Portfolio of Climate-Smart Agriculture Practices for scaling

World Agroforestry Centre

CGIAR

RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

CCAFS

ORANGE-BASED AGROFORESTRY SYSTEM

Permanent tree and grass covers help store carbon, reduce surface runoff, and prevent soil erosion. With the appropriate layout, an orange-based system can be implemented in various landscapes—from flat to undulating terrains—as well as in home gardens for microclimate regulation and income diversification.

1. CSA PRACTICE

Components

- ❑ Grafted orange: Chanh, Bu, V2
- ❑ Grass: *Arachis pintoi* and/or Guinea grass
- ❑ Seasonal annual crops for the first 2-3 years: peanut, bean, vegetables, ginger

Technologies

- ❑ Contour plantation of orange, spaced 4x5 m
- ❑ Taungya cropping
- ❑ Grass strips, spaced 40x50 cm
- ❑ Drip irrigation, mulching
- ❑ Composting

3. FARMER BENEFITS

- ❑ ***Year 1*:**
  - ○ Diversified food and feed
  - ○ Increased water use efficiency
- ❑ ***Year 2***:
  - ○ Increased recycling of crop residues
  - ○ Reduced direct soil evaporation
- ❑ ***Year 3***: Reduced soil erosion
- ❑ ***Year 4***: Net return from initial investment
- ❑ ***Year 5***:
  - ○ Reduced reinvestment cost for a new planting cycle if planting short-term plants
  - ○ Reduced burning of residues
  - ○ Increased tree cover
  - ○ Increased above-ground biomass
- ❑ ***Year 6-16***:
  - ○ More consistent income
  - ○ Higher average annual income
  - ○ Darker soil, improved soil nutrient levels

4. RISKS

- ❑ Shift in local market prices of oranges
- ❑ Natural hazards: frost, heavy rains, and storms

2. CSA INDICATORS

Food Security

- ❑ Diversified products
- ❑ Increased income in Year 5
- ❑ Diversified livelihoods/increased livelihood resilience

Adaptation

- ❑ Reduced direct soil evaporation
- ❑ Increased water use efficiency

Mitigation and Environmental Services

- ❑ Reduced soil erosion
- ❑ Increased recycled crop residue/reduced burning of crop residue
- ❑ Increased tree cover
- ❑ Increased above-ground biomass
- ❑ Improved soil nutrient levels

5. SCALING CONSIDERATIONS

- ❑ ***Soil*:** Fluvisols, humic and rhodic ferralsols, pH 5.5 to 6.5
- ❑ ***Slope*:** <15°
- ❑ ***Moisture:*** Rainfall from 1000-2000 mm year^{-1}, drip irrigation if needed, ensure proper drainage at all times
- ❑ ***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 organizing farmer groups or cooperatives
- ❑ ***Enabling policies*:**
  - ○ NQ 90/2014/NQ-HDND, Resolution of Ha Tinh Provincial People's Council
  - ○ QĐ 853/2012/QĐ-UBND, QĐ 1373/2014/QĐ-UBND, QĐ 59/2015/QĐ-UBND and QĐ 05/2017/QĐ-UBND, Decisions of Ha Tinh Provincial People's Committee
  - ○ QĐ 6465/2016/QĐ-UBND, Decision of Ky Anh District People's Committee
  - ○ NQ 01/2016/NQ-HĐND, Resolution of Ky Anh District People's Council

ORANGE-BASED AGROFORESTRY SYSTEM
COST AND BENEFIT ANALYSIS (CBA)

The CBA was estimated over a 16-year period for acacia with rotations every 4 years, spaced 1x1m, and over 16 years for both cassava and orange.

COSTS: Drip irrigation for an orange-based mixed system was included in the initial cost. All input costs such as seeds/seedlings, fertilizers and pesticides, and labour were taken into account and were based on the literature and local estimates. Initial investments for *Arachis pintoi* and guinea grass are estimated at VND 8,500 m^{-2} and VND 370 m^{-2}, respectively.

BENEFITS: The Net Present Value accounted for 16 years of orange-based system (VND 1,020 million ha^{-1}) was 8.6 times and 19 times higher than acacia-based (VND 118 million ha^{-1}) and cassava monoculture (VND 53 million ha^{-1}), respectively.

The establishment cost for the orange-based system can be reduced by intercropping annual crops or grass which is then continuously used for animal fodder. Farmers invest in establishment cost once every 16 years for an orange-based system, while they reinvest 4 times for acacia and 16 times for cassava over the same time period.

Grass strips can produce an additional 40-60 tons ha^{-1} $year^{-1}$, which is sufficient to feed 3 cattle heads (La et al., 2017) or 150 tons ha^{-1} $year^{-1}$ of *Arachis pintoi* with high crude protein and dry matter digestible fodder for livestock (Ngome *et al.*, 2010; NOMAFSI, 2007). In mixed systems, guinea grass strips can reduce soil erosion by 23-90% (La *et al.*, 2017) while *Arachis pintoi* forms a dense mat of rooted stolons that reduce weed invasion and soil loss by 50-80%, improve soil moisture by up to 15% (NOMAFSI, 2007), and improves soil fertility through nitrogen fixation (NOMAFSI, 2007; Thomas *et al.*, 1997).

CBA estimates are influenced by factors such as weather, topography, fruit variety, and supply and demand. Here, we assumed the lowest market price for orange to be VND 20,000 kg^{-1}. The actual price in Ha Tinh ranged between VND 20,000-100,000 kg^{-1} from 2015 to 2017.

Table 1. Net Present Value (NPV) of orange-based, acacia-based and cassava practices over a 16-year period with a 6.5% discount rate

Unit: million VND ha^{-1}

PRACTICE	Orange-based system*	Cassava	Acacia-based
Initial investment	110	10	16
Total profit	1,945	85	215
Average annual profit	121	7	13
NPV	1,020	53	118

* *Orange + peanut/mung bean + Arachis pintoi or Guinea grass*

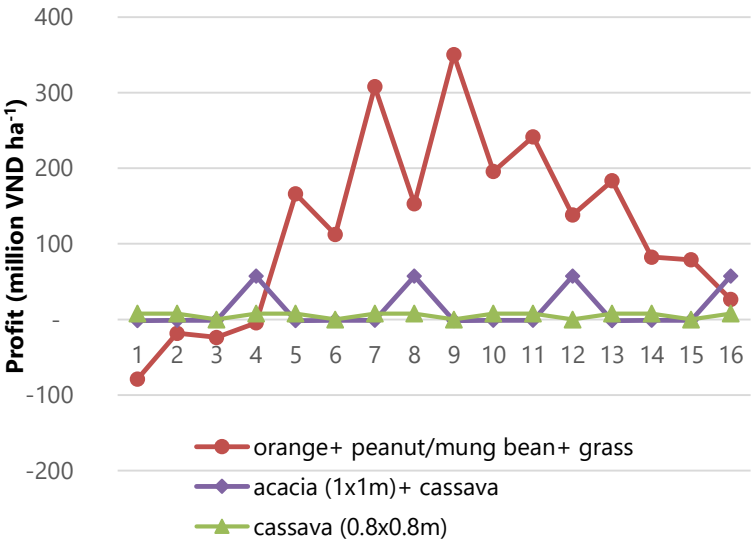

Figure 1. Profit by year for orange-based, acacia-based and cassava models

Note: *In Years 1 and 2, peanut (spring) and mung bean (autumn) are intercropped with orange. Grass strips and crops are planted 1 m from the tree bases, in at least the first and second year.*

REFERENCES

La *et al.*, 2017. Final report: Agroforestry for Livelihoods of Smallholder Farmers in Northwest Vietnam. ACIAR, Canberra, Australia. Available online at http://aciar.gov.au/files/fst-2010-034_final_report.pdf

Ngome *et al.*, 2010. Research note: Establishment, biological nitrogen fixation and nutritive value of Arachis pintoi (CIAT 18744) in western Kenya. Tropical Grasslands. 44(4)289–294

NOMAFSI, 2007. Báo cáo "Nghiên cứu, đánh giá khả năng che phủ, bảo vệ, cải tạo đất và xây dựng quy trình trồng cây lạc che phủ lưu niên _LD99 tại vùng miền núi phía bắc". Viện Khoa học kỹ thuật Nông Lâm nghiệp miền núi phía bắc (NOMAFSI)

Thomas *et al.*, 1997. Nitrogen fixation by three tropical forage legumes in an acid-soil savanna of Colombia. Soil Biology and Biochemistry. 29(5-6)801–808

Contact: Elisabeth Simelton e.simelton@cgiar.org; Le Thi Tam l.tam@cgiar.org
World Agroforestry Centre (ICRAF Vietnam), 249A Thuy Khue, Tay Ho, HaNoi.

BLACK PEPPER HOME GARDEN

Home gardens in Central Vietnam offer good potential for improving its functionality by utilizing vertical and horizontal spaces. For example, black pepper can make important contributions to household incomes by selecting of appropriate planting materials and improving management. Using vermicompost or compost and choosing living trees for support can provide microclimate regulation, biodiversity and mitigation benefits.

1. CSA PRACTICE

Components

- ❑ Black pepper cuttings
- ❑ Mấc/Mức (*Wrightia annamensis*) trees
- ❑ Grass: *Arachis pintoi* in well-drained areas

Technologies

- ❑ Shade and support trees, spaced 2.5x2.5m
- ❑ Windbreak trees exposed to strong wind
- ❑ Vermicompost/compost
- ❑ Mulching with grass and crop residue from rice straw, peanut, among others
- ❑ Drip irrigation

2. CSA INDICATORS

Food security

- ❑ Increased income on Year 4

Adaptation

- ❑ Drought, heat, and shade tolerance
- ❑ Reduced direct evaporation
- ❑ Increased water-use efficiency
- ❑ Mấc tree provides shade for pepper

Mitigation and Environmental Services

- ❑ Increased recycling of agricultural and livestock residues
- ❑ Increased above-ground biomass
- ❑ Improved soil nutrient levels

3. OBSERVED BENEFITS

- ❑ ***Year 1-2***:
  - Diversified food and feed
  - Provided shade for pepper seedlings
  - Reduced direct evaporation
  - Recycled agricultural and livestock residue
  - Increased water-use efficiency
- ❑ ***Year 3***: First pepper harvest
- ❑ ***Year 4***: Net return over initial investment
- ❑ ***Year 5-10***:
  - More consistent income
  - Higher average annual income
  - Increased above-ground biomass through living trees rather than cement poles
  - Darker soil, improved soil nutrient levels

4. RISKS

- ❑ Sudden shifts in global market prices
- ❑ Natural hazards: cold spells and heavy rain

5. SCALING CONSIDERATIONS

- ❑ ***Soil:*** Fluvisols, humus-rich soils, pH 5 to 6
- ❑ ***Slope*****:** 5-10°
- ❑ ***Moisture:*** Rainfall from 1500–2500 mm, ensure water never stagnates, drip irrigation if needed
- ❑ ***Temperature:*** Optimum within 18-27 °C, suitable within 10-35 °C, avoid direct sunshine
- ❑ ***Capital:*** Relatively high initial investment required
- ❑ ***Training needs:*** Composting, nursery, pest and disease management, post-harvest processing
- ❑ ***Market opportunities:*** Guidance needed from agricultural planning office, explore possibilities of organizing farmer groups or cooperatives
- ❑ ***Enabling policies*****:**
  - NQ 32/2016/NQ-HDND, Resolution of Ha Tinh Provincial People's Council
  - QĐ 59/2015/QĐ-UBND and QĐ 05/2017/QĐ-UBND, Decisions of Ha Tinh provincial People's Committee
  - QĐ 6465/QĐ-UBND, Decision of Ky Anh District People's Committee

BLACK PEPPER HOME GARDEN
COST AND BENEFIT ANALYSIS (CBA)

The CBA was estimated over a 16-year period for black pepper home garden. This is considered as a part of an integrated home garden where pepper is planted as the main crop. The integrated home garden incorporates numerous CSA practices and is recommended for having multiple benefits for smallholder farmers.

COSTS: Drip irrigation for black pepper was included in the initial cost while input costs such as seeds/seedlings, fertilizers and pesticides, and labour were considered and based on literature and local estimates.

BENEFITS: The CBA accounted for 16 years of black pepper home garden based on different market price scenarios. The interest rate is at 0.065, with the farmer gaining profit if market price is equal to or higher than VND 67,000 kg^{-1}. The Net Present Value on this practice is VND 2,493 million, followed by VND 691 million and VND 5.5 million in three cases of market price at VND 200,000, 130,000 and 65,000 kg^{-1}, respectively.

The high establishment cost can be reduced by (1) home production of pepper seedlings and living support trees through household nursery establishment, and (2) continuous intercropping of annual crops or grass for animal fodder. Intercropping *Arachis pintoi* can give 150 tons ha^{-1} year^{-1} with high crude protein and dry matter digestibility fodders for livestock (Ngome *et al.*, 2010; NOMAFSI, 2007). *Arachis pintoi* grass can form a dense mat of rooted stolons which reduce weed invasion and soil erosion by 50-80%, improve soil moisture by up to 15% (NOMAFSI, 2007) and improve soil fertility by nitrogen fixation (NOMAFSI, 2007; Thomas *et al.*, 1997) in comparision to monoculture.

CBA estimates are influenced by factors such as weather, topography, variety, and market price. While an average yield of pepper (dried seeds) can reach 3 kg per seedling per year in Central Vietnam (Nguyen, 2016), here, we assumed yield at 0.8 kg seed year^{-1} with peak at 1-1.5 kg per seedling per year from the 6th to the 11th year. Due to the fluctuation of pepper prices from VND 70,000-200,000 kg^{-1} from 2012-2017, CBA was estimated based on three price scenarios.

Table 1. Net Present Value (NPV) of pepper home garden over a 16-year period with 3 three market prices at 6.5% discount rate

Unit: million VND ha^{-1}

PRICE	VND 67,000 kg^{-1}	VND 130,000 kg^{-1}	VND 200,000 kg^{-1}
Initial investment	265	265	265
Total profit	238	1,483	2,866
Average annual profit	15	93	179
NPV	5.5	691	2493

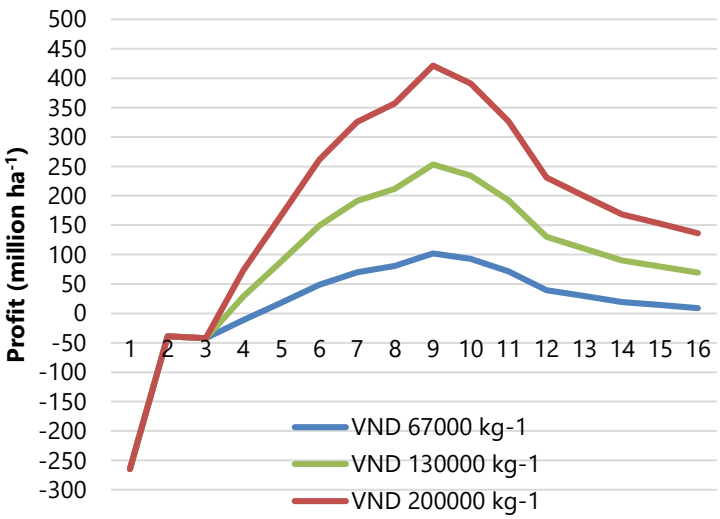

Figure 1. Profit by year of pepper home garden with 3 different market prices

INTEGRATED HOME GARDEN IMPROVEMENTS

Pepper home gardens can easily be combined with other technologies and practices such as vermiculture, composting, nursery establishment, and livestock. Timber trees can serve as shade, wind breaks, and hedges.

Adopting integrated home garden improvements can help increasing resource use efficiency (see Practice No. 4 on vermiculture) by saving production costs, reducing agro-chemicals, diversifying or increasing income and serving as a buffer during natural disasters.

REFERENCES

Ngome *et al.*, 2010. Research note: Establishment, biological nitrogen fixation and nutritive value of Arachis pintoi (CIAT 18744) in western Kenya. Tropical Grasslands. 44:289–294

Nguyen, 2016. Giống hồ tiêu. Available online at http://iasvn.org/chuyen-muc/Giong-Ho-Tieu-8195.html

NOMAFSI, 2007. Báo cáo "Nghiên cứu, đánh giá khả năng che phủ, bảo vệ, cải tạo đất và xây dựng quy trình trồng cây lạc che phủ lưu niên _LD99 tại vùng miền núi phía bắc". Viện Khoa học kỹ thuật Nông Lâm nghiệp miền núi phía bắc (NOMAFSI)

Thomas *et al.*, 1997. Nitrogen fixation by three tropical forage legumes in an acid-soil savanna of Colombia. Soil Biology and Biochemistry. 29(5-6)801–808

Contact: Elisabeth Simelton e.simelton@cgiar.org; Le Thi Tam l.tam@cgiar.org
World Agroforestry Centre (ICRAF Vietnam), 249A Thuy Khue, Tay Ho, HaNoi.

ACACIA-BASED AGROFORESTRY SYSTEM

Acacia-based agroforestry systems can be implemented in areas that are difficult to manage and hard to reach, or in areas on gently sloping land. Acacia requires little management after initial planting. It can effectively prevent soil erosion and improve moisture levels when integrated with other perennials and when harvested selectively rather than clear-cut with short-term rotations. Additionally, Acacia is a nitrogen-fixing species which improves soil fertility.

1. CSA PRACTICE

Components

- ❑ Acacia
- ❑ Cassava

Technologies

- ❑ Taungya
- ❑ Acacia initially spaced 1x1m
- ❑ Longer rotation of acacia, harvest in Year 8 and/or Year 12 for timber
- ❑ Selective cutting with 75% of acacia trees after each 4-year period

2. CSA INDICATORS

Food Security

- ❑ Diversified products/income, including cassava, pulp, and timber
- ❑ Stabilized income distribution

Adaptation

- ❑ Drought and heat tolerance
- ❑ Reduced soil evaporation

Mitigation and Environmental Services

- ❑ Increased tree cover
- ❑ Reduced burning of residue
- ❑ Increased above-ground biomass
- ❑ Reduced soil and water erosion
- ❑ Improved soil nutrient levels

3. FARMER BENEFITS

- ❑ ***Year 1***: Income from cassava
- ❑ ***Years 2-3***: Reduced direct soil evaporation
- ❑ ***Year 4***:
  - o First income from acacia
  - o Net return over initial investment
  - o Reduced burning of tree residue
- ❑ ***Years 5-8*:**
  - o Reduced reinvestment cost of acacia
  - o Reduced soil erosion
- ❑ ***From Year 8:***
  - o Higher income from timber
  - o Darker soil, improved soil nutrient levels

4. RISKS

- ❑ Natural disasters: storms, landslides, and flash floods
- ❑ Price fluctuations (selective harvest is useful during substantial price fluctuations)

5. SCALING CONSIDERATIONS

- ❑ ***Soil*:** Humic ferrasols, fluvisols, leptosols, arenosols, pH 3.5 to 5.0
- ❑ ***Slope*:** <20°, up to 20-35°
- ❑ ***Moisture*:** Optimal annual rainfall 1,600-2,100mm, suitable within 1,200-2,500 mm, ensure constant drainage
- ❑ ***Temperature:*** Optimum within 23-28°C**,** suitable within 16-32°C
- ❑ ***Capital:*** Moderate investment
- ❑ ***Training*:** Sustainable forest harvest management
- ❑ ***Market opportunities*:** High demand in Ha Tinh
- ❑ ***Enabling Policies*:**
  - o QĐ 3029/2016/QĐ-UBND, Decision of Ha Tinh Provincial People's Committee

ACACIA-BASED AGROFORESTRY SYSTEM
COST AND BENEFIT ANALYSIS

The CBA was estimated over a 12-year period for 3 different acacia-based models (spaced 1x1m initially) with rotations in 4th, 8th, and 12th years.

COSTS: The input costs, including seeds/seedlings, fertilizers, pesticides, and labour for planting and management were taken into account and were based on the literature and local estimates.

BENEFITS: The CBA estimated economic benefits from the three models, focusing specifically on farm-level returns. Rather than the commonly practiced acacia rotation cycle of 4 years, selective timber harvesting is recommended at years 4, 8, and 12. This lengthened management schedule reduces soil and water erosion by minimizing disturbances in the soil and its associated ecosystem functions. Also, a study in Indonesia showed that an increase in stand age of acacia contributes to an increase in carbon absorption (Ilyas, 2013).

The NPV model indicated that after 12 years, the 8-year and 12-year acacia management cycles yielded a return of VND 188 million ha^{-1} and VND 252 million ha^{-1} respectively, which were 2-2.5 times higher than the 4-year acacia rotation (VND 99 million ha^{-1}). The annual income from the 8-year and 12-year acacia management cycles were 2-3 times higher than the 4-year acacia cycle.

The long-term return from 8- and 12-year rotation models are compensated by intercropping cassava (year 1) and by selective harvesting at year 4 for an 8-year rotation model and both at year 4 and year 8 for a 12-year rotation model.

CBA estimates depend on factors such as weather, topography, and supply and demand. Here, we assumed the lowest market price in Ha Tinh between 2012-2016. The price for pulp is at VND 200,000 m^{-3} and VND 700,000 m^{-3} for 8-year old timber and VND 1,000,000 m^{-3} for 12-year old timber.

Table 1. Net Present Value (NPV) for acacia-based practices over a 12-year period at 6.5% discount rate

Unit: million VND ha^{-1}

PRACTICE	Model 1	Model 2	Model 3
Initial investment	16	16	16
Total profit	162	311	474
Average annual profit	13	26	39
NPV	99	188	252

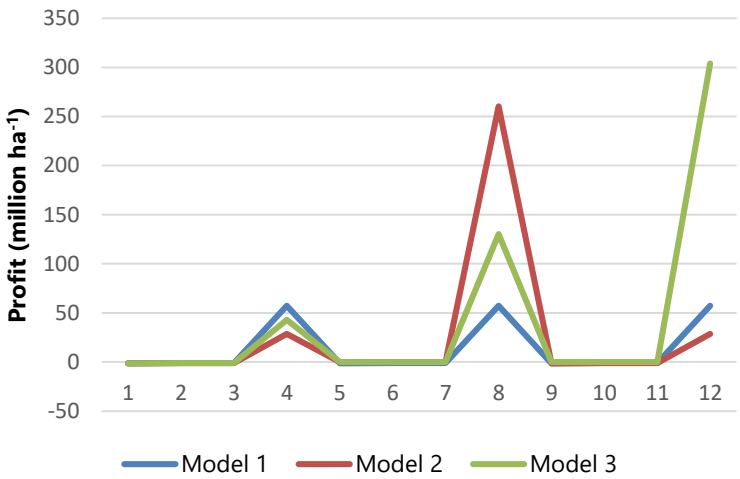

Figure 1. Profit per year for three acacia-based practices

Note: *Cassava is intercropped with acacia in Year 1 in all three models with the price of VND1000 kg^{-1}.*

- ***Model 1:*** *4-year acacia rotation, harvest all in Year 4*
- ***Model 2:*** *8-year acacia rotation, harvest 75% trees in Year 4, harvest all remaining trees at Year 8*
- ***Model 3:*** *12-year acacia rotation, harvest 75% trees in Year 4, harvest 75% of the remaining trees in Year 8, harvest the rest in Year 12*

REFERENCES

Ilyas, 2013. Allometric Equation and Carbon Sequestration of Acacia mangium Willd. in Coal Mining Reclamation Areas. Civil and Environmental Research. Available online at http://www.iiste.org/Journals/index.php/CER/article/viewFile/3862/3921

Contact: Elisabeth Simelton e.simelton@cgiar.org; Le Thi Tam l.tam@cgiar.org
World Agroforestry Centre (ICRAF Vietnam), 249A Thuy Khue, Tay Ho, HaNoi.

VERMICULTURE

Vermiculture uses earthworms to convert manure and crop residues into nutrient-rich compost material that can be used instead of inorganic fertilizers to reduce fossil fuel-based inputs. Vermijuice can be used as a bio-pesticides. The protein-rich worms can be used as animal feed for poultry or fish. Vermiculture involves an interconnected network of farm resources and is directly linked with soil health, agricultural productivity, and system resiliency. Additionally, vermiculture requires minimal investment and can be implemented with little space; thus, making it suitable for backyards and home gardens.

1. PRACTICE

Components

- ❑ Earthworm (*Perionyx excavatus)*
- ❑ Manure of cattle, pig, chicken
- ❑ Compost (decomposed mixture of crop residue and livestock manure)

Technology: Vermiculture

- ❑ Built on raised soil, or terraced slopes in flood-prone areas
- ❑ Built on shaded areas with mulching
- ❑ Bed thickness of 25-30 cm
- ❑ 8-12 kg worms with subtrates per m^2

2. CSA INDICATORS

Food security

- ❑ Improved available animal feed
- ❑ Diversified income streams
- ❑ Reduced cost for feed and fertilizer

Adaptation

- ❑ Relatively resilient to natural hazards
- ❑ Drought-tolerant when mulched and placed under tree shade
- ❑ Flood-tolerant when built on terraces or in areas with good water drainage

Mitigation and Environmental services

- ❑ Increased recycled agricultural and livestock residue
- ❑ Reduced greenhouse gas emissions from untreated manure, and inorganic NPK fertilizers
- ❑ Improved soil organic matter/soil fertility

3. FARMER BENEFITS

- ❑ ***Year 1-2***:
  - o Recycled agricultural and livestock residue
  - o Reduced greenhouse gas emissions compared with untreated manure and inorganic NPK fertilizers
  - o Improved available animal feed
  - o Diversified income from worm sales
  - o Indications of improving soil quality: plants grow faster and are greener in color; less pest-and disease-infected plants; higher crop yield and quality and texture; and better soil water holding capacity and nutrients

4. RISKS

- ❑ Worms escape when substrates dry out (can be avoided by mulching, feeding and irrigating worm subtrates once every 1-2 days during hot weather)

5. SCALING CONSIDERATIONS

- ❑ ***Slope*****:** Build on raised soil, elevated bed or terraced slopes
- ❑ ***Moisture*****:** Keep substrates at 76-83% moisture content, ensure drainage
- ❑ ***Temperature:*** Optimum within 25-30˚C, avoid direct sunshine or winds
- ❑ ***Capital:*** Low investment required
- ❑ ***Training*****:** Vermiculture management
- ❑ ***Market*****:** Organic farming, resource use efficiency
- ❑ ***Enabling policies:***
  - o NQ 32/2016/NQ-HDND, Resolution of Ha Tinh Provincial People's Council
  - o QĐ 59/2015/QĐ-UBND and QĐ 05/2017/QĐ-UBND, Decisions of Ha Tinh Provincial People's Committee
  - o QĐ 6465/2016/QĐ-UBND, Decison of Ky Anh District People's Committee

VERMICULTURE

COST AND BENEFIT ANALYSIS (CBA)

The CBA was estimated over 1 year by interviewing 3 farmers in My Loi Village, Ky Anh District, Ha Tinh Province, Vietnam. Direct financial breakdown was developed for 100 chickens, ducks, and geese to compare the value of worm feed for various poultry.

COSTS: Initial investments, maintenance, inputs in the vermiculture system, and quantifiable outputs were included. The initial worm cost is VND 50,000 (50 kg of worms with substrate per 4 m^2 enclosure). Some inputs like construction materials and worms' feed, including livestock manure and crop residues, were assumed to be available on the farm.

BENEFITS: Worm sales may occur twice annually. Farmers sell an average of 575 kg of worms with substrates per season at VND 10,000 kg^{-1}, a total of VND 11.5 million $year^{-1}$.

The worms provide supplemental protein for poultry. Farmers observed many beneficial effects from this additional protein source, including faster growth, smoother feathers, and resistance to diseases. They also noticed an increase of 5% in egg hatching rate, and the eggs from poultry fed with worms contained larger, darker yolks. Farmers perceive the darker colour as indicative of more nutritious eggs and, similarly, many consumers are willing to pay a premium for darker yolks (Stadelman, 1999). Earthworms are able to mineralize the nitrogen, phosphorous, and potassium found in organic waste and turn them into plant-available nutrients (Sinha *et al.,* 2010). The vermicompost can be used to improve soil structure, water filtration, and the overall farm productivity manifested as economic returns for the farmer. Futhermore, vermicompost can suppress pathogens in crops and inhibit fungal diseases in soils because of the beneficial microorganisms in the compost (Arancon *et al.*, 2005). Vermiculture also reduces methane emissions compared with spreading raw manure on fields (Sinha *et al.* 2014) .

The potential to scale out vermiculture practice is significant. The 3 interviewed farmers were able to share 30-50 kg each with 20 other farmers in 2 years.

Table 1. Costs and benefits from 50 kg of worms with substrates after 1 year of establishment

Unit: million VND

CBA FOR 1 YEAR	100 chickens	100 ducks	100 geese
TOTAL INPUTS	2.81	2.81	2.81
Cost to build worm enclosure	0.06	0.06	0.06
Worm subtrate	0.05	0.05	0.05
Maintenance	2.7	2.7	2.7
TOTAL OUTPUTS	13.1	14.2	15.8
Worm sales	11.5	11.5	11.5
Supplemental feed	1.6	2.7	4.3
NET INCOME	10.3	11.4	13

Table 2: Average weight of worm feed

Unit: gram

Supplemental worm feed	100 Chickens	100 ducks	100 geese
Weight of worms per day	450	750	1,175

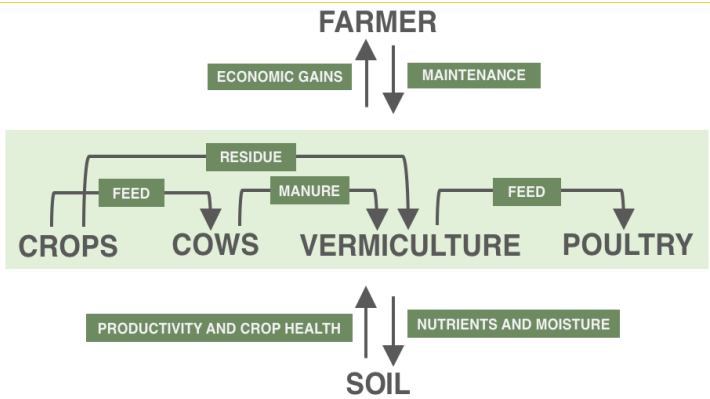

Figure 1. Vermiculture in an integrated farm system

Notes:

Two farmers managed 4 m^2 worm enclosures initially while the third had a 8 m^2 bed.

The estimated weight of each worm was 0.5 grams, according to Sinha et al. (2010).

REFERENCES

Stadelman, 1999. The incredibly functional egg. Poultry Science. 78(6)807-811

Sinha *et al.,* 2010. Vermistabilization of sewage sludge (biosolids) by earthworms: Converting a potential biohazard destined for landfill disposal into a pathogen-free, nutritive and safe biofertilizer for farms. Waste Management & Research 28(10)872-881

Sinha *et al.,* 2014. Earthworms for safe and useful management of solid wastes and wastewaters, remediation of contaminated soils and restoration of soil fertility, promotion of organic farming and mitigation of global warming: A review. Journal of Environment and Waste Management, 1(1)011-025.

Arancon *et al.*, 2005. Suppression of insect pest populations and damage to plants by vermicomposts. Bioresource Technology. 96(10)1137-1142.

Contact: Elisabeth Simelton e.simelton@cgiar.org; Le Thi Tam l.tam@cgiar.org
World Agroforestry Centre (ICRAF Vietnam), 249A Thuy Khue, Tay Ho, HaNoi.

World Agroforestry Centre

Hanoi office
Address: 13th floor HCMCC office building, 249A Thuy Khue, Tay Ho district, Hanoi, Vietnam
Phone: +84 (0)24 3783 4645
Email: icraf-vietnam@cgiar.org
Website: http://www.worldagroforestry.org/country/vietnam