Impact assessment of a local seventeen-year initiative on cassava-based soil conservation measure on sloping land as a climate-smart agriculture practice in Van Yen District, Yen Bai Province, Vietnam

Working Paper No. 308

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

Van Yen District in Yen Bai Province represents the general terrain conditions and farming systems of the northern mountainous region of Vietnam. It has suffered land degradation due to soil erosion and nutrient depletion, which in turn led to declined crop yield, and food insecurity. The district experienced these impacts due to unsustainable upland agricultural practices.

The Department of Agriculture and Rural Development realized that their previous practices would not leave anything behind for the next generations. This prompted them to launch an agricultural conservation program in 2003 to restore degraded soils, which would improve the production in the farms, and diversify incomes and the household economy of local farmers. Over the 17 years of implementation, the program has introduced six conservation measures that have been well-received and implemented by the farmers of Van Yen.

This report assesses the impacts of the 17-year program using the economic, environmental, and social lenses with a focus on the cassava crop, considering the traditional cassava monocrop system (or non-adoption group) and the six conservation measures (or adoption group). The economic impact component qualitatively looks at the differences of cassava productivity growth, stability of cassava yield, and investment of farmers. The environmental impact component investigates two major CCAFS areas, adaptation (soil infiltration rate and soil erosion) and mitigation (soil fertility and impact of pests and diseases), using qualitative and quantitative methods. The social impact component considers qualitatively the gender equity in decision making for farming practices, assessment suitability and feasibility of introduced measures, and the participation of farmers in implementation, trainings, and village meetings.

The study applied a mixed-methods approach, using semi-questionnaire to collect qualitative information from 488 farmers across six communes and surveys to collect soil samples to assess the levels of soil restoration among certain measures. The study also used the quantitative research findings from two other research studies conducted in Mau Dong Commune to help discuss its findings.

Keywords

Impact assessment; conservation agriculture; adaptation; mitigation; livelihoods.

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Acronyms and abbreviations

ARES-CCD	Académie de Recherche et d'Enseignement supérieur—Commission de la Coopération au Développement
BNF	Biological nitrogen fixation
CCAFS SEA	CGIAR Research Program on Climate Change, Agriculture and Food Security in Southeast Asia
CIAT	International Center for Tropical Agriculture
CSA	Climate-smart agriculture
DARD	Department of Agriculture and Rural Development
FP	Flagship project
NMR	Northern Mountain Region
SOC	Soil organic carbon
VNUA	Vietnam National University of Agriculture

I. Problem setting

Vietnam's agricultural sector has been impressive in recent decades as it met the country's food security goals and became a top rice exporter and coffee producer in the world. At the expense of these achievements, the country suffered environmental losses manifested in farm inefficiency, poor farmer welfare, and mediocre product quality. (World Bank, 2016).

Input- and resource-intensive strategies that prioritized maximizing yield over conserving and sustaining natural resources depleted soil nutrients (Tuan, 2015), degraded lands and significantly reduced forest cover for agricultural production (Trinh, 2007), and increased the prevalence of infectious diseases on plants and crops (Wyckhuys et al., 2017).

These issues persist in the Northern Mountain Region (NMR) of Vietnam, the country's poorest region. Due to the state's migration policy during the 1950s, farming practices had shifted from slash-and-burn agriculture (Vien, 2003; Vien et al., 2004) into non-fallow, forest clearance, and intensification and market orientation to meet the food demand of the growing population (Clemens et al., 2010).

Unsustainable management practices such as intensive farming and monocropping on steep slopes were found to be the main factor why crop yields declined, and soil fertility worsened. The study of Häring et al. (2010) in Son La Province indicated that the chemical properties of the soil declined: soil organic matter by 66%; N_t by 67%; exchangeable Ca^{2+} by 91%; Mg^{2+} by 94%; K^+ by 73%; available P by 75%; pH values by 2.2 units; and cation exchange capacity by 56% since forest clearance. Häring et al. (2013) later found a higher total soil organic carbon (SOC) loss (6–32%), a lower decomposition rate (13–40%), and a lower SOC input (14–31%). These changes in SOC dynamics happened most in the plow layer (0–10cm). Tuan et al. (2014) estimated that the soil loss due to the monocropped maize system in Yen Chau District in Son La reached 174 t ha^{-1} a^{-1}.

Studies (Loc DC et al., 1998; Vien, 2003; Vien et al. 2004; Le Doanh Q et al., 2004) have shown that conservation agriculture is the only and best way to mitigate environmental impacts (eg. Soil erosion, pest attacks), i.e. restoring soil fertility and improving crop production, leading to more local livelihood opportunities in the mountains. Effective conservation measures include grass barriers on contour lines to mitigate soil erosion; leguminous cover crops to reduce evapotranspiration, increase soil moisture to prevent pest attacks, and restore soil fertility via their biological nitrogen fixation (BNF) mechanism; and crop rotation to reduce pest/disease risks.

Studies of Tuan et al. (2015; 2014; 2012) and Ha PQ and Tuan VĐ (2006) showed that erosion was reduced from 39%–100% depending on different measures such as zero tillage, zero tillage and cover crop, and zero tillage-cover crop-grass barrier. Additional components can bring economic benefits. For example, a hectare of land with grass barrier can produce 5.5 tonnes of forage for livestock (Tuan et al. 2014) or 800 kg of cowpea (equivalent to almost USD 700 of extra income aside from the USD 1,000–1,500 income from cassava) as recorded in Van Yen District in the 2017 season by the CGIAR Research Program on Climate Change, Agriculture and Food Security in Southeast Asia (CCAFS SEA).

Realizing the prerequisites for change, the district government of Van Yen in the province of Yen Bai launched a sustainable upland initiative in 2003 (Figure 1). The initiative envisioned a long-term implementation of conservation agriculture on sloping cassava plantations. The initial intervention in 2003 was to cover 1,000 hectares a year and establish contoured strips of forage grass, green manure, and cassava stems to mitigate soil erosion and restore soil quality. Ten years later, Van Yen introduced intercropped legumes as the second practice to improve soil fertility and generate extra income. Since 2016, the International Center for Tropical Agriculture (CIAT) and the Vietnam National University of Agriculture (VNUA) collaborated to research Van Yen, where one assessment was on the triple-win solution of intercropping legumes. The solution included restoring degraded soils, improving cassava yields, and controlling the population build-up of herbivorous mites in cassava plantations. These are all conducted under the frameworks of the CIAT-led CCAFS project and VNUA-led project funded by Belgium’s Académie de Recherche et d'Enseignement supérieur - Commission de la Coopération au Développement (ARES-CCD).

The research team found out that this local initiative could be considered climate-smart and could provide the scientific tools to create more science-based evidence for the adoption and scaling of climate-smart agriculture (CSA). Data sets of three seasons (CIAT & VNUA, 2016, 2017, and 2018) proved this triple-win solution.

CCAFS (Project P1596) in Southeast and specifically, in Vietnam, was extended until 2021 primarily to scale CSA through policy uptake. Given the significant role of VNUA in this project, its research team aimed to assess the successful implementation of this local initiative for 17 years.

This study presented an exemplar on how a local initiative and an effective top-down approach with successful local synergies could boost the resilience of agriculture against climate change. Its findings also provided critical insights for CCAFS SEA to discover pathways in generating impacts and outcomes through multi-level policy approaches supported by strong scientific evidence. The VNUA team collaborated with CCAFS SEA in conducting this study and publishing an international scientific publication on agricultural policy.

II. Research Objectives and Methodology

Research objectives

Overall objective

To implement an impact assessment study on the triple-win solution (economic, social, and environmental) of a 17-year local initiative promoting conservation agriculture, focusing on contoured forage barriers on sloping cassava plantations. The study covered the period 2002–2019, wherein 2002 was the baseline year before the start of the intervention in 2003.

Specific objectives:

i. **To assess the economic impacts of the initiative:** The study differentiated agricultural economic aspects from two periods (2002 and 2003–2019), including cassava productivity growth, cassava yield stability, and cassava investment.

ii. **To assess the social impact of the initiative:** The team looked for possible improvements in gender equity at the family-level decision-making to select farming measures and conducted a social assessment of suitability and feasibility of conservation measures to local farming systems, level of family-based participation in implementing conservation measures, and social inclusion in technical trainings and village meetings.

iii. **To assess the environmental impacts on climate mitigation (carbon sequestration):** The study assessed the changes in soil fertility of conservation and non-conservation fields, including organic carbon (C_{org}) and total nitrogen (N_t).

Methodology

Site selection

Van Yen District (Figure 1), with a total natural area of 1,390 km^2 and a population of 124,153 people, is found in the north of Yen Bai Province. It houses 26 communes and one town, wherein 13 communes (Figure 1c) have cassava plantations occupying almost 5,900 ha out of the 26,000 ha of agricultural land (Van Yen Statistics, 2017). These communes are Mau Dong, Dong Cuong, An Binh, Lam Giang, Quang Minh, Lang Thip, Yen Hung, Yen Thai, Chau Que Thuong, Dong An, Ngoi A, Chau Que Ha, and Tan Hop.

This study categorized the communes into three groups, with each group having two communes each. Group 1 consists of Mau Dong and An Binh; Group 2 has Quang Minh and Lang Thip, and Group 3 has Ngoi A and Chau Que Ha. There are two sets for the groups, with one set being situated in the upper northwest while the other one is in the central north of the district. One set has an average natural area per commune that is remarkably smaller than that in the other set (Figure 1c). This selection enabled the research team to investigate how communal size matters to policy implementation and in turn performance aside from other identical sets of criteria of impact assessment. A set of site selection criteria is presented in Table 1.

Data collection

Secondary data and information

- Soil database for environmental impact assessment. Due to limited budget, secondary soil data were collected only in Mau Dong, Dong Cuong, and An Binh. The team inherited the secondary soil data from the CCAFS FP2.1 of CIAT and the ARES-CCD of VNUA.

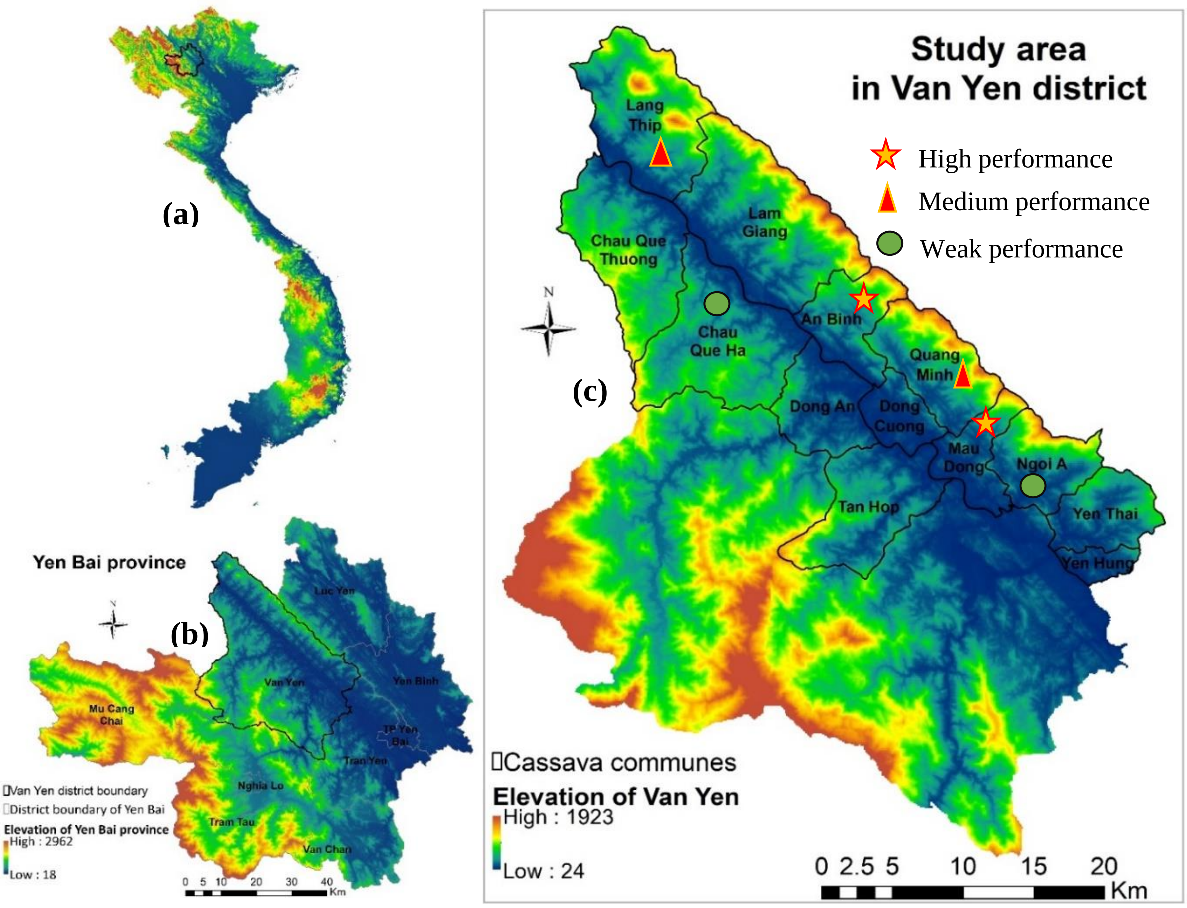

Figure 1. Study area in Van Yen district (c), Yen Bai province (b) of the NMR of Vietnam (a) Out of 26 communes and 01 town of Van Yen, 13 communes (c) have cassava plantations

Table 1. Criteria for selecting sites based on their proximity to the town center[1]

No.	Selection criteria	Group 1 (High performance)	Group 2 (Medium performance)	Group 3 (Low performance)
1	**Research budget**	Due to limited budget, especially related to compensation of farmers' time, cost for travels, and high support for enumerators, the study could only investigate 6 out of 13 communes with cassava plantations in Van Yen District		
2	**Annual performance**	Over completed annual plan with 100–120 hectares of monocrop cassava converted to conservation agriculture with contoured grass Cassava yields are between 35–40 tonnes/ha Good cassava-based livelihoods	Completed annual plan with 20–80 hectares of monocrop cassava converted to conservation agriculture with contoured grass Cassava yields are between 30–35 tonnes/ha Shifting towards cassava-cinnamon intercrop	Under completed annual plan with 80% completion Cassava yields are between 20–25 tonnes/ha Focused more on cinnamon and off-farm work
3	**Geographical location (distance from the district center)**	10-20 km from the district center	10-35 km from the district center	Over 40 km from the district center
4	**Ethnicity**	Highest percentage of Kinh[2] population (66–76%); less ethnic population (eg. Tay, Dao….)	Medium percentage of Kinh population (50–64%); less ethnic population (eg. Tay, Dao….)	Lowest percentage of Kinh population (34–43%); more ethnic population (eg. Tay, Dao….)
5	**Level of understanding and education**	Equally high level of understanding and education, mainly from the Kinh group	Equally high level of understanding and education, mainly from the Kinh group	Lower level of understanding and education, mainly because of higher ethnic population
6	**Result assessment regarding the implementation of the local initiative since 2003**	Before 2003, farmer practice was mainly utilized Since 2003, farmers have been following strict extension and technical recommendations on fertilizer application, establishment of grass contours, and cut-and-carry livestock production. Farmers can live well on cassava and cut-and-carry livestock production	Farmers have become more active in following extension and technical guidance to maintain the cassava-grass contour system to conserve soils and improve household incomes. However, there is still a dependence on government support. Some farmers are shifting cassava to tree crops, such as cinnamon, hoping to have more income.	Cassava is becoming a less important income component for a shift to other sources, such as tree crops, off-farm work (eg. construction worker, and daily labor work). This is because farmers are not interested in practicing this conservation measure and communal leaders are not putting enough effort in implementing the district's initiative.

[1] Information and performance evaluation for site selection provided by Van Yen extension station

[2] Kinh is the major group accounting for 86.2% of Vietnam's population. They are known for having higher level of understanding and education

Statistical data and information of Van Yen from the General Statistics Office, Department of Agriculture and Rural Development (DARD), and Extension station. Part of these data are used as a baseline for the study. Examples of data and information needed in this study were:

- Biophysical data: climatic (rainfall, temperature), cultivated area, seasonal and annual crop yields, and soils and water, among others.
- Socio-economic data: ethnicity, annual total production and market price, annual expanded cassava area, and adoption rate, among others. There are two types of data: secondary and primary. Secondary data are collected from the district level (DARD, Extension Department) and the communal level. Primary data are collected at the household level (household surveys, focus group discussions, in-depth interviews) and communal and district levels (in-depth interviews).

Primary data and information

Additional soil samples were collected to make a statistically significant data set for analysis. The soil data set covers two management practices: cassava monocrop (Figure 2a) and cassava-contoured forage barrier (Figure 2b)—the first practice to be introduced by the Van Yen initiative and one of the six identified cassava-related conservation measures in the study for soil restoration compared to the traditional cassava monocropping of local farmers. Soil parameters investigated were chemical properties (total carbon C_t, total nitrogen N_t, soil pH) with samples analyzed in a soil laboratory and soil physical properties (bulk density BD, water infiltration, and soil moisture content) obtained from field measurements.

Development of different questionnaires to collect socio-economic information on household livelihoods; implementation capacity and effectiveness of farmers and local authorities; adoption rate over time; changes in knowledge and attitude; qualitative and quantitative assessment of provincial, district and communal authorities and professionals on performance levels of investigated communes; and support of the government of Van Yen in achieving objectives and outcomes.

- Semi-interview questionnaire to collect information from individual households
- Focus group discussions to collect information from groups of households and local authorities
- In-depth interview questionnaire to interview key persons or informants

Sample size for farmer interviews is determined based on the following equation of Iarossi (2006):

$$n = \frac{z^2.S^2}{e^2 + z^2.\frac{S^2}{N}}$$

n: sample size

N: total observations (population size)

z: reliability value

e: expected error

S: Standard deviation

Van Yen has 33,247 households (N), with a standard deviation (S) of 15%, reliability value (z) of 99%, and expected error (e) of 1.8%. This study then needed at least 455 households for primary data collection.

Data analysis

Quantitative statistical analysis

The study used R-statistics to analyze the soil fertility of the two (*cassava monocrop* and *cassava-contoured forage barriers*) out of seven identified management practices to prove the hypothesis stating that conservation agriculture helps restore and improve soil fertility.

Likert scale

The study used the five-level Likert scale to study people's assessments on all three aspects of the economy (productivity growth and stability, level of investment); environment (erosion, soil fertility, pests); and society (suitability of farming management practices, gender equity, participation in social unions, training sessions, and village meetings).

Descriptive statistics

It was used to describe the common characteristics of research criteria. Parameters used were average values. This was an important step for further statistical analyses such as validation and regression analysis. (Hiton, P.R., 2014).

Comparative statistical analysis

Comparative statistics (Hoaglin D.C et al., 1991) was used to compare research criteria between household types, time durations, before/after, yes/no. The results of this method usually do not show clear differences. To increase the statistical significance, the team also used a one-way ANOVA, T-test, and χ^2 test, in which:

- One-way ANOVA analysis is used to examine differences of quantitative indicators for households that apply six conservation measures on sloping land.

- T-test analysis is used to evaluate statistical significance to quantitative indicators of two main groups of non-adoption (cassava monocrop) and adoption (of the six conservation measures).
- χ^2 test analysis is used to check the differences qualitative indicators and applied for the two main groups and seven identified management practices.

Impact assessment

This is to assess specific impacts of development initiatives/programs/policies based on three criteria: economic, social, and environmental. In this study, depending on the availability of baseline data and information collected from the field and the Van Yen government, the team uses some or all the following methods from Khandker et al. (2010):

- **Temporal comparison:** applied to compare the criteria before and after the implementation of the initiative (in the year of 2003). It helps in determining temporal impacts in areas practicing the intervention.
- **Yes/No comparison:** used to measure differences between impacted areas and non-impacted areas at the same time. In this study, the team used this method to investigate households that participated in the initiative from 2003, those that joined in the second phase, and those that did not participate at all (control or farmer practice).

III. Research Results

Description of surveyed households

Table 2 shows the total number of surveyed households in the six selected communes and their distribution over the seven different cassava-related management practices identified during the field surveys (Figure 2). Only two communes (An Binh and Mau Dong) implement all seven practices; two communes (Chau Que Ha and Quang Minh) with six practices; one commune (Lang Thip) with five practices; and one commune (Ngoi A) with four practices. Since farmers in Ngoi A Commune are focused more on paddy rice and tree crop production, there are only seven households with cassava plantations.

Table 2. General information of surveyed households

Commune	Total surveyed households		Adoption of conservation measures					
		Non-adoption	Contoured forage barriers	Contoured cassava stem barriers	Contoured fallopia barriers	Contoured forage barriers + cowpea	Inter-cropped cowpea	Agro-forestry
		I	II	III	IV	V	VI	VII
An Bình	104	23	10	25	24	5	1	16
Chau Que Ha	106	53	-	20	13	2	2	16
Lang Thip	88	37	4	21	7	-	-	19
Mau Dong	91	18	26	4	11	19	7	6
Quang Minh	92	22	5	22	10	1	-	32
Ngoi A	7	2	1	2	-	-	-	2
Total	**488**	**155**	**46**	**94**	**65**	**27**	**10**	**91**

The study identified seven main management practices on hill slopes related to cassava:

1. Cassava monocrop or *non-adoption* (Figure 2a) includes cassava plots that always cultivate cassava since the last land-use change.

2. Cassava with *contoured forage barriers* (Figure 2b) includes cassava plots planted with forage barriers along contour lines. The distance between two barriers varies depending on slope gradients. The average distance is 15 m. Forage is used as feed for livestock such as cows, buffalos, goats, or fish.

3. Cassava with *contoured cassava stem barriers* (Figure 2c) includes cassava plots where farmers have built erosion fences using cassava stems after harvesting. The average distance between the two barriers is 15 m.

4. Cassava with *contoured fallopia barriers* (Figure 2d) includes cassava plots planted with leguminous fallopia species to mitigate soil erosion and restore soil fertility. Fallopia cannot be used as livestock feed.

5. Cassava with *contoured forage barriers and (intercropped) cowpea* (Figure 2e) includes cassava plots planted with forage barriers along contour lines and intercropped with cowpea. A row of cowpea is planted in between two rows of cassava. Aside from its biological nitrogen fixation (BNF) mechanism to restore soil fertility, cowpea provides a significant additional income to the households.

6. Cassava with *(intercropped) cowpea* (Figure 2f) includes cassava plots intercropped with cowpea.

7. Cassava with *tree crops* (Figure 2g) includes cassava plots intercropped with various types of tree crops. The tree to be planted depends on the farmers' decision. Major tree crops in the investigated sites are cinnamon, acacia, and eucalyptus.

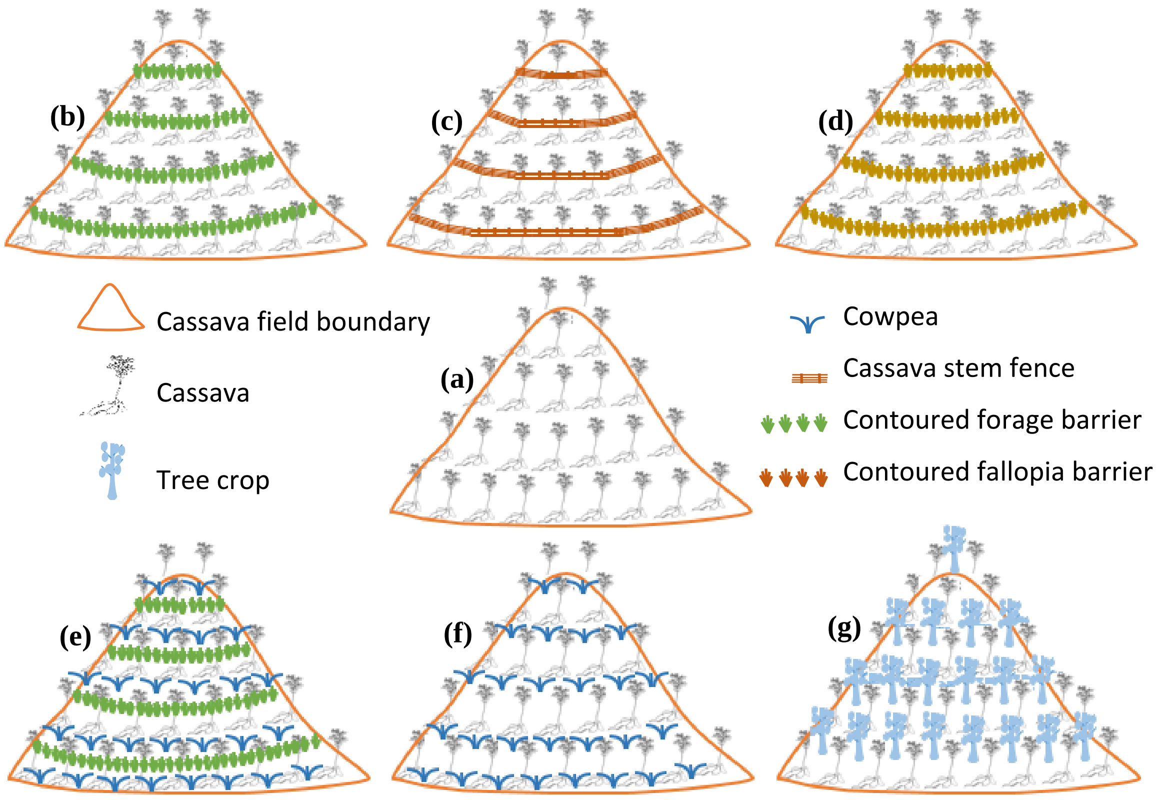

Figure 2. Cassava-related management practices identified in the study

(a) *Cassava monocrop;* **(b)** *Cassava-contoured forage barrier;* **(c)** *Cassava-contoured cassava stem fence;* **(d)** *Cassava-contoured fallopia barrier;* **(e)** *Cassava-contoured forage barrier, cowpea;* **(f)** *Cassava, cowpea;* **(g)** *Cassava, tree crops*

Appendix 1 shows the highest rate (30.68%) of the surveyed poor cassava farmers is in Lang Thip Commune while the highest rate (71.43%) of above-average/rich cassava farmers is in Ngoi A. However, this does not reveal the overall picture because there are only seven farmers in Ngoi A who still own cassava plantations. The other four communes have quite similar livelihood rankings. Mau Dong has the highest number of Kinh cassava farmers whereas four other communes (An Binh, Lang Thip, Ngoi A, and Quang Minh) have significantly high numbers of ethnic minorities. Chau Que Ha has quite an equal proportion between Kinh and other ethnic groups. In terms of education, cassava farmers in Mau Dong and Chau Que Ha have the highest educational attainment than the other four communes. Most surveyed cassava households (between 86% to 100%) are male-led. The average ages of the surveyed cassava farmers are quite similar, falling within mid to late 40 years of age.

Table 3 lists some major information of the surveyed households. The statistical results show no statistically significant differences between non-adoption and adoption of conservation measures in terms of the average family member/household, livelihood ranking (of poor/near-poor, average, and above-average/rich), total land area, education of family heads, sex of family heads. Statistically significant differences (at p-value =< 5%) are found in average number of plots (p-value = 0.040), ethnicity of households (p-value = 0.025), and average age of family head (p-value = 0.037). These values show that the adoption groups have more plots than the non-adoption group. The Kinh group tend to apply more conservation measures than other ethnic groups for having significantly higher adoption rates across the measures, and people with higher educational backgrounds tend to practice more of these measures, respectively.

Statistical comparisons show that only livelihood ranking, the ethnicity of households, and education of family heads show significant differences among the conservation measures. In *livelihoods ranking*, average households have a significantly higher adoption rate among all conservation measures compared to poor/near-poor and above average/rich households (p-value = 0.028). In *ethnicity*, farmers from the Kinh group show the highest adoption rates in four out of six measures (p-value = 0.000). In *education*, farmers that did not finish secondary school have the highest adoption rates in five out of six measures (p-value = 0.003). The *average age of the family head* in the adoption group is higher than that of the non-adoption group at the statistical significance level of p-value = 0.037.

Economic impact assessment

Cassava productivity growth

Table 4 describes the statistical breakdown analysis, using the five-level Likert scale method on farmers' feedback on cassava productivity growth between the non-adoption and adoption groups over three different categories: (i) the *first 3 years*, (ii) the *following 5 years*, and (iii) the *years after*. In all categories, the significant difference between the non-adoption and adoption groups is statistically presented by all three p-values at 1% significance. In the adoption group, cassava yield increased most significantly in the first category and leveled out in the others.

In the first category, the *cassava-intercropped cowpea* and *cassava-contoured forage barrier + cowpea* measures have the highest total increase rate (slight and much increase) of 100%, in which the *latter* one has higher significant increase (59.26% to 30%) and highest among the adoption group. The second and third categories witness reduction in the much increase indicator throughout the adoption group. There is a slight average improvement in the slight increase indicator in the second category (53.02%) compared to that of the first (52.15%). Cassava yield starts to become more stable (neutral) at this stage (34.05%) compared to that of the first category (15.18%). Nine years into the implementation of the initiative the third category has slowed down in the slight increase indicator to the second category, 32.02% to 53.02, and higher stability in yield compared to the second and first categories, 48.25% to 34.05% and 15.18%, respectively.

Yield stability

Table 5 describes the statistical analysis of farmers' responses on cassava yield stability between the non-adoption and adoption groups over three different categories using the five-level Likert scale method. In all categories, the significant difference between the groups is statistically presented by all three p-values at 1% significance. In the slightly stable and very stable indicators of the adoption group, yield stability remained most stable in the first category and started to vary in the second and third categories, i.e., 46.71% and 20.07% compared to 40.69% and 2.60% and 30.40% and 1.32% of the slightly stable and very stable, respectively. In the adoption group, yield stability of the first category can be seen highest in the *cassava-contoured forage barriers* measure with high values in both slightly stable and very stable indicators and highest value in the very stable indicator. This tendency prevails in the second and third categories and that the very stable indicator remains highest, 14.29% in both cases.

Table 3. Breakdown of analysis of surveyed households across different management practices

Category	Indicator	Unit	Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	Average	Grand Total
				Adoption of conservation measures							
			I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
Average member/ household		People	4.28	4.28	4.35	4.22	3.96	3.80	4.53	4.32	4.31
		p-value (non-adoption/adoption) = 0.8085			p-value (among conservation measures) = 0.521						
Wealth ranking	Poor/near poor	%	18.71	8.70	14.89	15.38	0.00	20.00	20.88	14.71	15,98%
	Average	%	68.39	73.91	68.09	72.31	59.26	80.00	60.44	67.27	67,62%
	Above average/ rich	%	12.90	17.39	17.02	12.31	40.74	0.00	18.68	18.02	16,39%
		p-value (non-adoption/adoption) = 0.251				p-value (among conservation measures) = 0.028					
Total land area		m^2	35.115.00	25.890.65	40.724.62	32.017.72	33.820.00	15.970.00	30.098.02	32.768.76	33.513.98
		p-value (non-adoption/adoption) = 0.410				p-value (among conservation measures) = 0.012					
Average number of plots		Piece	3.44	3.61	4.07	3.60	4.59	3.40	3.10	3.67	3.60
		p-value (non-adoption/adoption) = 0.040				p-value (among conservation measures) = 0.252					
Ethnicity of household head	Kinh	%	29.68	69.57	24.47	50.77	88.89	70.00	21.98	41.74	37,91%
	Tay	%	16.77	2.17	19.15	7.69	0.00	20.00	13.19	11.41	13,11%
	Others	%	53.55	28.26	56.38	41.54	11.11	10.00	64.84	46.85	48,98%
		p-value (non-adoption/adoption) = 0.025				p-value (among conservation measures) = 0.000					
Education of household head	Illiterate	%	19.35	4.35	17.02	16.92	0.00	10.00	24.18	15.62	16,80%
	Not finished primary	%	24.52	21.74	28.72	20.00	14.81	30.00	15.38	21.32	22,34%
	Not finished secondary	%	22.58	36.96	30.85	33.85	22.22	40.00	23.08	29.73	27,46%
	Not finished high school	%	27.10	30.43	15.96	27.69	51.85	0.00	26.37	25.53	26,02%
	High school and above	%	6.45	6.52	7.45	1.54	11.11	20.00	10.99	7.81	7,38%
		p-value (non-adoption/adoption) = 0.449				p-value (among conservation measures) = 0.003					

Percentage of male household head	%	89.68	97.83	91.49	89.23	92.59	50.00	90.11	90.39	90.16
	p-value (non-adoption/adoption) = 0.806				p-value (between conservation measures) = 0.001					
Average age of household head	years	43.87	47.20	43.52	50.15	52.85	49.80	42.59	46.02	45.33
	p-value (non-adoption/adoption) = 0.037			p-value (among conservation measures) = 0.469						

Table 4. Breakdown of analysis of cassava productivity growth from different management practices

Category	Likert scale	Non-adoption	Adoption of conservation measures							Grand Total
			Contoured forage barriers	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	Average	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
First 3 years of implementation	Much reduction	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.33	0.29
	Slight reduction	6.82	2.17	2.15	0.00	0.00	0.00	3.13	1.65	2.31
	Neutral	52.27	6.52	9.68	22.22	0.00	0.00	31.25	15.18	19.88
	Slight increase	29.55	67.39	62.37	47.62	40.74	70.00	32.81	52.15	49.28
	Much increase	11.36	23.91	24.73	30.16	59.26	30.00	32.81	30.69	28.24
		p-value (non-adoption/adoption) = 0.000				p-value (among conservation measures) = 0.001				
Following 5 years	Much reduction	0.00	0.00	1.39	0.00	0.00	0.00	0.00	0.43	0.37
	Slight reduction	17.50	7.32	2.78	0.00	0.00	0.00	23.64	7.76	9.19
	Neutral	60.00	29.27	27.78	41.03	14.29	75.00	45.45	34.05	37.87
	Slight increase	17.50	51.22	65.28	56.41	76.19	25.00	29.09	53.02	47.79
	Much increase	5.00	12.20	2.78	2.56	9.52	0.00	1.82	4.74	4.78
		p-value (non-adoption/adoption) = 0.001				p-value (among conservation measures) = 0.000				
Years after	Much reduction	2.56	2.50	0.00	5.71	0.00	0.00	1.82	1.75	1.87
	Slight reduction	48.72	20.00	14.08	2.86	4.76	0.00	25.45	14.91	19.85
	Neutral	35.90	45.00	43.66	62.86	33.33	66.67	50.91	48.25	46.44
	Slight increase	5.13	22.50	40.85	28.57	57.14	33.33	20.00	32.02	28.09
	Much increase	7.69	10.00	1.41	0.00	4.76	0.00	1.82	3.07	3.75
		p-value (non-adoption/adoption) = 0.000				p-value (among conservation measures) = 0.011				

Table 5. Breakdown of analysis of yield stability of different management practices

Category	Likert scale		Adoption of conservation measures							Grand Total
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	**Average**	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
First 3 years of implementation	Very unstable	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.33	0.29
	Slightly unstable	11.36	2.17	2.15	0.00	3.70	0.00	12.31	3.95	4.89
	Neutral	61.36	26.09	30.11	30.16	7.41	30.00	36.92	28.95	33.05
	Slightly stable	25.00	56.52	51.61	49.21	51.85	50.00	27.69	46.71	43.97
	Very stable	2.27	15.22	15.05	20.63	37.04	20.00	23.08	20.07	17.82
		p-value (non-adoption/adoption) = 0.000				p-value (among conservation measures) = 0.014				
Following 5 years	Very unstable	0.00	2.44	1.41	0.00	0.00	0.00	0.00	0.87	0.74
	Slightly unstable	17.50	17.07	11.27	7.69	0.00	25.00	30.91	15.58	15.87
	Neutral	67.50	48.78	36.62	41.03	23.81	0.00	47.27	40.26	44.28
	Slightly stable	15.00	29.27	47.89	51.28	61.90	75.00	21.82	40.69	36.90
	Very stable	0.00	2.44	2.82	0.00	14.29	0.00	0.00	2.60	2.21
		p-value (non-adoption/adoption) = 0.010				p-value (among conservation measures) = 0.001				
Years after	Very unstable	0.00	7.50	1.41	0.00	0.00	0.00	1.82	2.20	1.88
	Slightly unstable	43.59	20.00	12.68	14.71	4.76	16.67	32.73	18.50	22.18
	Neutral	43.59	42.50	49.30	58.82	38.10	16.67	49.09	47.58	46.99
	Slightly stable	12.82	30.00	36.62	26.47	42.86	66.67	16.36	30.40	27.82
	Very stable	0.00	0.00	0.00	0.00	14.29	0.00	0.00	1.32	1.13
		p-value (non-adoption/adoption) = 0.006				p-value (among conservation measures) = 0.000				

Table 6. Breakdown of analysis of investment on different management practices

Category	Likert scale		Adoption of conservation measures							Grand Total
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	Average	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
First 3 years of implementation	Much reduction	0.00	4.35	2.15	1.59	0.00	10.00	3.13	2.64	2.31
	Slight reduction	11.36	10.87	5.38	9.52	7.41	10.00	4.69	7.26	7.78
	Neutral	56.82	28.26	44.09	52.38	22.22	30.00	43.75	40.92	42.94
	Slight increase	31.82	47.83	41.94	25.40	55.56	40.00	29.69	37.95	37.18
	Much increase	0.00	8.70	6.45	11.11	14.81	10.00	18.75	11.22	9.80
		p-value (non-adoption/adoption) = 0.048				p-value (among conservation measures) = 0.162				
Following 5 years	Much reduction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Slight reduction	12.50	21.95	28.17	7.69	19.05	0.00	14.55	19.05	18.08
	Neutral	35.00	29.27	26.76	41.03	23.81	25.00	25.45	29.00	29.89
	Slight increase	52.50	41.46	33.80	48.72	47.62	75.00	56.36	45.02	46.13
	Much increase	0.00	7.32	11.27	2.56	9.52	0.00	3.64	6.93	5.90
		p-value (non-adoption/adoption) = 0.221				p-value (among conservation measures) = 0.224				
Years after	Much reduction	2.56	0.00	0.00	5.71	0.00	0.00	0.00	0.88	1.12
	Slight reduction	5.13	17.50	28.17	2.86	19.05	0.00	10.91	16.67	14.98
	Neutral	5.13	32.50	22.54	37.14	28.57	16.67	20.00	26.32	23.22
	Slight increase	64.10	30.00	35.21	42.86	33.33	66.67	58.18	41.67	44.94
	Much increase	23.08	20.00	14.08	11.43	19.05	16.67	10.91	14.47	15.73
		p-value (non-adoption/adoption) = 0.004				p-value (among conservation measures) = 0.019				

Investment

Table 6 describes the statistical analysis of farmers' responses on investment on identified cassava-related management practices between the non-adoption and adoption groups using the five-level Likert scale method. Investment includes fertilizers, pesticides, herbicides, labor, and varieties. The significant difference in investment between the groups is statistically highest in the first and third categories presented by two good p-values of 0.048 and 0.004, respectively. On average, the non-adoption group invested less in the first category, and more in the third category than the adoption group did. In the second category, both main groups used more investment but there is no statistical significance between them.

Environmental impact assessment

Adaptation

Qualitative assessment of soil infiltration rate between conservation measures based on an argument that infiltration rate has improved in conservation measures

Table 7 presents the qualitative statistical results of the impacts of conservation measures on improved infiltration of soils, applying the Likert scale method. The farmers' feedback on this matter is very positive that all measures, except the *VII* measure, have improved soil infiltration quite remarkably. On the *agree* scale, the *V* measure receives the highest score on the Likert scale, 68%, whereas the *VII* is ranked the least effective measure with only 16.67%. The *II, III, IV, and VI* get a quite similar ranking from farmers for their performance with results falling within 45%–53%.

Table 7. Variability of soil infiltration rate applying different conservation measures

Likert scale	Adoption of conservation measures						
	Contoured forage barriers	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Inter-cropped cowpea*	*Agro-forestry*	**Average**
	II	*III*	*IV*	*V*	*VI*	*VII*	
Disagree totally	0.00	0.00	3.75	0.00	0.00	0.00	0.85
Do not agree	4.08	1.75	3.75	0.00	5.00	13.64	4.80
Neutral	10.20	7.89	5.00	8.00	5.00	43.94	14.12
Agree	32.65	41.23	35.00	24.00	45.00	25.76	34.75
Agree totally	53.06	49.12	52.50	68.00	45.00	16.67	45.48
	p-value (among conservation measures) = 0.000						

Assessment of erosion mitigation by conservation measures

Table 8 presents the qualitative statistical results of the impacts on erosion mitigation of the conservation measures, applying the Likert scale method. The farmers' feedback on this matter is very positive that all measures, except the *VII* measure, have reduced soil erosion quite remarkably.

Table 8. Variability of erosion mitigation applying different conservation measures

Likert scale	Adoption of conservation measures						
	Contoured forage barriers	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Inter-cropped cowpea*	*Agro-forestry*	**Average**
	II	*III*	*IV*	*V*	*VI*	*VII*	
Unchanged	0	0	0	0	0	0	0
Unnoticeably reduced	6.12	3.51	2.50	0.00	5.00	15.15	5.65
Slightly reduced	6.12	1.75	2.50	0.00	0.00	45.45	10.45
Obvious reduced	16.33	24.56	41.25	16.00	20.00	22.73	25.99
Much reduced	71.43	70.18	53.75	84.00	75.00	16.67	57.91
	p-value (among conservation measures) = 0.000						

Among these five erosion-effective measures, the *V* measure receives the highest score on the Likert scale, 84%, in the *much-reduced* scale. The *VII* is assessed as the least effective erosion preventive measure, with only 39.4% in total for obvious and much reduction. The *II*, *III*, and *IV* have the same function, which is providing contoured barriers to mitigate erosion; they should work equally well. However, results show that the highest Likert scale for the *IV* measure is the lowest among the three, 53.75% to 71.43% and 70.18% in *II* and *III*, respectively. The rate of the *VI* measure (not having erosion barriers) is surprisingly high, 75%.

Mitigation - Carbon sequestration

Qualitative farmers' assessment of soil quality

Table 9 presents the qualitative statistical results on the farmers' overall perceptions on soil fertility in three categories (I—*first 3 years*; II— *following 5 years*; and III— *years after*) using the five-level Likert scale method. The farmers' feedback shows a high statistical significance in soil quality variability between the non-adoption and the adoption groups. On average, 77.88% of the interviewed farmers agreed that the six conservation measures have a much higher impact on the restoration of soil quality throughout their long implementation than the traditional cassava monocropping practice. Among the conservation measures, the *V* measures receive the highest evaluation on soil quality restoration recording the highest significant increase in scale values throughout categories I (66.67%), II (28.57%), and III (4.76%). The *VII* measure has the least impact on soil quality.

Table 10 presents the qualitative statistical results of the farmers' in-depth perceptions of soil fertility in three categories (I—*better topsoil aeration*, II—*thicker plow soil layer*, and III—*darker topsoil*, an indicator for having good fertile topsoil) using the five-level Likert scale.

The farmers' feedback on this matter is very positive that all measures, except the *VII* measure, have improved soil infiltration quite remarkably. Overall, most of the interviewed farmers said that soil quality got improved by applying the *V* measure throughout all three categories with a total of 95% answers falling under the *agree* and *agree totally* scales. Surprisingly, the *IV* measure received the highest percentage of *agree totally* scale throughout categories I (80%), II (60%), and III (64%).

Quantitative assessment of soil quality between cassava monocrop and conservation measures

Figure 3 presents a one-way ANOVA quantitative analysis of soil fertility variability of organic carbon ($C_{og,}$ %) and total nitrogen (N_t, %) in two practices, *cassava monocrop* and *cassava-contoured forage barriers* (6–8 years and 12–14 years of implementation), in An Binh, one of the six studied communes.

Both analytic C_{org} and N_t values show significant differences between the *cassava monocrop* measure and the two temporal types of *cassava-contoured forage* barriers measure, in which values of the latter is remarkably higher than those of the traditional monocrop system. Between the two subcategories of the conservation measure, the differences between the two categories of 6–8 years and 14–16 years do not have high statistical significance, although both mean C_{org} and N_t values of the latter category are slightly higher than those of the first one. This case only shows a positive impact on the restoration of soil fertility of a conservation agriculture but does not prominently prove this impact in the long run.

Qualitative farmers' assessment on pests and disease

Table 11 presents the qualitative statistical results of the farmers' overall perceptions on pests and disease situations between different management practices over three temporal categories, I (*first 3 years*), II (*following 5 years*), and III (*years after*), using the five-level Likert scale. From the farmers' assessment, no statistically significant difference was recorded between the non-adoption and adoption groups in their first three years of implementing conservation measures. This difference, however, became more significant during the five years after, represented by the p-value of 0.006 at 1% significance level. After this period, this difference became less significant at 6% significance. Overall, in the adoption group, farmers evaluate the *V* measure highest in terms of mitigation of pest and disease, followed by the *VI* measure in the long run, i.e., categories II and III.

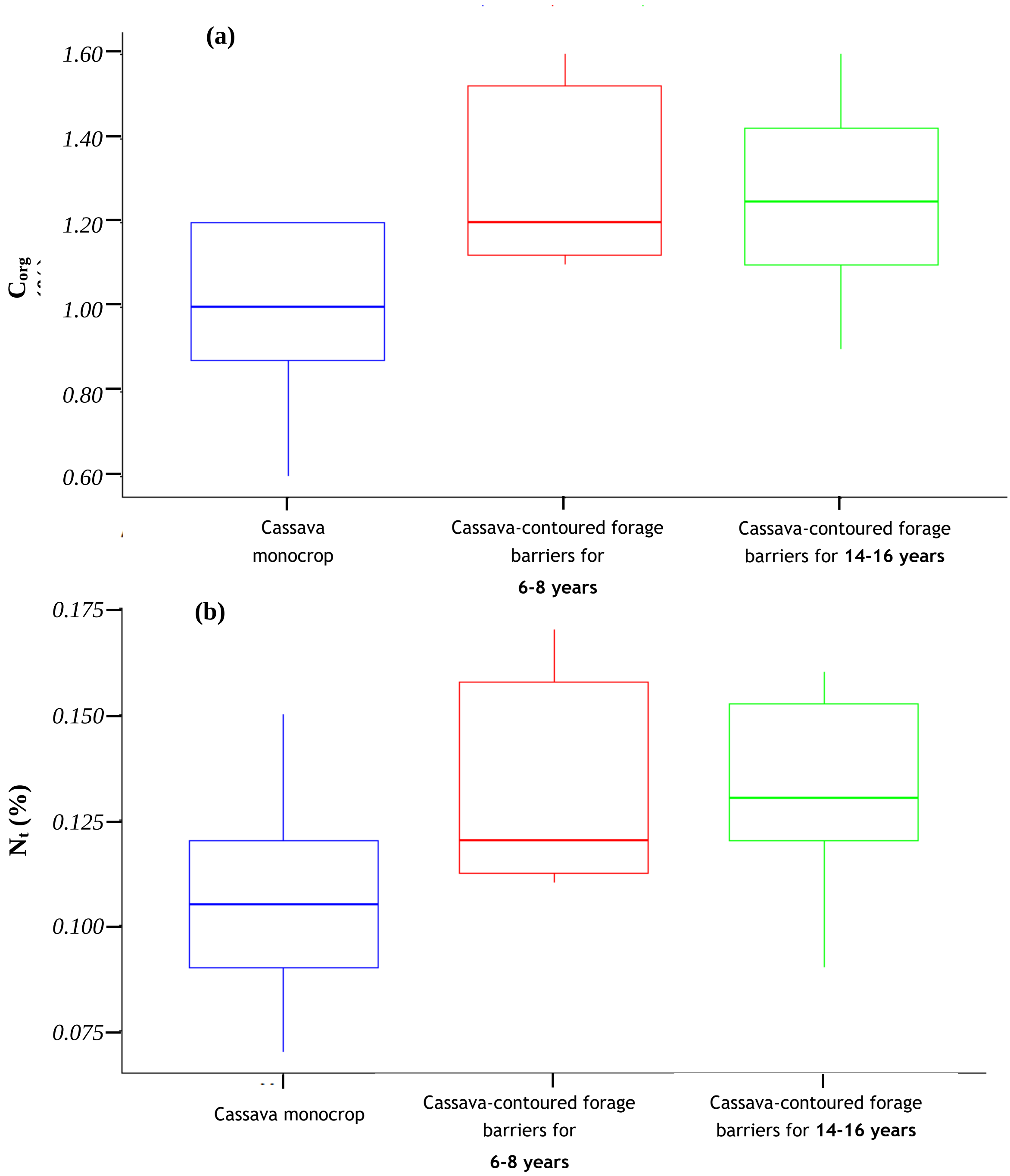

Figure 3. Variability of organic carbon Corg (a) and total nitrogen Nt (b) contents in An Binh commune between *cassava monocrop* and *cassava-contoured forage barriers*

Table 9. Breakdown of analysis of farmers' overall assessment on soil quality in all management practices over different implementation periods

Category	Likert scale		Adoption of conservation measures							Grand Total
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	Average	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
First 3 years of implementation	Significant reduction	2.27	0.00	1.08	0.00	0.00	0.00	1.56	0.66	0.86
	Slight reduction	9.09	0.00	2.15	0.00	0.00	0.00	4.69	1.65	2.59
	Neutral	59.09	19.57	21.51	11.11	14.81	10.00	29.69	19.80	24.78
	Slight increase	18.18	34.78	47.31	52.38	18.52	50.00	32.81	40.92	38.04
	Significant increase	11.36	45.65	27.96	36.51	66.67	40.00	31.25	36.96	33.72
		p-value (non-adoption/adoption) = 0.00				p-value (among conservation measures) = 0.037				
Following 5 years	Significant reduction	2.50	2.44	0.00	0.00	0.00	0.00	0.00	0.43	0.74
	Slight reduction	40.00	14.63	8.45	10.26	19.05	0.00	33.33	16.52	20.00
	Neutral	42.50	31.71	26.76	33.33	9.52	25.00	42.59	30.87	32.59
	Slight increase	15.00	46.34	61.97	53.85	42.86	75.00	22.22	46.96	42.22
	Significant increase	0.00	4.88	2.82	2.56	28.57	0.00	1.85	5.22	4.44
		p-value (non-adoption/adoption) = 0.000				p-value (among conservation measures) = 0.000				
Years after	Significant reduction	28.21	7.50	0.00	8.57	0.00	0.00	3.64	3.49	7.09
	Slight reduction	46.15	20.00	19.44	20.00	14.29	0.00	43.64	24.45	27.61
	Neutral	15.38	55.00	47.22	51.43	33.33	50.00	38.18	45.85	41.42
	Slight increase	7.69	17.50	33.33	20.00	47.62	50.00	12.73	25.33	22.76
	Significant increase	2.56	0.00	0.00	0.00	4.76	0.00	1.82	0.87	1.12
		p-value (non-adoption/adoption) = 0.000				p-value (among conservation measures) = 0.005				

Table 10. Breakdown of analysis of farmers' in-depth assessment on topsoil aeration, thickness of the plow layer, and fertility in all management practices

Category	**Likert scale**	**Adoption of conservation measures**						
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*
Better topsoil aeration	Disagree totally	0.00	0.00	3.75	0.00	0.00	0.00	0.85
	Do not agree	4.08	2.63	5.00	0.00	5.00	13.64	5.37
	Neutral	10.20	10.53	12.50	4.00	0.00	43.94	16.10
	Agree	42.86	46.49	35.00	16.00	45.00	25.76	37.29
	Agree totally	42.86	40.35	43.75	80.00	50.00	16.67	40.40
		p-value (among conservation measures) = 0.000						
Thicker plow soil layer	Disagree totally	0.00	0.00	3.75	0.00	0.00	0.00	0.85
	Do not agree	4.08	2.63	5.00	0.00	5.00	10.61	4.80
	Neutral	8.16	11.40	7.50	4.00	0.00	46.97	15.54
	Agree	40.82	43.86	40.00	36.00	55.00	25.76	39.27
	Agree totally	46.94	42.11	43.75	60.00	40.00	16.67	39.55
		p-value (among conservation measures) = 0.000						
Darker topsoil	Disagree totally	0.00	0.00	3.75	0.00	0.00	0.00	0.85
	Do not agree	4.08	2.63	7.50	0.00	5.00	15.15	6.21
	Neutral	12.24	7.02	6.25	4.00	0.00	43.94	13.84
	Agree	30.61	46.49	33.75	32.00	60.00	22.73	36.72
	Agree totally	53.06	43.86	48.75	64.00	35.00	18.18	42.37
		p-value (among conservation measures) = 0.000						

Table 11. Breakdown of analysis of farmers' perceptions on pests and disease in all management practices over different implementation periods

Category	Likert scale	Adoption of conservation measures								Grand Total
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	**Average**	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
First 3 years of implementation	Much reduction	0.00	4.35	2.15	3.17	18.52	10.00	4.69	4.95	4.32
	Slight reduction	4.55	19.57	7.53	14.29	3.70	10.00	9.38	10.89	10.09
	Neutral	88.64	63.04	70.97	69.84	44.44	80.00	79.69	69.31	71.76
	Slight increase	6.82	10.87	18.28	6.35	33.33	0.00	3.13	12.21	11.53
	Much increase	0.00	2.17	1.08	6.35	0.00	0.00	3.13	2.64	2.31
		p-value (non-adoption/adoption) = 0.097				p-value (among conservation measures) = 0.000				
Following 5 years	Much reduction	0.00	2.44	0.00	0.00	4.76	25.00	0.00	1.30	1.11
	Slight reduction	5.00	26.83	28.17	25.64	23.81	0.00	14.55	23.38	20.66
	Neutral	85.00	53.66	47.89	48.72	42.86	50.00	69.09	53.68	58.30
	Slight increase	10.00	14.63	19.72	25.64	23.81	25.00	16.36	19.48	18.08
	Much increase	0.00	2.44	4.23	0.00	4.76	0.00	0.00	2.16	1.85
		p-value (non-adoption/adoption) = 0.006				p-value (among conservation measures) = 0.020				
Years after	Much reduction	2.56	2.50	0.00	2.86	0.00	0.00	0.00	0.88	1.12
	Slight reduction	5.13	20.00	23.94	11.43	14.29	0.00	10.91	16.67	14.98
	Neutral	71.79	47.50	49.30	51.43	61.90	50.00	41.82	48.68	52.06
	Slight increase	17.95	25.00	21.13	31.43	14.29	50.00	47.27	29.82	28.09
	Much increase	2.56	5.00	5.63	2.86	9.52	0.00	0.00	3.95	3.75
		p-value (non-adoption/adoption) = 0.060				p-value (among conservation measures) = 0.173				

Social impact assessment

Gender equity in family decision making on selection of farming measures

Table 12 presents the qualitative statistical results of farmers' feedback on gender equity in family decision-making across five categories: (i) *husband*, (ii) *wife*, (iii) *husband and wife*, (iv) *children*, and (v) *others*. No statistically significant difference was recorded on who has more importance in selecting the farming practices within a family. However, husbands tend to play a more important role in deciding what measures to take based on the average percentage of almost 42%. Husband and wife making decisions together make up 35.73%. Wives making decision occupies nearly 20% only.

Table 12. Breakdown of analysis of farmers' feedback on family decision-making

Category		Adoption of conservation measures							Grand Total
	Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopian barriers*	*Contoured forage barriers + cowpea*	*Inter-cropped cowpea*	*Agro-forestry*	Average	
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
Husband	46.45	43.48	41.49	43.08	25.93	20.00	40.00	39.76	41.89
Wife	17.42	23.91	17.02	18.46	22.22	60.00	21.11	21.08	19.92
Husband and wife	32.90	30.43	41.49	32.31	48.15	20.00	37.78	37.05	35.73
Children	2.58	2.17	0.00	6.15	3.70	0.00	1.11	2.11	2.26
Others	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21

Social assessment of suitability and feasibility of conservation measures to local farming systems

Table 13 presents the qualitative statistical results of farmers' feedback on suitability and feasibility of conservation measures to their farming experience in four categories, I (*suitable with local farming practices*), II (*suitable with local farming experience*), III (*suitable with local production materials*), and IV (*techniques are not difficult*), using the five-level Likert scale. Overall, responses from the interviewed farmers about conservation measures are remarkably more positive than the traditional cassava monocrop system, shown by all four p-values at 1% significance. Among the six conservation measures, the *V* measure receives the highest agree totally levels across the four categories.

Table 13. Breakdown of analysis of farmers' evaluation on suitability and feasibility of conservation measures

Category	Likert scale	Adoption of conservation measures						
		Contoured forage barriers	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	**Average**
		II	*III*	*IV*	*V*	*VI*	*VII*	
Suitable with local farming practices	Disagree totally	0.00	0.00	0.00	0.00	5.00	3.03	0.85
	Do not agree	0.00	0.88	8.75	0.00	5.00	0.00	2.54
	Neutral	0.00	0.00	1.25	0.00	0.00	3.03	0.85
	Agree	44.90	54.39	42.50	24.00	70.00	46.97	47.74
	Agree totally	55.10	44.74	47.50	76.00	20.00	46.97	48.02
		p-value (among conservation measures) = 0.000						
Suitable with local farming experience	Disagree totally	0.00	0.00	0.00	0.00	5.00	3.03	0.85
	Do not agree	0.00	0.88	7.50	0.00	5.00	0.00	2.26
	Neutral	0.00	0.88	0.00	0.00	0.00	3.03	0.85
	Agree	46.94	54.39	42.50	20.00	65.00	46.97	47.46
	Agree totally	53.06	43.86	50.00	80.00	25.00	46.97	48.59
		p-value (among conservation measures) = 0.001						
Suitable with local production materials	Disagree totally	0.00	0.00	0.00	0.00	5.00	3.03	0.85
	Do not agree	0.00	0.88	7.50	0.00	5.00	0.00	2.26
	Neutral	2.04	0.00	1.25	0.00	0.00	3.03	1.13
	Agree	42.86	54.39	46.25	24.00	65.00	46.97	48.02
	Agree totally	55.10	44.74	45.00	76.00	25.00	46.97	47.74
		p-value (among conservation measures) = 0.003						
Techniques are not difficult	Disagree totally	0.00	0.00	1.25	0.00	5.00	4.55	1.42
	Do not agree	6.25	1.75	5.00	4.00	0.00	0.00	2.83
	Neutral	2.08	0.00	0.00	0.00	0.00	7.58	1.70
	Agree	29.17	39.47	50.00	20.00	45.00	57.58	42.78
	Agree totally	62.50	58.77	43.75	76.00	50.00	30.30	51.27
		p-value (among conservation measures) = 0.000						

Table 14. Breakdown of analysis of farmers' feedback on family-based participation in implementing conservation measures

Category	Likert scale	Adoption of conservation measures								Grand Total
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	Average	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
Husband	Totally not	5.83	0.00	3.03	8.51	0.00	20.00	5.17	4.18	4.68
	Rarely	7.77	5.26	1.52	8.51	4.00	20.00	13.79	7.11	7.31
	Sometimes	5.83	13.16	12.12	0.00	4.00	20.00	6.90	7.95	7.31
	Usually	57.28	55.26	63.64	59.57	52.00	0.00	39.66	53.14	54.39
	Always	23.30	26.32	19.70	23.40	40.00	40.00	34.48	27.62	26.32
		p-value (non-adoption/adoption) = 0.802				p-value (among conservation measures) = 0.019				
Wife	Totally not	2.33	0.00	1.19	5.08	0.00	0.00	2.44	1.99	2.09
	Rarely	5.43	2.38	0.00	8.47	0.00	11.11	7.32	4.30	4.64
	Sometimes	6.98	7.14	13.10	3.39	11.54	11.11	14.63	10.60	9.51
	Usually	58.91	64.29	67.86	57.63	42.31	22.22	47.56	56.29	57.08
	Always	26.36	26.19	17.86	25.42	46.15	55.56	28.05	26.82	26.68
		p-value (non-adoption/adoption) = 0.799				p-value (among conservation measures) = 0.018				
Son	Totally not	15.56	6.25	2.86	18.18	25.00	0.00	6.45	8.47	10.43
	Rarely	4.44	6.25	5.71	4.55	12.50	16.67	19.35	10.17	8.59
	Sometimes	15.56	62.50	11.43	13.64	37.50	33.33	12.90	22.03	20.25
	Usually	48.89	25.00	68.57	50.00	0.00	16.67	41.94	44.92	46.01
	Always	15.56	0.00	11.43	13.64	25.00	33.33	19.35	14.41	14.72
		p-value (non-adoption/adoption) = 0.459				p-value (among conservation measures) = 0.001				
Daughter	Totally not	25.00	10.00	0.00	40.00	0.00	0.00	5.88	9.38	14.13
	Rarely	0.00	0.00	0.00	0.00	11.11	0.00	35.29	10.94	7.61
	Sometimes	21.43	40.00	20.00	10.00	11.11	0.00	29.41	21.88	21.74
	Usually	35.71	50.00	60.00	40.00	55.56	0.00	23.53	42.19	40.22
	Always	17.86	0.00	20.00	10.00	22.22	100.00	5.88	15.63	16.30
		p-value (non-adoption/adoption) = 0.153				p-value (among conservation measures) = 0.000				
Others	Totally not	23.33	20.00	0.00	33.33	0.00	0.00	28.57	19.05	20.83

	Rarely	0.00	0.00	0.00	0.00	0.00	0.00	7.14	2.38	1.39
	Sometimes	10.00	40.00	30.00	11.11	0.00	0.00	14.29	19.05	15.28
	Usually	40.00	40.00	50.00	22.22	100.00	100.00	35.71	42.86	41.67
	Always	26.67	0.00	20.00	33.33	0.00	0.00	14.29	16.67	20.83
		p-value (non-adoption/adoption) = 0.613				p-value (among conservation measures) = 0.675				

Table 15. Breakdown of analysis of social inclusion in terms of technical trainings and village meetings

Category	Likert scale		Adoption of conservation measures							Grand Total
		Non-adoption	*Contoured forage barriers*	*Contoured cassava stem barriers*	*Contoured fallopia barriers*	*Contoured forage barriers + cowpea*	*Intercropped cowpea*	*Agroforestry*	Average	
		I	*II*	*III*	*IV*	*V*	*VI*	*VII*		
Being invited to trainings	Never	40.00	28.26	34.04	25.40	18.52	20.00	60.44	37.16	38.07
	Sometimes	34.19	30.43	25.53	30.16	14.81	70.00	19.78	25.98	28.60
	50%	3.23	0.00	4.26	9.52	11.11	0.00	4.40	5.14	4.53
	Almost	22.58	36.96	35.11	30.16	40.74	10.00	10.99	27.49	25.93
	Everytime	0.00	4.35	1.06	4.76	14.81	0.00	4.40	4.23	2.88
		p-value (non-adoption/adoption) = 0.025				p-value (among conservation measures) = 0.000				
Village meeting attendance	Never	7.74	2.17	0.00	1.59	0.00	0.00	3.30	1.51	3.50
	Sometimes	16.77	23.91	18.09	7.94	11.11	40.00	10.99	15.11	15.64
	50%	12.26	10.87	9.57	1.59	3.70	0.00	7.69	6.95	8.64
	Almost	38.71	47.83	47.87	60.32	44.44	20.00	52.75	50.45	46.71
	Everytime	24.52	15.22	24.47	28.57	40.74	40.00	25.27	25.98	25.51
		p-value (non-adoption/adoption) = 0.001				p-value (among conservation measures) = 0.086				
Training attendance	Never	25.81	21.74	26.60	19.05	22.22	20.00	54.95	31.72	29.84
	Sometimes	24.52	34.78	25.53	26.98	14.81	30.00	10.99	22.36	23.05
	50%	18.06	10.87	15.96	7.94	14.81	0.00	5.49	10.27	12.76
	Almost	29.03	28.26	28.72	34.92	25.93	20.00	21.98	27.49	27.98
	Everytime	2.58	4.35	3.19	11.11	22.22	30.00	6.59	8.16	6.38
		p-value (non-adoption/adoption) = 0.020				p-value (among conservation measures) = 0.000				

Level of family-based participation in implementing conservation measures

Table 14 presents the qualitative statistical results of farmers' feedback on family-based participation in implementing conservation measures across four categories, I (*husband*), II (*wife*), III (*son*), and IV (*daughter*), using the five-scale Likert method. This analysis aims to look at any differences in family members' participation in implementing the non-adoption and adoption groups. Results from the table show that no statistically significant differences are seen between the non-adoption and adoption groups for all four family members.

Social inclusion in technical trainings and village meetings

Table 15 presents the qualitative statistical results of social inclusion in technical trainings and village meetings between the non-adoption and adoption groups and across the conservation measures in three categories, I (*being invited to training*), II (*training attendance*), and III (*village meeting attendance*), using the five-scale Likert method. Results show that farmers are more interested in attending trainings and meetings on conservation agricultural practices than cassava monocrop, with all three p-values at the 5% and 1% significance levels. Within the adoption group, farmers tend to attend village meetings for the conservation measures equally; however, more attendees were recorded for technical trainings on the *IV*, *V*, and *VI* measures.

IV. Comments and recommendations

Comments of results

This section discussed the results of the study from the suitability of the study area, identified management practices related to cassava crops on sloping land to the impact assessment of Van Yen's long-term conservation program since 2003 in the economic, environmental, and social aspects. The team tried to capture an overall picture of the impacts of the program from different lenses, extensively based on farmers' feedback on semi-structured questionnaires, supported by qualitative and quantitative statistical analyses. This session also includes quantitative research results from completed studies in Van Yen District to support the discussion of results. These research results are being developed into peer-reviewed journal publications and can only be used upon two conditions: (i) with proper citations and (ii) citations of these results must address the work of these studies rather than the C-2019-148 research work.

Van Yen success story in conservation agriculture

Van Yen District represents the northern mountain region of Vietnam in terms of high dependency on upland agriculture, strong relief conditions of mountainous terrains, susceptibility to climate risks, and a high number of ethnic minority groups who are more vulnerable to climate change and far behind from the overall development of the country. Van Yen has stood out to be a leading district in agricultural innovations by initiating a conservation agriculture program in 2003, which has been successfully implemented until today.

The program was started with two main measures, *cassava-contoured forage barriers* and *cassava-contoured fallopia barriers,* with its original goal being mitigating the consequences of erosion caused by the monsoonal climate to the traditional cassava monocrop practice of locals, restoring degraded soil, improving cassava yields. The other conservation measures were introduced later with the initial successes of the program. Until 2018, the time the cassava production area started to decline due to fluctuating cassava market price, Van Yen established over 10,000 hectares of upland cassava plantations practicing the six identified conservation measures across the district boundary. With this great achievement, Van Yen became not only a lighthouse in Yen Bai in innovations for sustainable agriculture but also the northern mountain region. The following sections discussed the Van Yen success story using qualitative and quantitative statistical analyses.

Economic impact

In Table 4, cassava productivity is highest in all conservation measures compared to that in the traditional cassava monocrop, in which cassava with *contoured forage barriers + cowpea* and with *intercropped cowpea* are the best measures in terms of improving cassava yield. The additional impacts of the cowpea component on cassava productivity were extensively studied by the CCAFS FP2.1 (by CIAT) and ARES-CDD (by VNUA) projects in Mau Dong Commune from 2016–2019. Bui et al. (2020b) found that cassava yield (tonne/ha) increased by 25% after only two seasons of implementation and cowpea contributed to 40% of the total income from a hectare of cassava in the intercrop systems.

The total income coming from these systems also increases almost twice as compared to the monocrop system. Results from economic surveys from Bui et al. (2020a) also indicated that the *cassava-contoured forage barriers* measure helped increase cassava yield by 15–20% after a long period of implementation (over five years). The farmers' feedback from Table 4 leads to similar yield performance in the *cassava-contoured cassava stem barriers* and *cassava-contoured fallopia barriers* measures. As evaluated by farmers, cassava yield in these four measures has maintained high levels of stability over the years of production (Table 5).

To obtain these great production achievements from the conservation measures, Van Yen farmers initially relied much on increased investment. In the first three years of implementation, farmers had to invest a lot more time in making contour barriers, taking care of them, and cutting forage to feed their cattle; money in buying forage and cowpea seeds and additional fertilizer for forage; and time to take care of the field components overall. As erosion was reduced much by contour barriers (up to 93% based on Tuan et al 2014) and soil fertility got improved by cowpea's leguminous BNF mechanism, soil quality (physical and chemical properties) was improved, which led to less investment (Table 6) in later stages. This is because soils need less fertilizers and farmers can use forage and cowpea seeds from their fields. Therefore, in the long run, conservation measures not only generated higher cassava yields, household income, but also reduced investment costs.

Environmental impact

Adaptation is one of the three pillars of CCAFS. In this study, it includes improved capacities of the production systems to adapt to climate-triggered impacts on sloping land, such as soil erosion, manifested by low vertical infiltration leading to more run-on water.

Overall, farmers observed that vertical water infiltration rates are a lot better in the conservation measures compared to those of the traditional cassava monocrop system. Among the conservation measures, the *cassava-contoured forage barriers+cowpea* receives the highest scoring for good infiltration speed (Table 7). Although this result is rather qualitative based on the farmers' response, it still reveals the actual status of this physical soil property in conservation agriculture. Bui et al. (2020) in Mau Dong Commune conducted an infiltration rate measurements in the rainy and dry seasons of 2019 for two management practices: *cassava monocrop* and *cassava-contoured forage barriers*. Quantitative findings confirmed the qualitative results of this study that the latter practice had significantly better infiltration rates in both rainy and dry seasons with both p-values at a 1% significance level.

The additional cowpea factor would undoubtfully improve the infiltration speed due to its BNF and soil covering functions. In principle, a higher infiltration rate means reduced run-on water on the surface, which consequently leads to a lower impact of soil erosion. Farmers seem to have observed this (erosion) process well by still confirming that the *cassava-contoured forage barriers + cowpea* has the best impact on erosion reduction (Table 8). Tuan et al. (2014) also found that grass barriers and simultaneous cover crops helped reduce 39–84% and 93–100% erosion compared to the locals' traditional maize monocrop system, which led to annual soil losses of 174 tonnes/ha.

Mitigation is another pillar of CCAFS. This study looked at two mitigation aspects of (i) carbon sequestration through improved soil quality and (ii) the ability to reduce the impact of pests and diseases on cassava production, applying the conservation measures.

Table 9, Table 10 and Figure 3 qualitatively and quantitatively prove that conservation measures have significantly improved soil fertility over the years of implementation in comparison to the traditional cassava monocrop system, in both physical (topsoil aeration, thickness, color) and chemical (organic carbon and total nitrogen) soil properties. The study of Bui et al. (2020a) in Mau Dong Commune within the collaborative CCAFS FP2.1 and ARES-CCD projects also proved the improved soil chemical properties of C_{org} and N_t in the *cassava-contoured forage barriers* measure (Figure 4), similar to the findings of this study as presented in Figure 3. In the case of Mau Dong, the results show more distinguished differences between the *cassava monocrop* system and two periods of applying contoured forage barriers. Within 6–8 years in implementing the measure, the mean C_{org} and N_t content values are significantly higher than those of the monocrop system. These mean values in plots of 14–16 years into implementation can still be seen higher than those of the 6–8 years category. This shows that soil fertility improves eventually by applying a conservation measure. Mau Dong Commune is also one of the top-performing communes in this local initiative, partly evidenced by slightly higher C_{org} and N_t content values than those in An Binh Commune (Figure 3 and Figure 4).

The study of Bui et al. (2020b) also studied the impact of intercropped cowpea to restoring degraded soils, dampening population build-up of herbivorous red spider mites, and improving household income in cassava plantations. In summary, the findings show that the population densities of red spider mites and their natural enemies are inversely proportional to each other in two different field settings, i.e. *cassava monocrop* and *cassava-intercropped cowpea*. The average population density of red spider mites in the latter measure is much lower than that of the traditional monocrop system and vice versa. This means that intercropped cowpea increases the density of natural enemies that significantly reduce the densities of red spider mites. These quantitative findings agree with the qualitative results of this study as presented in Table 11. From this table, the farmers' feedback also tells that the cassava-intercropped cowpea has the highest positive impact on the mitigation of pests and diseases.

Social impact

The study assesses the impact of the Van Yen initiative on social aspects, including (i) gender equity in family decision making in selecting farming measures; (ii) social assessment of suitability and feasibility of conservation measures to local farming systems; (iii) level of family-based participation in implementing the conservation measures; and (iv) social inclusion in technical trainings and village meetings.

Although the analysis (Table 12) did not show any clear statistically significant differences in who is the most important family member on making decisions on farming practices, husbands seem to have the highest importance level (41.89%). They are followed by the wives at 35.73%. These results do not show much of inequity in family decision making. Rather, they present quite a good equity figure with a small difference between husbands and wives.

The fact that the interviewed farmers highly rank the suitability and feasibility of the introduced measures to their local farming systems shows that they have been open to new interventions and have applied them successfully in their biophysical and socio-economic contexts. This is an important finding that can be used to make recommendations to scale the initiative to other locations that have not been able to start. It emphasizes that the determination of the local government to make a change and willingness and cooperation of the local farmers to accept and try the conservation incentive have been the key to success.

The results for the level of family-based participation in implementing conservation measures (Table 14) dot not clearly distinguish the participation of family members in the traditional cassava monocrop system and introduced conservation measures. This can also be seen in implementing the adoption group of conservation measures. This shows that farmers treat all management practices the same for their livelihood dependencies and their resources.

Aside from the response of farmers to participating in technical trainings and village meetings, Table 15 shows a serious intension of the local government in providing farmers with technical knowledge to implement measures that are initiated to make a positive change, driving upland agriculture towards more sustainability. Unrecorded interviews with Van Yen authorities from the DARD and district extension unit revealed that, since 2003, annual technical trainings have been provided to villages and communes that needed to be introduced to new measures. Photos of these activities can be seen in Appendix 2.

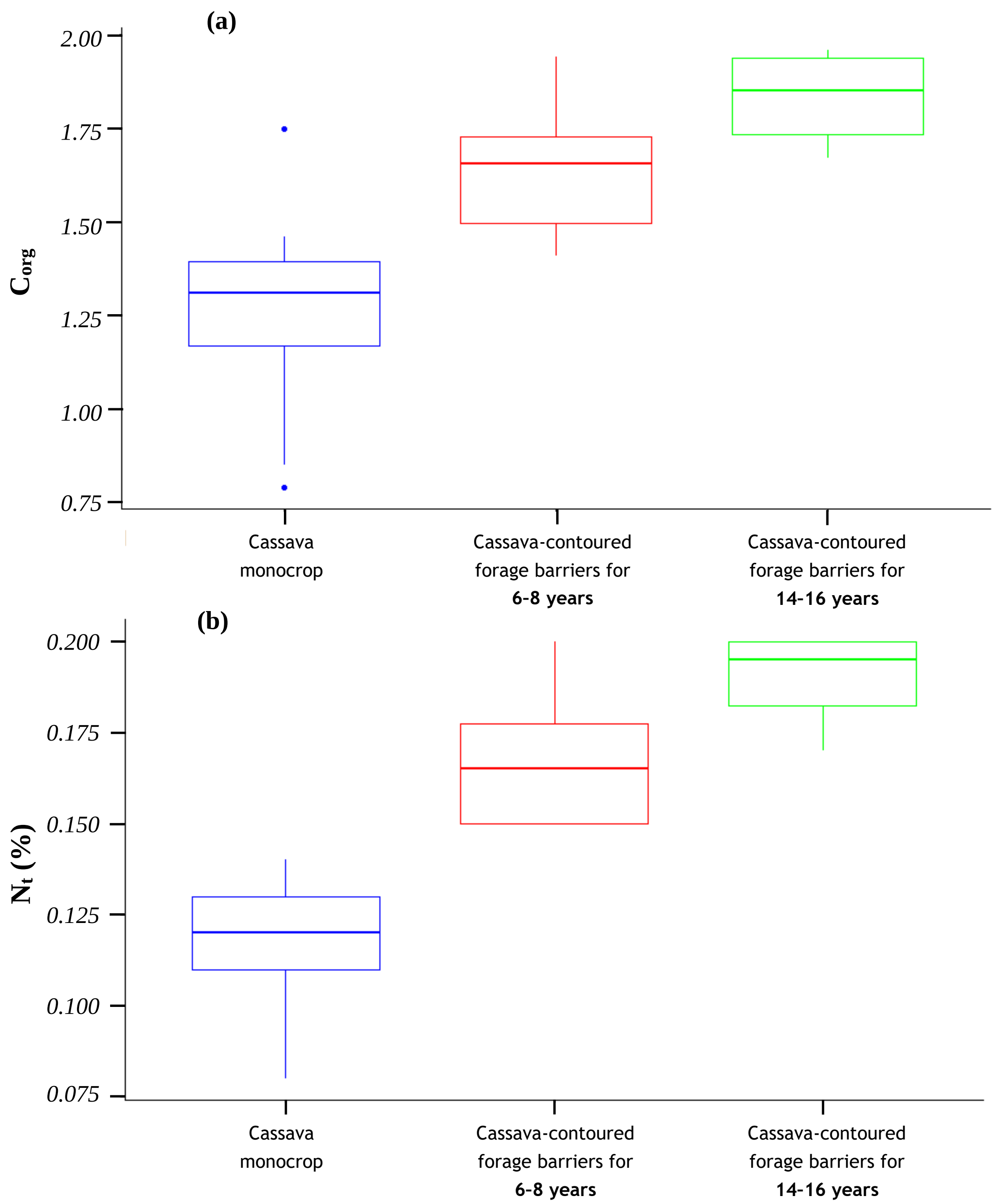

Figure 4. Variability of organic carbon C_{org} (a) and total nitrogen N_t (b) contents in Mau Dong commune between cassava monocrop and cassava-contoured forage barriers

Source: ARES-CCD VNUA project

Recommendations

The study performed a detailed impact assessment of Van Yen's conservation agriculture program that started in 2003. The qualitative and quantitative research results from six out of the 13 cassava communes of the district have shown the great impacts of conservation measures in terms of household economy, environmental adaptation and mitigation, and social inclusion and equity. This has contributed to making Van Yen a standard for sustainable agriculture in the northern mountain region of Vietnam over the past two decades. This success story was also documented and shared by national and international organizations such as CIAT (2016).

Despite the success, Van Yen cassava farmers have been switching cassava to other crops such as cinnamon due to their higher economic values. This is because the market price of cassava has been very unstable in the last five years and has been too low for smallholder farmers who are gaining little to continue. This gave farmers no choice but to switch to cinnamon and/or other crops (like in the case of Ngoi A Commune with only 7 cassava households remaining). Van Yen has lost around 40% cassava plantation area for this reason. The district government of Van Yen is determined to maintain production in the remaining cassava areas. However, it needs to overcome the low cassava price.

Below are some solutions that Van Yen District and the entire Yen Bai Province may consider:

i. Increase the subsidies and support for cassava farmers, including fertilizers, pesticides, and technical training. This should help Van Yen and Yen Bai keep their current cassava areas from falling further until the price rises again.

ii. Make a long-term strategy for a more sustainable cassava value chain through different channels to avoid market failure, which may come from a strong dependence on one big market. Yen Bai will need to work with the Vietnam Cassava Association to seek market-related solutions.

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Appendices

Appendix 1. Population breakdown of the six studied communes

Category	Values	Unit	Communes					
			An Binh	*Chau Que Ha*	*Lang Thip*	*Mau Dong*	*Ngoi A*	*Quang Minh*
Average member/ household		People	4.18	4.07	4.53	4.01	6.00	4.66
Livelihood ranking	Poor/near poor	%	13.46	15.09	30.68	5.49	0.00	17.39
	Average	%	70.19	72.64	61.36	72.53	28.57	63.04
	Above average/ rich	%	16.35	12.26	7.95	21.98	71.43	19.57
Total land area		Ha	35.4	42.4	39.4	15.3	47.5	32.6
Average number of plots		Plot	3.71	3.86	3.52	3.51	4.43	3.27
Ethnicity of households	Kinh	%	39.42	44.34	6.82	98.90	14.29	0.00
	Tay	%	3.85	47.17	0.00	0.00	0.00	10.87
	Others	%	56.73	8.49	93.18	1.10	85.71	89.13
Education of family heads	Illiterate	%	19.23	1.89	46.59	0.00	0.00	20.65
	Not finished primary	%	21.15	22.64	26.14	10.99	57.14	28.26
	Not finished secondary	%	31.73	32.08	12.50	34.07	28.57	25.00
	Not finished high school	%	23.08	34.91	11.36	41.76	0.00	19.57
	Above high school	%	4.81	8.49	3.41	13.19	14.29	6.52
Percentage of male family head		%	90.38	85.85	92.05	89.01	100.00	93.48
Average age of family head		years	46.83	43.71	42.60	49.37	46.57	44.04

Appendix 2. Technical trainings and village meetings to implement conservation measures

Annual launch of conservation measures
(Source: Van Yen extension unit)

Technical training
(Source: Van Yen extension unit)

Village meeting to select farmers
(Source: Van Yen extension unit)

Village meeting to make implementation plan
(Source: Van Yen extension unit)

Mass communications to promote adoption
(Source: Van Yen extension unit)

Village communications to promote adoption
(Source: Van Yen extension unit)

Appendix 3. Examples of implementation of conservation measures on the ground

Breakdown erosive slope length on contours
(Source: Van Yen extension unit)

Plant contoured forage/fallopia barriers
(Source: Van Yen extension unit)

Make contoured cassava stem barriers
(Source: Van Yen extension unit)

A terrace formed by a forage barrier
(Source: Van Yen extension unit)

Cassava-contoured grass barriers+peanut
(Source: Van Yen extension unit)

Forage barriers on a hill slope from distance
(Source: Van Yen extension unit)

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