Portfolio of Climate-Smart Agriculture Practices

No. 5 - 9

DCC
Department of Climate change

SIPA | SUPPORT TO VIET NAM FOR THE IMPLEMENTATION OF THE PARIS AGREEMENT

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RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

CCAFS

Portfolio of Climate-Smart Agriculture Practices from No.5-9

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Introduction

This portfolio of Climate-Smart Agriculture (CSA) practices has been compiled to inspire wide-scale implementation. Each sheet in the portfolio provides

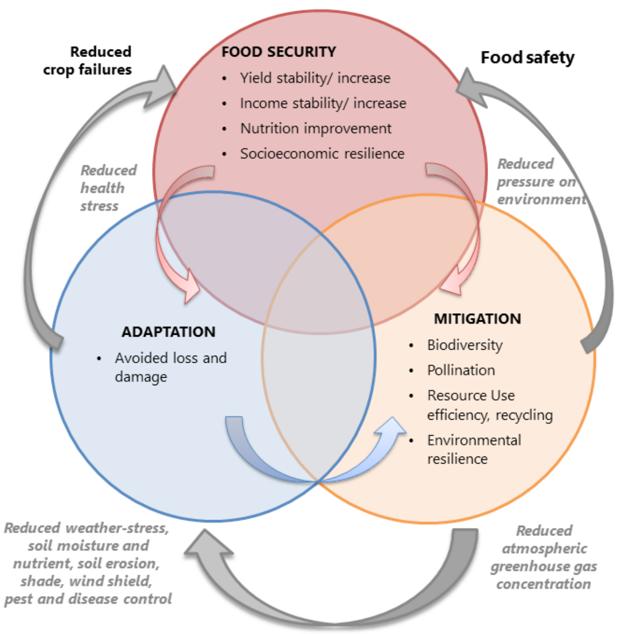
- A short description of the practice
- Key CSA indicators that the practice contributes to
- Cost and benefit assessment based on local knowledge, primary and secondary data
- Risks that may affect benefits, such as natural hazards, pests and diseases, market uncertainties
- Considerations for increasing scale, such as biophysical requirements, capacity and investment needs, and enabling policies

CSA practices are context specific. The practices and information in this portfolio are based on actual observation, local and expert knowledge as well as secondary data, and have been piloted in Ha Tinh Province, Central Viet Nam. Farmers selected the practices and indicators through consultative processes and participatory action-research methods. The practices represent farmers' outlook at the time of implementation and the indicators are specific, measurable, achievable, responsible, and time-related.

This portfolio offers technologies and practices that may be applicable in other contexts. However, expansion of scale requires local consultation and adaptation to the new specific cultural and geographical context (more about these strategies can be found in Le et al 2018).

It's important to note that CSA are not a static practices. Conditions for agriculture and adaptation are constantly changing and CSA is similarly in flux as improvements and innovations are continually made.

CSA VENN DIAGRAM



What is CSA and why is it useful?

Climate-smart agriculture is intended to bring synergies among food security, adaptation and mitigation efforts (FAO 2013). Food security is often interpreted as yield, livelihoods or income, and nutrition. Adaptation can contribute to food security by reducing disturbance due to climatic variability. Mitigation refers to production with reduced greenhouse-gas emissions and carbon sequestration.

In the pilot climate-smart villages, those CSA indicators were considered too minimalistic. The main motivation for farmers to implement farming practices are for livelihoods and stability. With stability understood as sustainability, we drew on ICRAF's agroforestry research and added indicators on ecosystem functions contributing to more resilient farming systems. At wider scale this evolves into ecosystems-based adaptation.

Increasing the scale of CSA is necessarily informed by local support within specific social, political, legal and economic circumstances. This means articulating which technologies and components will be implemented, where, by how much, by whom, when. We distinguish CSA practice as a technology (the 'how to', such as terrace, pond, or agroforestry) which can be generic or context-specific, with components (the 'what to', such as the specific variety, breed) which are always context-specific. Either technology or components or both can be changed to improve livelihoods, to adapt to or mitigate climate change.

With this ecosystem-based CSA, a natural step is to consider more circularity and resource-use efficiency in production systems to contribute to livelihoods' improvements and ecosystem benefits. One such example is livestock → manure → vermiculture → chicken feed and soil improvement → production gains. As a general principle, we recommend project implementers to be creative in ways that enhance biodiversity and respect nature using the 5R principles, such as exploring practices that avoid toxic chemicals and plastics, reduce waste products, reuse non-biodegradables such as fruit bags, recycle water and biomass, and repair soils.

Climate-Smart practices
Ha Tinh Province

Portfolio of CSA practices

Climate-smart Village Project (2015-2018)
Portfolio of CSA practices No. 1-4 (click to read)

§ No. 1. Orange-based agroforestry system

§ No. 2. Black pepper home garden

§ No. 3. Acacia-based agroforestry system

§ No. 4. Vermiculture

Ha Tinh SIPA project (2019-2022)
Portfolio of CSA practices No. 5-9

§ No. 5. Apiculture in agroforestry and forestry systems

§ No. 6. Fruit-tree-based agroforestry

§ No. 7. Local ‘tăm’ onion and bean rotation

§ No. 8. Drought-tolerant grass

APICULTURE IN AGROFORESTRY & FOREST SYSTEMS

The main sources of honey in Ha Tinh Province are wild ones in forests and from beekeeping in log- and top-bar hives. To collect wild honey, the collector must destroy the combs, which is an unsustainable practice with negative impact on natural ecosystems. Meanwhile, beekeepers who rely on log- or top-bar hives have difficulties in knowing the seasonal cycle of bee colonies, how to divide or join colonies, breed new queens, detect diseases, and monitor brood conditions. Apiculture is promoted by the provincial extension centre for use in planted tree-crop systems to improve livelihoods and reduce extraction from natural forests. Apiculture is a low-cost intervention that complements many farming activities, in particular, pollination. With further product development, apiculture can contribute significantly to diversification of farm incomes.

CLIMATE-SMART PRACTICE

COMPONENTS

- Honeybees
- Existing trees and crops (for example, fruit, timber and native tree species in homegardens, orchards, forest gardens)

TECHNOLOGIES

- Agroforestry
- Apiculture
- Improved quality of farmed beehives to reduce wild-honey and bee extraction from forests

BEEHIVE CALENDAR

Month	1	2	3	4	5	6	7	8	9	10	11	12
Apiculture												

Tending Feeding Harvest

BENEFITS

YEARS 1–2

- Tree shade provides microclimate-regulation
- Additional harvest, risk diversification
- Diversified and increased income
- Better planned labour inputs
- Pollination benefits to surrounding biota
- Resource use and cost efficiency: reduced use of chemical pesticides for tree-crop farming systems

FROM YEAR 3

- Biodiversity maintained in natural forests
- Increased soil biota

RISKS

- Agrichemical spray from nearby fields
- Bees escaping, especially if not well managed during hot and cold spells

INDICATORS

FOOD SECURITY

- Diversified products, opportunity for further product development
- Increased and diversified incomes
- Increased resource-use efficiency (tree-crop ecosystems for bees)
- Improved product quality

ADAPTATION

- Climate-suitable honeybee: species native to the area
- Increased microclimate-regulation: trees provide shade for bees
- Risk diversification: spread harvesting time of products and apply technical skills to the management of bees

MITIGATION AND ECOSYSTEM SERVICES

- Maintained biodiversity of forest ecosystems: reduced wild-honey and bee extraction from forests
- Increased pollination
- Reduced chemical fertilizer and pesticides
- Increased field biota

CONSIDERATIONS FOR EXPANDING SCALE

- **Humidity:** Most suitable at 95% inside the beehive
- **Temperature:** Optimal temperature is 35 °C inside the beehive
- **Capital:** Low-to-medium investment required, nectar from flowers (chives, dill, mint, calendula, sunflower, fruit trees such as longan, citrus, persimmon)
- **Training:** Important skills include splitting and joining beehives, feeding, management during extreme weather, pest and disease control, harvesting and storage
- **Market opportunities**: Explore possibilities for establishing farmers' groups or cooperatives; processing and product development
- **Enabling policies:** 1) Can Loc District: Resolution 40/NQ HĐND, Document No.3579 /UBND-NN; Huong Son District: Resolution 170/2020/NQ-HDND; Ky Anh District: Resolution 105/2021/NQ- HDND; 2) Ha Tinh Province: Resolution 255/2020/NQ-HDND (extension of 123/2018/NQ-HDND & 194/2020/NQ-HDND); Decisions: 786/2019/QĐ-UBND, 2914/QĐ-UBND; 3) National: Decisions: 899/QĐ-TTg, 819/QĐ-BNN-KHCN, 891/QĐ-BNN-KHCN, 3969/QĐ-BNN-KN

COST–BENEFIT ANALYSIS

Cost–benefit analysis of apiculture was conducted for a 5-year period. The data for calculation was collected from farmers, extension staff and the literature. See Do et al (2021) for more details.

COSTS

Fixed costs for apiculture included 10 beehives, protective clothing, honey extractor, smokers and labour for beehive establishment (site clearing and beehive hanging). Maintenance costs included feed (sugar or flower pollen) during the cold spells or when pollen is unvailable (for approximately 3 months), bottles for honey storage, and time for routine inspections, pest and disease control and harvest.

RISKS

Risks in apiculture were about the likelihood and consequences of events causing bees to escape and a reduction in honey yields. The risks included:

- Limited feed availability, especially during cold and hot spells
- Pests and diseases

METHOD

The cost–benefit analysis calculation was based on distribution outcomes generated from 10,000 system runs with randomly selected input variables in a Monte Carlo simulation using the decisionSupport R package developed by Luedeling et al (2021).

Important uncertainties that affect farm profits were identified using the Variable Importance in Projection score of a Partial Least Squares regression system (Luedeling et al 2021).

Based on the experience of farmers, beekeepers spend the first year multiplying colonies up to 20 hives, which are likely to be well managed by most beekeepers in the pilot districts. Honey is harvested twice in the first year and then 5–8 times in each subsequent year. For the selling price, we used a range of VND 70,000–200,000 per kg, with a probability of 5% that the price will be lower than VND 70,000 or higher than VND 200,000. This is the farm-gate selling-price range for the last 5 years in Ha Tinh Province.

FINANCIAL BENEFIT

The risk of financial loss from apiculture was lower than 1% (Table 1). After the first year, the annual average net profit was VND 50 million, ranging VND 18 million–89 million. After 5 years, the average net present value (NPV) was VND 156 million (ranging VND 52 million–283 million). The return on investment (ROI) of apiculture was high, ranging 1.6 to 10.3 after 5 years following implementation.

The most influential factors in the cost–benefit analysis were the prices and yields of the honey. Extension staff and project beekeepers observed that honey yields depended on the technical skills of beekeepers, especially, management of the bees during cold and hot spells and the availability of feed.

Table 1. The 5-year NPV of apiculture, with discount rates of 5–10%.

PRACTICE	Apiculture
Initial fixed investment (VND million)	9 - 12
Average NPV (VND million)	156
NPV range (VND million)	52 - 283
Return on investment (ROI)	1.6 - 10.3
Risk of financial loss (%)	<1%

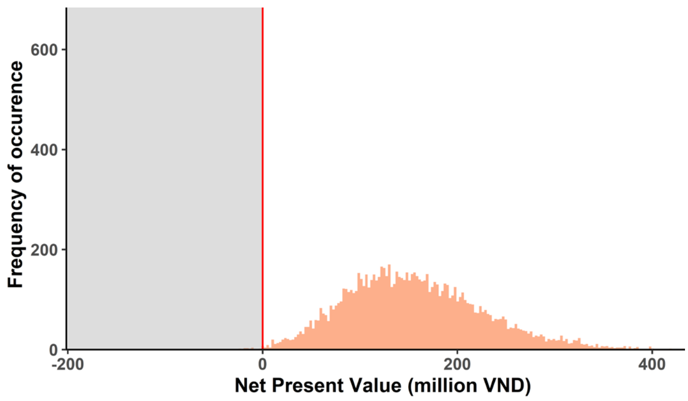


Figure 1. The 5-year NPV of apiculture in agroforestry and forest ecosystems

OTHER BENEFITS

Project beekeepers in Huong Son and Can Loc districts, Ha Tinh Province observed that beekeeping was not labour-intensive and that maintenance could be done outside peak working hours. Beekeeping provides rapid return on investment and is a good source of income diversification in many farming systems (Schouten et al 2019, Gupta et al 2014, Klein et al 2007), mitigating risks and sudden shocks (Ellis 1999). Moreover, bees provide important ecosystem services through pollination, enhancing the yields of most animal-pollinated plants, and improve biodiversity (Schouten et al 2019, Gupta et al 2014, Sharmaet et al 2014, Bradbear 2009).

In a case study in Lao PDR, beekeepers also reduced use of agro-chemicals, especially pesticides, and gave more attention to forest protection and biodiversity maintenance (Chanthayyod et al 2017). This was also observed for project beekeepers in Ha Tinh Province by extension and project staff during field monitoring in 2021. A study in Vu Quang and Huong Son districts by Yap et al (2015) found that apiculture enhanced participants' wellbeing as recorded by improved health, happier family relations, maintenance of cultural traditions and greater community respect. Specifically, beekeepers felt happier because 1) they enjoyed managing bees and observing their habits; 2) honey provided a good source of healthy nutrition; and 3) apiculture brought jobs for vulnerable groups like elders and people unable to undertake heavy physical work. Beekeeping households also had more joint decision-making and shared housework between husband and wife (Yap et al 2015). Some of the male beekeepers learned to be more patient with family members while women felt that their husbands respected them more when they earned money from honey sales. Beekeepers also gave honey to their relatives, strengthening their relationships.

APICULTURE IN AGROFORESTRY & FOREST SYSTEMS

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PARTNERS AND CONTACTS

Project owner: Ministry of Natural Resource and Environment, Department of Climate Change, Viet Nam

Project implementor: World Agroforestry (ICRAF) Viet Nam; Ha Tinh Extension Center

Provincial partners: Ha Tinh Department of Agriculture and Rural Development with sub-departments for Water Resources; Crop Production and Protection; Forestry; and Aquaculture; Ha Tinh Department of Natural Resources and Environment; Hydro-meteorological Center; and Ha Tinh Farmers' Union

District partners: District Department of Agriculture and Rural Development and Farmers' Union

Donor: The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) commissions German Development Cooperation GIZ through the International Climate Initiative

Project sites: Can Loc District (Dong Loc Commune), Huong Son District (Son Tien and Son Hong communes), Ha Tinh Province

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FRUIT-TREE-BASED AGROFORESTRY

Permanent trees, crop cover and contour plantations help store carbon, reduce surface runoff and evaporation, and prevent soil erosion. With the appropriate layout, fruit-tree-based agroforestry can be implemented on various landscapes from flat to undulating terrain as well as in homegardens for microclimate regulation and income diversification. Poorly designed, bare land or monocultural farming practices can be improved by adopting fruit-tree-based agroforestry. Apiculture (see Portfolio of CSA practices No.5) can also be integrated alongside this practice to provide additional ecosystem services.

CLIMATE-SMART PRACTICE

COMPONENTS

- Grafted fruit trees: orange (Chanh, Bu, V2), pomelo, guava
- Pineapple and/or guinea grass
- Cover crops: *Arachis pintoi* or seasonal crops for the first 2–3 years: vegetables, local 'tăm' onion, beans or pest-repellent plants.

TECHNOLOGIES

- Contour planting of trees, spaced 4x5 m
- 'Taungya' cropping (food crops while tree canopy develops
- Pineapple and/or grass double strips along contour lines, spaced 40x50 cm
- Mulching, composting
- Drip irrigation as necessary

BENEFITS

YEAR 1

- Diversified food and fodder
- Reduced direct soil evaporation
- Increased water use efficiency

YEAR 2

- Increased recycling of crop residues

YEAR 3

- Increased microclimate-regulation
- Reduced soil erosion

YEAR 4

- Net return from initial investment

YEARS 5–6

- More consistent income
- Higher average annual income
- Increased tree cover
- Increased above-ground biomass
- Increased field biota
- Darker soil, improved soil nutrient levels

RISKS

- Shift in local market prices of fruits
- Natural hazards: frost, heavy rain, and storms

INDICATORS

FOOD SECURITY

- Diversified products and incomes
- Increased product quality
- Increased resource-use efficiency
- Increased income in Year 4

ADAPTATION

- Increased microclimate regulation: shade trees
- Reduced direct soil evaporation: trees, mulching, composting
- Increased water-use efficiency
- Risk diversification: spread harvesting time of products and apply technical skills to the management of trees and crops

MITIGATION AND ECOSYSTEM SERVICES

- Reduced soil erosion
- Increased recycled crop residue
- Reduced chemical fertilizer and pesticides
- Increased tree cover, aboveground biomass, field biota
- Improved soil-nutrient level
- Connects diverse landscapes with trees and agroforestry

CONSIDERATIONS FOR EXPANDING SCALE

- **Soil:** Fluvisols, humic and rhodic ferralsols, pH 5.5 to 6.5
- **Slope:** <15°
- **Moisture:** Rainfall 1300–2500 mm/year, drip irrigation if needed, always ensure proper drainage
- **Temperature:** 23–29 °C, suitable within 13–38 °C
- **Capital:** High initial investment required
- **Training:** Composting, slope layout, pruning, pest and disease management
- **Market opportunities:** Guidance needed from agricultural planning office; explore possibilities of organising farmers' groups or cooperatives
- **Enabling policies:** 1) Can Loc District: Resolution 40/NQ HĐND, Document No.3579 /UBND-NN; Huong Son District: Resolution 170/2020/NQ-HDND; Ky Anh District: Resolution 105/2021/NQ- HDND; 2) Ha Tinh Province: Resolution 255/2020/NQ-HDND (extension of 123/2018/NQ-HDND & 194/2020/NQ-HDND); Decisions: 59/2015/QĐ-UBND, 05/2017/QĐ-UBND, 786/2019/ QĐ-UBND, 2914/QĐ-UBND; 3) National: Decisions: 899/QĐ-TTg, 819/QĐ-BNN-KHCN, 891/QĐ-BNN-KHCN, 3969/QĐ-BNN-KN, Document No.173/ TB-VPCP

FRUIT-TREE-BASED AGROFORESTRY

COST–BENEFIT ANALYSIS

A cost–benefit analysis calculated the benefits of orange monoculture, orange-based agroforestry, and mixed fruit-tree-based agroforestry systems over a 15-year period. The orange-based system included orange, pineapple and annual crops (vegetables, local onion, beans) or *Arachis pintoi.* The mixed fruit-tree-based system included orange, pomelo, guava (with a tree area ratio of 4:3:3, respectively, per ha), pineapple and seasonal crops (vegetables, *Allium schoenoprasum L*, beans) or *Arachis pintoi*. Other fruit trees included lemon, jackfruit, persimmon. The different systems were practised by households involved with the project. The data for calculation was collected from farmers, extension staff and the literature. See Do et al (2021) for more details.

COSTS

The expenses for inputs included seeds or seedlings, fertilizers, biological pest control and labour. Drip irrigation counted as a fixed cost.

RISKS

Risks were about the likelihood and consequences of events affecting crop yields, which were calculated as yield decline compared to normal years. The risks included:

- Drought and tropical storms during the summer-autumn season
- Frost during winter

METHOD

The cost–benefit calculation was based on outcome distribution generated from 10,000 system runs with randomly selected input variables in a Monte Carlo simulation using the decisionSupport R package developed by Luedeling et al (2021).

The uncertainties of variables (for example, input costs, selling price) were represented in the system as probability distributions (value range and distribution shapes). Important uncertainties that affect farm profits were identified using the Variable Importance in Projection score of a Partial Least Squares regression system (Luedeling et al 2021).

FINANCIAL BENEFITS

The risk of financial loss was low in all systems and lowest in the mixed fruit-tree-based agroforestry (Table 1). Additionally, the latter system generated a higher average Net Present Value (NPV) than orange monoculture (VND 1124–1305 million per ha versus VND 920 million per ha). Return on investment (ROI) was high in all systems with tree-based agroforestry having closer ROI upper and lower limits than orange monoculture. See Table 1 and Figure 1 for more details.

Establishment costs for fruit-tree-based systems can be mitigated by short-term income from pineapple and other annual crops. With additional income sources, break-even point can be reached after 4 years with mixed fruit trees compared to 5 years with orange monoculture (Figure 2). Alternatively, with *Arachis pintoi* as a cover crop, farmers can harvest 150 tons per ha annually of fodder grass with high crude protein and dry matter content (Ngome and Mtei 2010, NOMAFSI 2007).

OTHER BENEFITS

Fruit-tree-based agroforestry with forage grass strips can reduce soil erosion on sloping land by 23–90% (La et al 2019).

Planting trees and/or crops along contour lines is effective for erosion control. Pineapple can be as effective as grass (Craswell et al 1997). Hedgerows such as *Vetiver* spp, *Tephrosia* spp and pineapple can reduce soil and organic matter loss by 50–70% compared to none (Nguyen et al 2001).

Mulching and green manure or composting improved rainwater infiltration, reduced runoff and evaporation, and protected against soil erosion (FAO 1996). Leguminous cover crops reduced soil loss by up to 80% (NOMAFSI 2007, Nguyen et al 2001). Moreover, *Arachis pintoi* forms a dense mat of rooted stolons, which improve soil moisture content by up to 15% (NOMAFSI 2007), reduce weeds and improve soil fertility through nitrogen fixation (NOMAFSI 2007, Thomas et al 1997).

Table 1. NPV of orange monoculture, orange-based agroforestry and mixed fruit-tree-based agroforestry (AF) over a 15-year period, with discount rate of 5–10%

PRACTICE	Orange mono-culture	Orange-based AF	Mixed fruit tree-based AF
Initial fixed invest-ment (VND million per ha)	35–50	67–100	67–100
Average NPV (VND million per ha)	920	1305	1124
NPV range (VND million per ha)	152–1970	390–2518	536–1858
Return on Investment	0.4–5.8	0.85–5.7	1.2–4.2
Risk of financial loss (%)	2%	< 1%	< 1%

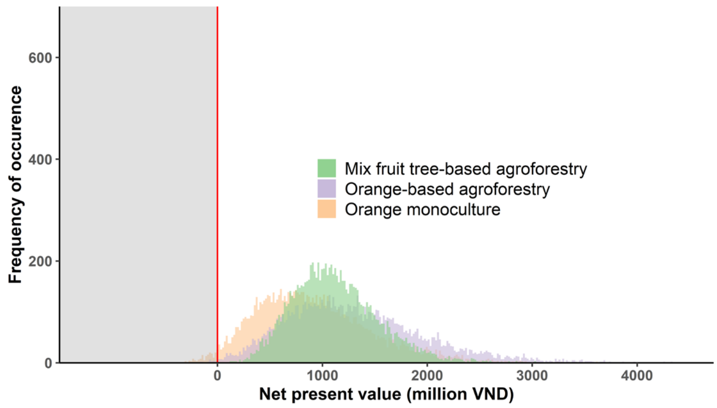

Figure 1. The 15-year NPV of orange monoculture and fruit-tree-based agroforestry

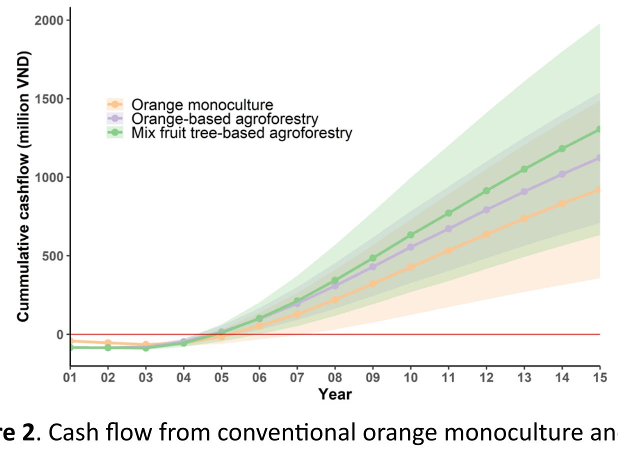

Figure 2. Cash flow from conventional orange monoculture and fruit-tree-based agroforestry

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- **Further reading:** Le TT, Simelton E. 2018. *Portfolio of CSA practices for scaling.* No. 1. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security. https://hdl.handle.net/10568/92835.

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LOCAL 'TĂM' ONION & BEAN ROTATION

National agricultural plans and policies promote the conversion of 'ineffective' wet rice to climate-resilient land uses with high-value crops. 'Ineffective' wet rice refers to rice fields with low productivity and regular susceptibility to extreme weather events like droughts and storms. In Ha Tinh Province, the local 'tăm' onion is registered under the One Commune, One Product (OCOP) program, which can provide competitive advantages to agricultural and agribusiness development. With appropriate establishment and management techniques, onion grown in rotation with beans is a promising, low-input, 'safe' (organic or near-organic) practice that builds up soil organic matter, conserves soil moisture, improves soil nutrient status, and is a low-risk adaptation strategy, improving farmers' livelihoods.

CLIMATE-SMART PRACTICE

COMPONENTS

- Local 'tăm' onion (*Allium schoenoprasum L.)*
- Sesame, beans or leguminous crops, for example, mung bean, black bean and peanut

TECHNOLOGIES

- Organic-oriented input: biofertilizers, biopesticides, compost, green manure
- Temporal rotation
- Raised bed, 20-25 cm deep, 100-120 cm wide
- Rice-straw mulch (cover)
- Drought-tolerant species for rotation
- Pest-repellent crop (onion)

CROP CALENDAR

Month	1	2	3	4	5	6	7	8	9	10	11	12
Onion	Mid season	Mid season	Harvest	Harvest	Harvest			Plant	Plant	Mid season	Mid season	Mid season
Bean				Plant	Plant	Mid season / Harvest	Harvest	Harvest				
Peanut				Plant	Plant	Plant / Mid season	Harvest	Harvest	Harvest			

Plant   Mid season   Harvest

BENEFITS

YEARS 1–2

- Additional harvest, risk diversification
- Diversified and/or increased income
- Increased land-use efficiency
- Better-planned labour input (onion can be harvested/stored in the field for several months)
- Resource use and cost efficiency: biological fertilizers and pest control reduce input costs

FROM YEAR 3

- Soil improvement

RISKS

- Shifts in market demand and price of onion
- Natural hazards: extended periods of heavy rain or drought

INDICATORS

FOOD SECURITY

- Increased and/or diversified income
- Increased land use efficiency (rotation)
- Improved product quality

ADAPTATION

- Risk diversification: enables extending harvest time of products
- Drought tolerant: mulch reduces direct soil evaporation and retains soil moisture for the subsequent crop
- Flood adaptation: raised beds reduce risks associated with saturated soils after heavy rain and flooding
- Windproof: short/low-lying crops are resistant to strong winds
- Onion is pest repellent: reduced pest and disease problems during abrupt weather changes

MITIGATION AND ECOSYSTEM SERVICES

- Using crop residues: straw mulch reduces straw burning and makes plastic mulch redundant
- Soil improvement - organic mulch and compost build up soil organic matter, soil nutrients and biota
- Reduced use of chemical fertilizer and pesticides

CONSIDERATIONS FOR EXPANDING SCALE

- **Soil:** A rich, moist but well-drained soil such as sandy loam, loam, silt loam, sandy, chalky, optimal pH 6 to 6.5, tolerating pH 5–8.2
- **Slope:** Flat to lightly undulating
- **Moisture:** Mean annual rainfall 450–1600 mm but tolerates 300–2800 mm with proper drainage
- **Temperature:** High heat tolerance, mean monthly temperature is optimal at 12–24 °C but min-max of 7– 29 °C
- **Sunlight:** Partial shade, full sun
- **Investment cost:** Low
- **Training:** Crop management
- **Market opportunities:** Guidance needed from the Agricultural Planning Office, DARD. Explore possibilities for farmer-producer groups or cooperatives to join market value chains
- **Enabling policies:** 1) Can Loc District: Resolution 40/NQ HĐND, Document No.3579 /UBND-NN; 2) Ha Tinh Province: Resolution 255/2020/NQ-HDND (extension of 123/2018/ NQ-HDND & 194/2020/NQ-HDND), Decisions: 786/2019/QĐ-UBND, 2914/ QĐ-UBND; 3) National

LOCAL 'TĂM' ONION & BEAN ROTATION

COST-BENEFIT ANALYSIS

A cost–benefit analysis compared a 1-year onion–bean rotation with two conventional practices of one and two crops of rice monoculture per year. The data for the calculation was collected from farmers, extension staff and the literature. See Do et al (2021) for more details.

COSTS

Expenses for inputs included seeds, fertilizers and biopesticides, mulching material, and labour.

RISKS

Risks in onion and bean rotation were about the likelihood and consequences of events affecting crop yields, calculated as yield decline compared to normal years. The risks included:

- Drought and extreme rain events for onion–bean rotations
- Drought and tropical storms for summer–autumn rice
- Pests and disease due to warm and humid weather for spring rice

METHOD

The calculation was based on distribution outcomes generated from 10,000 system runs with randomly selected input variables in a Monte Carlo simulation using the decisionSupport R package developed by Luedeling et al (2021). Uncertainties of variables (for example, input costs, selling price of onion) were represented in the systems as probability distributions (value ranges and distribution shapes).

Important uncertainties that affected farm profits were identified using the Variable Importance in Projection score of a Partial Least Squares regression system (Luedeling et al 2021).

The annual productivity of onion ranged 5000–8000 kg per ha and of mung bean 600–1200 kg per ha. The selling prices ranged VND 20,000–45,000 per kg for onion and VND 25,000–35,000 per kg for mung bean. There was a 5% probability that the price will be lower or higher than the above price ranges for each crop. These are the common farm-gate selling-price ranges during the last 5 years in Ha Tinh Province.

FINANCIAL BENEFITS

The risk of financial loss was low in all practices. The risk in any given year was lower with rice monoculture (1–2.5 %) compared to onion–bean (7.5%) (Table 1). However, the onion–bean practice can reach up to 5 times higher net profit compared to rice monoculture (VND 93 million per ha versus VND 17 million per ha). The average return on investment was also higher from onion–bean (0.59) than from rice monoculture (0.35). However, while oni-bean resulted in lower limit of ROI compared to rice, it also had a higher upper limit of ROI compared to rice.

Table 1. Net profits of onion–bean rotation and rice monoculture

PRACTICE	Rice (1 season/ year)	Rice (2 seasons/ year)	Onion–bean rotation
Annual investment (VND million per ha)	20–25	41–50	144–189
Average net profit (VND million per ha)	7	17	93
Net profit range (VND million per ha)	1.2–14	4.8–27	-13–218
Return on Investment	0.05–0.64	0.1–0.63	-0.08–1.16
Risk of financial loss	2.5%	1%	7.5%

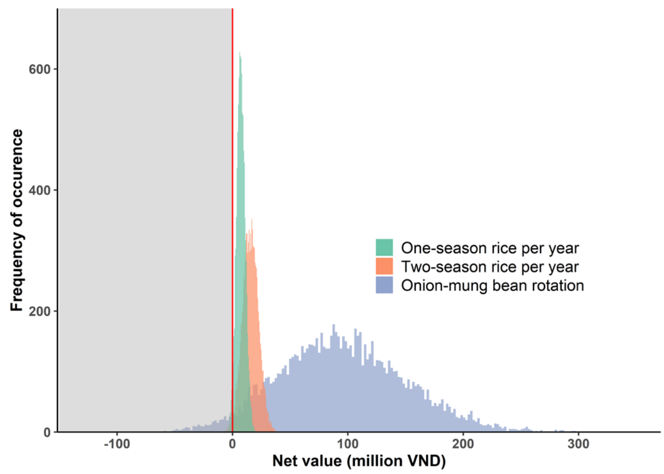

Figure 1. Distributions of annual net profit for onion-bean and rice monocultures

OTHER BENEFITS

Farmers and extension staff in Ha Tinh Province observed very few pest and disease issues with the 'tăm' onion. Moreover, rotations prevented transmission via soil and host plants and onion was repellent to certain insects.

Mulching onion with rice straw suppresses weed growth, reduces direct soil evaporation, and increases a range of soil quality indicators, such as available water capacity, soil porosity and structure (Mulumba et al 2007). Compost applications have similar benefits.

The environmental benefits of legumes are widely reported. For example, mung bean can fix up to 50 kg of nitrogen per hectare (Ro et al 2016, Phoomthaisong et al 2003, Ha et al 2002), which reduces soil nutrient depletion, making more nutrients available for the subsequent crop. Incorporating legumes as green manure reduces the need for inorganic nitrogen fertilizer in the following crop by 13–50% (Zhang et al 2016; Aulakh et al 2000). Mung bean in rotation with rice increases the soil organic carbon and the bio-available carbon fraction compared to rice monoculture (Linh et al 2015).

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PARTNERS AND CONTACTS

Project owner: Ministry of Natural Resource and Environment, Department of Climate Change, Viet Nam

Project implementor: World Agroforestry (ICRAF) Viet Nam; Ha Tinh Extension Center

Provincial partners: Ha Tinh Department of Agriculture and Rural Development with sub-departments for Water Resources; Crop Production and Protection; Forestry; and Aquaculture; Ha Tinh Department of Natural Resources and Environment; Hydro-meteorological Center; and Ha Tinh Farmers' Union

District partners: District Department of Agriculture and Rural Development and Farmers' Union

Donor: The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) commissions German Development Cooperation GIZ through the International Climate Initiative

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DROUGHT-TOLERANT GRASS

In disaster-prone regions, a common practice is to fallow or plant monoculture of cassava after a spring crop of maize because the risk of crop failure owing to droughts and storms is high in the summer–autumn season. However, neither fallow nor cassava monoculture is a sustainable nor effective practice because natural grass generated from the fallow will not produce enough feed for livestock and monoculture of cassava for livestock feed will deplete the soil, causing degradation in the long term. Instead, the drought-tolerant perennial grass, Mombasa guinea (*Megathyrus maximus cv Mombasa)*, has been introduced as an alternative based on the experience of extension centres, project staff and leading farmers in Ha Tinh Province. The grass lasts for 5 years, has high nutritious biomass content for fodder, provides efficient soil-erosion control, and has important livelihood benefits.

CLIMATE-SMART PRACTICE

COMPONENTS

- Grass: Mombasa guinea (*Megathyrus maximus cv Mombasa* formerly *Panicum* maximum), can be mixed in the tree-based agroforestry systems (see Portfolio of CSA practices No.6)
- Livestock

TECHNOLOGIES

- Rice-straw mulch for a better germination rate: 8–10 tons per ha
- Cut and carry
- Composting
- Contour planting in sloping land.

CROP CALENDAR FOR GRASS

Month	1	2	3	4	5	6	7	8	9	10	11	12
Plant	Management and harvest	Sowing	Sowing	Sowing	Management and harvest	Management and harvest	Management and harvest	Management and harvest	Management and harvest	Management and harvest	Management and harvest	Management and harvest

Sowing   Management and harvest

BENEFITS

YEAR 1

- High quality fodder
- Reduced costs for animal feed and agricultural inputs
- Reduced risk of crop failure from natural disasters

YEARS 2-5

- Regulated soil moisture content
- Reduced soil erosion

RISKS

- Natural hazards: frost, flood (grass can withstand a maximum of 10 days under water)

INDICATORS

FOOD SECURITY

- High-quality feed for livestock
- Reduced costs for buying animal feed
- Increased circular agriculture/resource-use efficiency: grass provides feed for livestock and manure from livestock can be composted and applied to the grass

ADAPTATION

- Drought, shade and fire tolerant grass
- Grass recovers fast after drought, whirlwinds and storms compared to crops like rice, maize or cassava
- Regulates soil moisture content (grass cover for 5-6 years continuously)

MITIGATION AND ECOSYSTEM SERVICES

- Deep roots that bind soils and reduce surface runoff and erosion on sloping land
- Reduced use of chemical fertilizers and pesticides compared to other crops, for example, maize, rice

CONSIDERATIONS FOR EXPANDING SCALE

- **Soil:** Well-drained and light-textured soils, preferably sandy loams or loams, tolerates various soil types, pH 4–8
- **Moisture:**
  - Rainfall 800–2200 mm per year
  - Dry season (number of consecutive months with <40 mm rainfall): 0–4 months, tolerates up to 7 dry months
- **Temperature:** Optimal average annual temperature 18–27°C, average temperature in coldest and hottest month 6–31 °C
- **Capital:** Low investment needed
- **Training:** Sowing seeds and cut-and-carry management, silage and hay for feed storage during dry or cold seasons
- **Enabling policies:** 1) Huong Son District: NQ 170/2020/NQ HDND; 2) Ha Tinh Province: Decisions: 786/2019/QĐ-UBND, 2914/QĐ-UBND; 3) National Decisions-899/QĐ-TTg, 819/QĐ-BNN-KHCN, 891/QĐ-BNN-KHCN

DROUGHT-TOLERANT GRASS

COST-BENEFIT ANALYSIS

The cost–benefit analysis compared maize monoculture with guinea grass over a 5-year period. The data for calculation was collected from farmers, extension staff and the literature. See Do et al (2021) for more details.

COSTS

Costs for maize included seeds, fertilizers, pesticides and labour. Costs for grass included seeds, fertilizer and labour.

RISKS

The risks for maize were droughts and storms, quantified as the likelihood of each to occur in a certain year and the associated reduced maize yield.

METHOD

The calculation was based on outcome distribution generated from 10,000 system runs with randomly selected input variables in a Monte Carlo simulation using the decisionSupport R package developed by Luedeling et al (2021).

Uncertainties of variables (for example, input costs, selling price) were represented as probability distributions (value ranges and distribution shapes).

The annual grass-yield ranged 80,000–150,000 kg per ha and maize yield (grain) 4000–7000 kg per ha. The prices ranged VND 300–700 per kg for grass and VND 5000–7000 per kg for maize grain. There was a 5% probability that the price will be lower than or higher than the above price ranges for each crop.

FINANCIAL BENEFITS

The risk of financial loss was lower for grass (6%) compared to maize monoculture (11%) (Table 1). Additionally, grass reached up to 2.5 times higher average 5-year net present value (NPV) than maize monoculture (VND 103.5 million per ha versus VND 38.5 million per ha). In practice, most farmers do not sell grass but use it as livestock feed. With 1 ha of guinea grass, farmers can feed 5–10 head of cattle per year under the assumption that one head needs around 14 tons of grass per year (or 40 kg of grass per day). With grass available as feed throughout the year, livestock production can be sustained and contribute to income generation. Moreover, the return on investment of grass was higher than that of maize monoculture.

Table 1. NPV of maize monoculture and guinea grass over a 5-year period, with discount rate of 5–10%.

PRACTICE	Maize	Grass
Initial fixed investment (VND million per ha)	0	7–11
Annual cost (VND million per ha per year)	14–23	16–36
Average NPV (VND million per ha)	38.5	103.5
NPV range (VND million per ha)	-11.5–93.5	-5–223
Return on Investment	-0.13–1.3	-0.03–2.3
Risk of financial loss	11%	6%

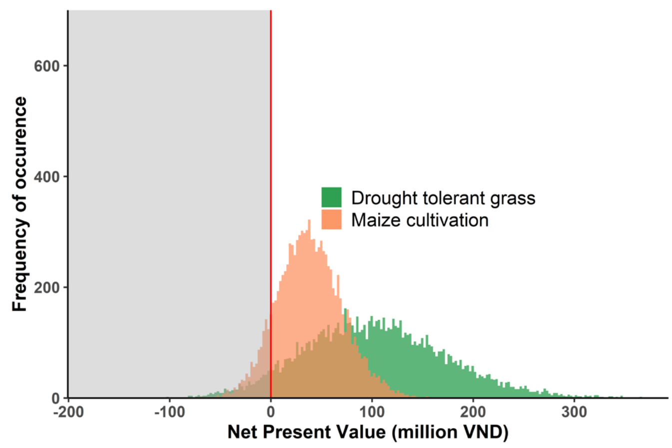

Figure 1. The 5-year NPV for grass and maize monoculture

OTHER BENEFITS

Guinea grass is not only drought tolerant but also shade and fire tolerant. Therefore, it is suitable to intercrop in tree-based farming systems and in upland areas.

Guinea is a perennial grass and if managed well can continuously cover the soil for long time, contributing to regulation of soil-moisture content.

On flat land, intercropping fodder grass appropriately into tree-based systems helps to cover the soil, especially, during the first 2–3 years of establishment, contributing to reducing direct soil evaporation.

On sloping land, guinea grass can be planted along contour lines, which can help in reducing soil and organic matter loss by 50–70% compared to sloping land without this practice (Nguyen et al 2001). Compared to maize monoculture, fruit-tree-based agroforestry with forage-grass strips can reduce soil erosion by 23–90%, depending on the type of system and the stage of maturity (La et al 2019).

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GIANT FRESHWATER PRAWN - FISH ROTATION WITH AGROFORESTRY

National agricultural plans and policies promote the conversion of 'ineffective' wet rice to climate-resilient land uses with higher-value crops. 'Ineffective' wet rice refers to rice with low productivity that is regularly exposed to extreme weather events like flooding and storms. In Ha Tinh Province, besides converting rice fields to other cropping patterns, aquaculture is promoted in places with access to water. With appropriate timing, species' selection and management, freshwater prawn and fish rotations can generate higher income from two seasons and control disease with the rotation. Moreover, agroforestry can diversify income further and provide windbreaks and shade. Lastly, phytoremediation plants can provide water-cleaning functions.

CLIMATE-SMART PRACTICE

COMPONENTS

- Giant river prawn *(Macrobrachium rosenbergii)* male juveniles
- Various fish: Common carp *(Cyprinus carpio var. communis)*, grass carp *(Ctenopharynogodon idella)*, silver carp *(Hypophthalmichthys molitrix)*, mrigal carp *(Cirrhinus mrigala)* or other fishes such as *Anguilla* spp., red tilapia, tilapia.
- Trees, for example, jackfruit, citrus, timber species
- Grasses, for example, guinea or napier as feed for fish
- Phytoremediation plants, for example, common water hyacinth, *Cyperus* spp, *Cyperus alternifolius, Phragmites australis*

TECHNOLOGIES

- Rotation of fish and prawn
- Windbreak, dust and air-pollutant protection, shade trees
- Pond-bank stabilizing trees and grasses
- Phytoremediation plants for inlet and outlet water

CROP CALENDAR FOR GRASS

Month	1	2	3	4	5	6	7	8	9	10	11	12
Prawn			Stocking	Stocking	Tending	Tending	Tending	Tending	Harvesting			
Fish	Tending	Tending	Tending	Harvesting	Harvesting					Stocking	Stocking	Tending

Stocking Tending Harvesting

BENEFITS

YEAR 1

- Two harvests

YEARS 2–3

- Net return from initial investment
- Diversified and increased income
- Water purification (phytoremediation)

FROM YEAR 4

- Stable yields
- Higher average annual income
- Increased microclimate regulation: reduced direct soil and water evaporation: shade trees
- Increased tree cover and aboveground biomass
- Agroforestry production (fruit, fodder)

RISKS

- Water pollution
- Natural hazards: flooding

INDICATORS

FOOD SECURITY

- Diversification of products and income
- Increased income in years 2–3

ADAPTATION

- Risk diversification: spread harvesting time of products
- Increased microclimate regulation: shade trees, windbreaks, dust and air-pollutant protection
- Reduced direct soil and water evaporation
- Can function as water-harvesting pond, if needed

MITIGATION AND ECOSYSTEM SERVICES

- Increased tree cover and aboveground biomass
- Water-pollution control (phytoremediation)
- Hedgerows, green fencing

CONSIDERATIONS FOR EXPANDING SCALE

- **Water:**
  - Water temperature: optimal at 26–31 °C but tolerates 18–32 °C, pH 6.5–8.5
  - Salinity: optimal at 0–5 parts per thousand (ppt) but tolerates 0–10 ppt
  - Water transparency: optimal at 30–40 cm but tolerates 30–50 cm
  - Alkalinity: optimal at 80–120 ppm but tolerates 60–180 ppm
  - Dissolved oxygen: suitable at > 5 mg/l, min > 3 mg/l
  - Ammonia [unionised]: <0.3 mg/l; boron: < 0.75 mg/l; copper: <0.02 mg/l; zinc: <0.2 mg/l; calcium carbonate: 40–100 mg/l; nitrate: <20 mg/l for larva, < 75 mg/l for adult, nitrite: < 1 mg/l
- **Air temperature:** optimal 26–31 °C but tolerates 18–40 °C
- **Capital:** High initial investment
- **Training:** Important skills; landscape layout, pond preparation, management of prawn, fish and water, harvest and post-harvest handling
- **Market opportunities:** Guidance needed from agricultural planning office; explore farmers' groups or cooperatives
- **Enabling policies:** 1) Can Loc District: Resolution 40/NQ HĐND, Document No.3579 /UBND-NN; 2) Huong Son District: NQ 170/2020/NQ-HDND; 3) Ha Tinh Province: Decisions: 786/2019/QĐ-UBND, 2914/QĐ-UBND; 4) National Decisions: 899/QĐ-TTg, 79/QĐ-TTg, 819/QĐ-BNN-KHCN, 891/QĐ-BNN-KHCN

COST-BENEFIT ANALYSIS

The cost–benefit analysis compared 10-year benefits from rice monoculture (two crops per year) with a system of rotation of giant freshwater prawn and fish surrounded by agroforestry. For 1 ha of the system, agroforestry accounted for around 0.05–0.15 ha while prawn or fish area was 0.85–0.95 ha. The data for calculation was collected from farmers, extension staff and the literature. See Do et al (2021) for more details.

COSTS

Aquaculture included 1) fixed costs: initial investment for setting up the pond system (land clearance, embankments) and agroforestry on the pond bank (seedlings, fertilizer, establishment labour); and 2) annual costs for prawn fingerlings, fish seed, probiotics and labour for management and harvesting. Rice costs included annual cost for seeds, labour, fertilizers and pesticides.

RISKS

Risks for prawn and fish rotation with agroforestry were the likelihood and consequences of events affecting crop, prawn and fish yields, calculated as yield decline compared to normal years. The risks included:

- Hot spells and flooding for aquaculture
- Droughts and storms for rice cultivation

METHOD

The calculation was based on outcome distribution generated from 10,000 system runs with randomly selected input variables in a Monte Carlo simulation using the decisionSupport R package developed by Luedeling et al (2021).

The uncertainties of variables (for example, input costs, selling price) were represented in the system as probability distributions (value ranges and distribution shapes).

The annual productivity of prawns ranged 750–3500 kg per ha (average 2000 kg per ha) and of fish 4700–12,000 kg per ha (average 8500 kg per ha). The selling price ranged VND 170,000–220,000 per kg for prawn and VND 30,000–60,000 per kg for various fish species.

FINANCIAL BENEFITS

Table 1 shows that the 10-year average Net Present Value (NPV) of the aquaculture system was 16 times higher than for rice monoculture (VND 2.311 billion per ha versus VND 140 million per ha). The high initial investment for pond preparation and essential infrastructure for aquaculture resulted in 14% negative cash flow in the first year, however, it is likely that these investments would be compensated by the second to third year. Appropriate stocking densities and timely harvest are required to optimize yields and prices of fish and prawn. Return on investment of the aquaculture system was higher than that of rice monoculture. The risk of financial loss was relatively the same in the two practices.

Table 1. Net Present Value (NPV) for rice monoculture and aquaculture rotation over a 10-year period, with discount rate of 10–30%

PRACTICE	Rice monoculture	Aquaculture*
Initial fixed investment (VND million per ha)	0	100–250
Annual cost (VND million per ha per year)	13–29	237–575
Average NPV (VND million per ha)	140	2311
NPV range (VND million per ha)	31.5–264	416–4942
Return on Investment	0.15–1.4	0.2–2.1
Risk of financial loss	1%	1%

* Giant freshwater prawn and fish rotation with agroforestry

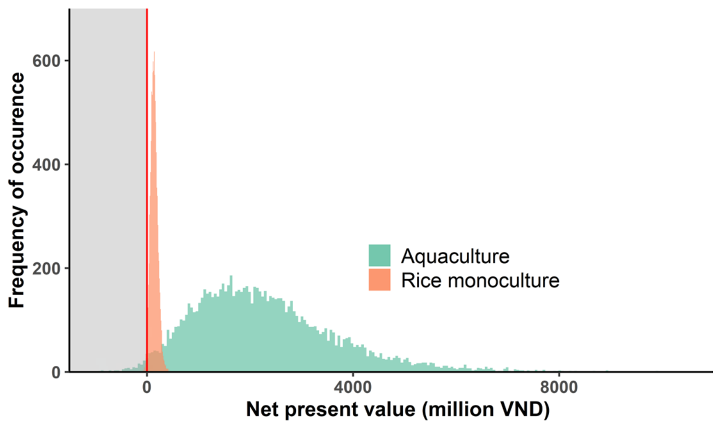

Figure 1. Distribution of 10-year NPV of rice monoculture and giant freshwater prawn–fish rotation with agroforestry (aquaculture)

OTHER BENEFITS

Giant freshwater prawn has numerous advantages, such as a high growth rate compared to other freshwater prawns, a tolerance of salinity up to 10 ppt and can be in monoculture or polyculture with carp (Tran et al 2020, Meena et al n.d.). Continuous monoculture of prawn will cause an increase in pathogenic bacteria, for example, a sucrose-negative strain of *Vibrio harveyi*, which produces a biofilm coating that protects it from drying and disinfection procedures (Yuvaraj et al 2015, Paclibare et al 1998). Crop rotation (fish and prawn) serves as a sanitation practice to reduce the spread of this bacterial strain in prawn culture (Paclibare et al 1998). During fish cultivation, the population of sucrose-positive bacteria (mainly *Vibrio*) that can be used as probiotics increases (Yuvaraj et al 2015, Paclibare et al 1998). Moreover, trees help protect the pond from dust and air pollution, stabilise banks and regulate the micro-climate for fish and prawn growth. Grass in the pond will help clean the water with its capacity to take up heavy metals.

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- **Further reading:** Le TT, Simelton E. 2018. *Portfolio of CSA practices for scaling.* No. 1. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security. https://hdl.handle.net/10568/92835.

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Project implementor: World Agroforestry (ICRAF) Viet Nam; Ha Tinh Extension Center

Provincial partners: Ha Tinh Department of Agriculture and Rural Development with sub-departments for Water Resources; Crop Production and Protection; Forestry; and Aquaculture; Ha Tinh Department of Natural Resources and Environment; Hydro-meteorological Center; and Ha Tinh Farmers' Union

District partners: District Department of Agriculture and Rural Development and Farmers' Union

Donor: The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) commissions German Development Cooperation GIZ through the International Climate Initiative

Project sites: Vuong Loc Commune, Can Loc District, Ha Tinh Province.

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POLICY OVERVIEW

DOCUMENT CODE	DATE	ISSUER	TITLE
National			
Document No.173/ TB-VPCP	10/5/2018	Prime Minister	Announcement - Conclusion of Deputy Prime Minister Vuong Dinh Hue at the national conference on building new-style rural areas and homegarden demonstration systems
Decision 899/2013/ QĐ-TTg	10/6/2013	Prime Minister	Approving the Project on "Agricultural restructuring towards raising added value and sustainable development"
Decision 819/2016/QĐ-BNN-KHCN	14/03/2016	Ministry of Agriculture and Rural Development (MARD)	Decision approving the action plan for the climate change response of the agricultural and rural development sector for the period of 2011-2015 and their vision to 2050
Decision 891/QĐ-BNN-KHCN	17/3/2020	MARD	Decision approving the plan of implementation of the Paris Agreement on climate change for the period 2021–2030
Decision 3969/QĐ-BNN-KN	8/10/2020	MARD	Decision approving the list of central agricultural extension projects to be implemented during the period of 2021-2023
Decision 79/QĐ-TTg	18/1/2018	Prime Minister	Decision on the issuance of a national action plan for development of Viet Nam's shrimp sector to 2025
Ha Tinh Province			
Resolution 255/2020/ NQ-HDND (extension of 123/2018/NQ-HDND & 194/2020/NQ-HDND)	8/12/2020	Provincial People's Council	Resolution to support (agriculture, forestry, aquaculture) production and processing to encourage development of agricultural, new rural and urban areas in Ha Tinh province for the period of 2019- 2021
Decision 59/2015/ QĐ-UBND	24/11/2015	Provincial People's Committee	Decision on the promulgation of criteria for building demonstration homegardens under the new-style rural area system in Ha Tinh province
Decision 05/2017/ QĐ-UBND	7/2/2017	Provincial People's Committee	Decision on the promulgation of criterion of new rural communes for the period of 2017-2020 in Ha Tinh province
Decision 786/2019/ QĐ-UBND	18/3/2019	Provincial People's Committee	Decision on the plan for restructuring the agricultural sector of Ha Tinh province during the period of 2019-2020 and in subsequent years
Decision 2914/QĐ-UBND	11/10/2017	Provincial People's Committee	Decision on promulgating the plan for implementing the Paris Agreement on climate change in Ha Tinh province
District			
Resolution 40/2019/ NQ-HDND	8/7/2019	Can Loc District People's Council	Resolution to support agricultural production and processing to encourage the development of agriculture, rural areas, new-style rural and urban areas in Can Loc district, Ha Tinh province for the period of 2019-2021
Document No.3579 / UBND-NN	30/10/2020	Can Loc district People's Committee	Agricultural planning of Can Loc district for 2021
Resolution 170/2020/ NQ-HDND	17/12/2020	Huong Son District People's Council	Resolution to support the development of agricultural, rural, new-style rural and urban areas and One Commune One Product (OCOP) in Huong Son district, Ha Tinh province, in 2021
Resolution 105/2021/ NQ-HDND	5/1/2021	Ky Anh district People's Council	Resolution to encourage the development of agricultural, rural and new-style rural areas in Ky Anh district, 2021-2023

COST–BENEFIT ANALYSIS METHODOLOGY

BACKGROUND

Farmers face a lot of uncertainty when choosing between various farming options. They must make decisions on crop production, farm practices, resource allocation, the scale of operations and capital investment, on a daily basis. Predicting how farms will respond to change is a challenge because agricultural systems are complex and surrounded by uncertainty and farmers lack the support of objective data to assist in decision-making (Luedeling and Shepherd 2016).

Decision analysis is an interdisciplinary approach that provides methods and tools to support decision-making under uncertainty (Hardaker and Lien 2010; Luedeling and Shepherd 2016). The method allows for a comprehensive assessment of options by incorporating all available, relevant information, including expert knowledge. Experts can be scientific specialists (Page et al 2012), farmers and/or other land managers (Oliver et al 2012). Decision analysis can incorporate this knowledge to obtain a qualitative understanding of a system which then can be translated into a set of mathematical equations (Krueger et al 2012, Luedeling et al 2015). Probability distributions derived from subjective judgments are widely recognized as an appropriate quantitative representation of uncertainty (Hubbard 2014). Assigning a range for a particular quantity helps to overcome the need for any assumptions of certainty, which are rarely true in reality (Do et al 2020). Decision analysis, therefore, is an effective method when statistical data is missing.

Mathematical systems such as cost-benefit analyses are common tools to estimate the profitability of an investment under certain given conditions. There are two common systemling approaches for conducting cost-benefits analyses:

- Deterministic systems use mathematical equations with precise values to calculate a single estimate of financial performance. The precision of this method may overlook the risks and uncertainty associated with agricultural investments.
- In contrast, probabilistic approaches can explicitly represent uncertainty by presenting uncertain factors as probability distributions that represent the plausibility of achieving all possible values (Hubbard 2014). In agricultural investments, probability distributions of uncertain inputs can be used to derive ranges of costs and benefits under scenarios involving risk and uncertainty.

METHOD

We used a probabilistic approach to conduct cost–benefit analyses of climate-smart agricultural practices in Can Loc and Huong Son districts, Ha Tinh Province. We adapted a decision-analysis approach (Figure 1) that has been applied in agricultural research (Luedeling and Shepherd 2016).

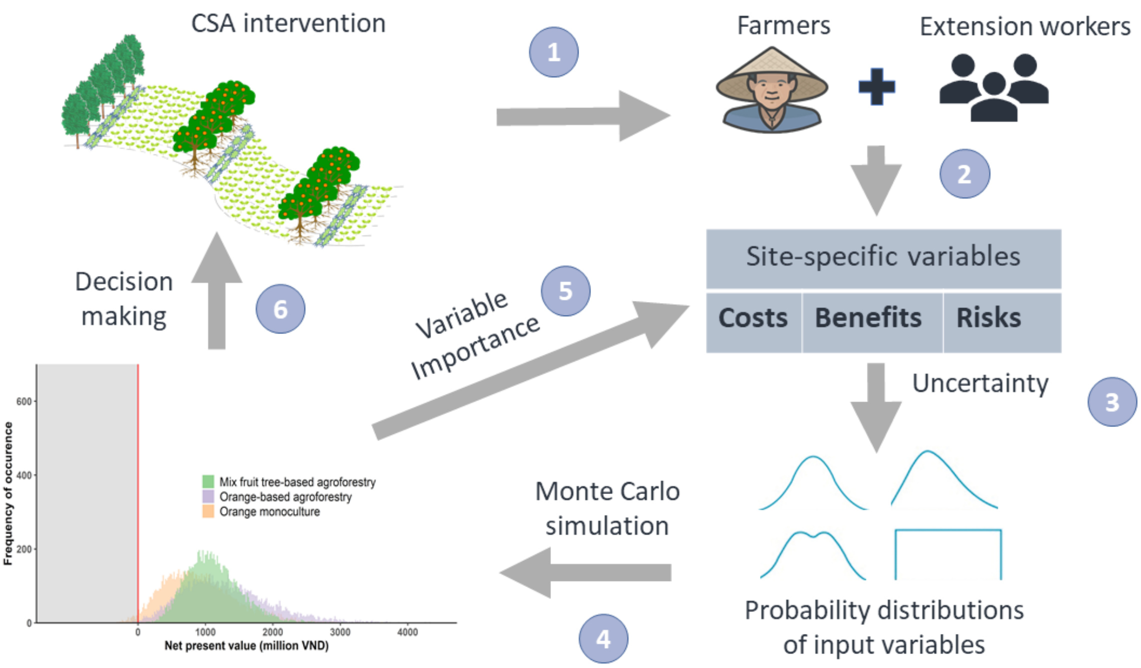

Figure 1. Decision-analysis procedure for climate-smart agricultural (CSA) intervention assessment (adapted from Do et al 2020)

COST–BENEFIT ANALYSIS METHODOLOGY

METHOD

The key informants were farmers and extension workers who had trialled new farming practices as part of the Support to Viet Nam for the Implementation of the Paris Agreement in Ha Tinh project's framework. We talked face to face with five fruit-tree farmers, two onion farmers, five beekeepers, three farmers who had fishponds and four extension workers. In addition, we used references provided by the extension workers to conceptualize system components (costs, benefits and risks) and derive estimates for system inputs in later stages.

Steps in the cost-benefit analysis:

1. In collaboration with key informants, we first identified all the costs, benefits and risks associated with the implementation of each practice.

2. Risk and uncertainty were quantified in the mathematical system.

- Risks were quantified in the system by simulating the likelihood of the risk events (values ranged 0–1, in which 0 indicates that the event will not occur and 1 represents certainty that the event will occur) and the consequences of risks to farm-scale outcomes given risk events. In all the systems, the main consequences were calculated as decline in agricultural yield compared to those in normal years.
- Uncertainty surrounding system parameters is formally represented by expressing all variables as probability distributions. The probability distributions expressed a 90% confidence interval and distribution shapes. The intervals were specified with lower (5th percentile) and upper bounds (95th percentile), derived from estimations by key informants and literature. Given the ranges, there was a 5% chance that the value was below the lower bound and a 5% chance that the value was above the upper bound. The systems used two different distribution shapes: 1) 'posnorm' is a normal distribution truncated at 0 (only positive values allowed); and 2) 'tnorm_0_1' is a truncated normal distribution that can only have values between 0 and 1 (0 and 1, as well as numbers outside this interval are not permitted as inputs) (Luedeling et al 2021).

3. We then assessed the performance of each new farming practice by calculating plausible ranges of economic profits. The profit was simulated as the net benefit over a specific period. The net benefit was calculated as the total cost subtracted from the revenue generated.

For the intervention with short-term planning and low establishment costs, such as onion–mung bean rotation, net values (NVs) were used during evaluation using the following formula:

$$NV = \sum_{i=1}^{t}(C_i - R_i)$$

C = cost at year i

R = revenue at year i

t = time

For long-term interventions with large initial investment costs, such as aquaculture and agroforestry, we applied a discount factor to the net value and converted it into Net Present Values (NPVs). The formula for NPV is written as:

$$NPV = -C_0 + \sum_{i=1}^{t}\frac{C_i - R_i}{(1+r)^i}$$

C_0 = establishment cost

C_i = implementation cost at year i

R_i = revenue at year i

r = discount rate

t = time of simulation

4. Lastly, to assess how uncertain values contributed to the system outputs, we performed a sensitivity analysis using a Partial Least Squares (PLS) regression. The results of the PLS regression were presented as Variable Importance in Projection (VIP) scores for each input variable. Input variables with a larger VIP (> 0.8) (Luedeling et al 2015) are the most relevant for explaining the outcome. The variables with VIP > 0.8 indicate important factors for further allocation of research efforts when decision makers are reluctant under the current status of information provided by the systems.

System coding and probabilistic simulation were implemented in R programming language (R Core Team 2019) using the decisionSupport package (Luedeling et al 2021). A Monte Carlo simulation was used to implement the mathematical calculation of the ranges, which is problematic with traditional calculating spreadsheets (Hubbard 2014). The calculation of system outputs was performed for many iterations (10,000 system runs) to obtain a set of values instead of single estimates (Arunraj et al 2013).

Limitations of cost–benefit analyses: Cost–benefit analyses in this study only considered tangible costs and profits associated with each practice. The system may omit intangible values (for example, social, environmental and ecological benefits) of implementation. Evidence regarding these benefits should be monitored and recorded with consistent follow up.

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