 m x 2
134 m) from cuttings produced locally (Fig. 3). Cassava is grown in the first and second years in
135 a density of 3,330 stumps per ha (1.5 m x 2 m) for harvesting in the second and third years.
136 The rotation for this model is seven years.

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

141 Beside the limitation of market for cassava as mentioned above, difficulty for selling wood
142 of *A. hybrid* is a big concern for most mountainous areas planting *Acacia*. Generally, this
143 AFS system is established by local people themselves, which is in remote areas with
144 difficult access. Transporting logged timbers is usually conducted by traditional manner as
145 using buffalos and human. In addition, the market is instability because of no contract for
146 selling product between growers and companies. These are the main concerns for extending
147 *Acacia hybrid + cassava* AFS.

148

149 *Acacia mangium* + maize

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

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

161 Maize is widely used for food industry for animal husbandry and market is generally stable
162 for this product. However, market for wood of *A. mangium* is unstable the same as
163 mentioned above for *A. hybrid* wood.

164 Discussion

165 The prerequisites for the success of establishing any AFSs are stability of market and price
166 of products. Such two points must be carefully considered. Establishing and extending the
167 agroforestry systems in North Vietnam have generally been conducted by households
168 themselves other than decision of government, leading to no clear strategy for market [12].
169 At the time of establishing, the price of products is high. When all households harvest the
170 same products without any clear contracts for their product leading to low price and even
171 not being able to sell product. Such issues have been usually happening, then agroforestry
172 systems are abandoned or even cleared for other purposes. It is recommended that before
173 establishing any AFS, local government must firstly establish stable market for products by
174 making contracts with local processing companies and exporters, secondly make a clear
175 plan where people are allowed to establish AFSs, and thirdly support growers technically
176 and financially [13].

177 Ecologically, not all AFSs can be established in a region, since each species can only grow
178 well in its ecological region. Even in its ecological region, AFSs should not be established if
179 there is no market for products or access difficulty. However, such points are usually

180 ignored by local people when they recognize there is a high benefit of any AFS outside of
181 their ecological region. Then, such model will be established by themselves without any
182 ecology and market availability considerations. This can only be controlled by a clear
183 strategy for AFS development from collaboration among farmer, researcher, businessman,
184 and local government.

185 AFSs are usually established by ethnic people, who are in low educational level or even
186 illiterate, leading to difficulties of technical extension. On-job training courses are the best
187 way to train and guide them in establishing their own AFSs. In addition, ethnic people are
188 the poorest of the poor, who cannot afford themselves to establish AFSs. Financial support
189 from local government is required by long-term and short-term loans with low interest rate
190 [14].

191 Increasing value of products by applying new technology in pre-processing and packing
192 should be conducted at local other than selling raw/fresh products which have been widely
193 applied recently. For example, tea leaves are usually sold freshly in the garden. While, main
194 product of tea is packed-dry leaves, which increases the value more than 90%. Generally,
195 traditional drying method has been widely applied, however it can only be applied in
196 small-scale, leading to low benefit.

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235 **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

236 Input is used for labor, seedlings, fertilizer. Income is from selling products as tea leaves
 237 and fruits of *I. verum*. ^afrom 5th year to 11th year, ^bfrom 12th year afterward.

238

239 **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
<i>Net Present Value</i>			20,332

240 Input is used for labor, seedlings, fertilizer. Income is from selling products.

241

242 **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
<i>Net Present Value</i>			7,298

243 Input is used for labor, seedlings, fertilizer. Income is from selling products.

244 **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
<i>Net Present Value</i>			5,224

245 Input is used for labor, seedlings, fertilizer. Income is from selling products.

246



Fig. 1. *Illiciumverum* +teaagroforestry system. Yellow circles indicate teas and red circles indicate *I. verum* trees.

247



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

248



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

249



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

250