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Scaling Climate-smart Agriculture in North-central Vietnam

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Abstract While the demand for climate-smart agriculture practices is rapidly growing in the 2010s, it remains vague in practice how to evaluate integrated farming systems, in particular. The study draws lessons learned from the My Loi climate-smart village, Ky Son commune, Ky Anh district, Ha Tinh province to explore the scalability potential to Ky Trung commune in the same district, and in the province. Specifically, we use mixed participatory field-based approaches to categorise current farming practices for the purpose of proposing context-specific climate-smart interventions, in addition to biophysical feasibility, policy support and expert consultations. Originating from local knowledge, five climate-smart agriculture models were derived with incremental implementation steps developed with technical expertise. While the specific components of the models are context-specific, the technologies and this improved approach for identifying CSA practices can be generically applied.

Keywords: *climate-smart agriculture, scaling, agroforestry, food security, adaptation, mitigation, Southeast Asia*

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1. Introduction

Climate-smart agriculture (CSA) was coined by FAO and WB in 2010, as a means to tackle the luring threats of climate change on global food security, while also recognizing the double role of agriculture as sink and source of greenhouse gases [1]. However, to balance immediate needs (typically the focus of farmers and consumers) and longer-term impacts of climate change (typically the focus for policymakers and mitigation targets), temporally and spatially seamless frameworks are needed to maximize stakeholder engagement and diffuse the boundaries between climate shock and climate change adaptation [2].

To better understand the context-specific conditions for agricultural innovation and adoption, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) introduced the concept of climate-smart village (CSV) in 2011 and a global research program on characterizing and scaling climate-smart agriculture practices. Often ranked among the countries with high adverse effects of climate change, the Government of Vietnam proactively adopted climate-responsive policies and became an active member of the Global Alliance of CSA in 2012. In 2014, CCAFS initiated three CSVs in Vietnam to act as demonstration sites for researchers, farmers and practitioners. Among them was My Loi village in Ky Anh district, representing the uplands of North-central Vietnam with poor agricultural diversity and high exposure to various extreme weather events year-round.

Different approaches for scaling CSA practices are now beginning to take shape based on ongoing research and innovation. For example, the ASEAN has developed guidelines for CSA, mainly related to key staple crops such as rice, maize and cassava [3]. Monoculture rice practices, in particular System of Rice Intensification and Alternate Wetting and Drying, with apparent triple benefits of adaptation, mitigation, and increased productivity, have seen rapid large-scale uptake. In contrast, upland smallholders with more diverse land uses may require more context-specific interventions both in the sense of biophysical suitability as well as market opportunities. Some argue that the slow uptake depends on CSA being perceived as too technology and knowledge intensive [4]. Furthermore, the stress on CSA as being 'context-specific' somehow contradicts the notion of CSA as a scalable practice [1]. One particular CSA-practice that frequently meets such criticism is agroforestry. Despite multiple livelihood, adaptation and mitigation benefits [5,6,7], low autonomous adoption of agroforestry was explained by that farmers who prioritised food security (and leaders) perceived the period for return-on-investment being too long, markets uncertain (or unknown) and banks offering inhibitingly short-term loans [8]. The study also indicated that many were willing to try agroforestry, if farmers and extension received training.

To avoid losing adopters due to technology traps, Simelton, Dam [6] suggested a gradual transition from current towards more complex integrated systems, to change either the crops *or* the management rather than changing both simultaneously. Furthermore, for identifying problems and differing between 'generic' and 'context-specific' aspects of complex CSA interventions, such as agroforestry, Duong, Simelton [9] then separated practices into *technologies* - how things are grown, and *components* - what is grown, whereby the former can be applied broadly and the latter is context-specific. In other words, agroforestry or contour planting can be done anywhere, while the specific trees and crops in such system would depend on local suitability. Their framework focused on participatory solutions at the field to landscape scale, but did not consider factors that enable or limit scalability at district or province levels, such as policy support and market potential or risk for market saturation.

Although there is emphasis on innovation in CSA [1,10], farmers may already be doing many climate-smart practices and the innovative aspect may simply be making stakeholders aware on how farming practices can be improved to accommodate environmental or economic changes, and how to assess the progress towards such climate-smart goals [9]. In 2015, four priority areas for climate-smart agriculture were selected in My Loi CSV: home garden, livestock, agriculture intensification, and forestry [11,12]. Hence, the overall purpose of this study were to categorise common current practices and propose steps towards 'climate-smarter' interventions, and to identify opportunities for scaling-out climate-smart agriculture practices in Ky Anh district. Specifically, the ambition was to apply a pragmatic participatory methodology which local stakeholders on minor budgets might be able to use, and with a considered scaling out potential beyond the scoping area itself.

2. Data and Methods

2.1. Study Location

Three villages located along a transect, Dat Do, Dong Son and Truong Son, in Ky Trung commune, Ky Anh district, Ha Tinh province were selected for in-depth fieldwork (see map Figure 1). The villages represent different land uses in the commune, within a similar context to the CSV, thus making a case to test the scaling potential.

The key geographical characteristics for the study sites are provided in Table 1. The commune has about ten times as much forestland as agriculture land. At lower elevations (<40 m.a.s.l.), rice is planted on alluvial soils (~68 ha). Ferralitic acid soils are dominated by rainfed monocultures of peanut (60 ha), cassava (40 ha) at low elevations, and by tea (~160 ha) at mid-elevation (40-50 m.a.s.l.). With regards to scaling out CSA from My Loi CSV, the main difference in land uses was a relatively larger share of tea in Ky Trung commune, hence providing opportunities to develop climate-smart tea models. About 90% of the tea is sold to a state-owned tea factory in the commune and 10% kept for household consumption; (many villagers are former workers from when the factory was established as cooperative). Above 50 m.a.s.l. on ferralitic rocky soils, forest plantations dominate, particularly acacia and pine.

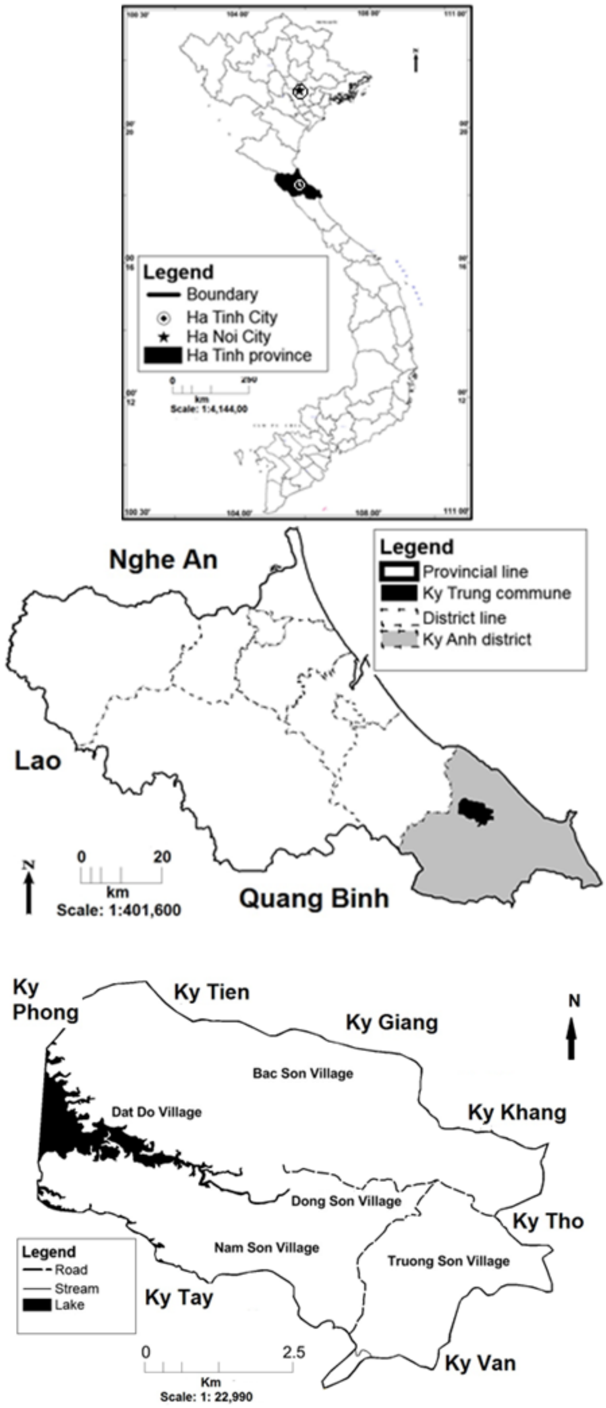

Figure 1. (a) Map of Vietnam with Ha Tinh province (black), (b) Ha Tinh province with Ky Anh district (grey) and Ky Trung commune (black), and (c) Ky Trung (and neighbouring) communes with approximate location of villages (no boundaries)

Table 1. Key indicators for Ky Trung commune and study villages, 2015-2016

	Ky Trung commune	Villages		
		Dat Do	Dong Son	Truong Son
Population	1583	502	447	214
Total area (ha)	3385	1003	ca 570	ca 780
Agriculture land				
Annual crops	168	38	24	29
Tea	160	53	20	13
Forest land (ha)	1809	400	42	61

Source: Agricultural production report 2015 for Ky Trung commune [13], oral communication with commune leader, 2017.

2.2. Approach

The process for establishing a climate-smart village and prioritising climate-smart practices has been described widely [11,12,14]. To determine the potential for converting current crop production systems into climate-smart interventions in Ky Trung commune, we adapted a CSA framework [9] with quantitative and qualitative criteria to assess food security, adaptation, and mitigation.

The analysis was done at two levels. Information from household interviews and focus group discussions were synthesized to characterise current farming systems and practices [15], and for developing climate-smart interventions based on local and scientific knowledge [9]. The study starts with a neutral approach to agricultural challenges, to try to minimise answer bias on climate change [16]. For identifying the spatial scaling potential of different systems in the commune, we used village information, maps, key informant interviews and expert opinions (representatives from commune and district authorities, farmer organisations, and academia).

2.3. Data

Climate data. Daily rainfall, minimum and maximum temperatures for Ky Anh meteorological station for the period 1982-2011 were tested for conventional trend and variability analysis [17], in Microsoft Excel 2013 and R version 3.3.2 softwares. To indicate future rainfall and temperature trends and assess the potential risk to cropping system in Ky Trung commune, we applied the analysed climate change scenario RCP8.5 for North Central Vietnam for 2005-2055 [18]. The meteorological station is located about 45 km from the study site at lower elevation towards the coast hence Ky Trung commune has a hotter and drier microclimate than the official meteorological observations and My Loi CSV in the same district. *Caveat*: After this study, the climate change scenarios have been updated. While some specific details have been updated for temperature (higher projected increase) and rainfall (higher variability), the crude qualitative scenarios used in this study indicate little difference up to the 2030s.

Agriculture census data. Land use and agriculture production estimates for 2015 were taken from the annual social-economic report [19], including soil type, cropland area, yield, pest, cultivation techniques. For scaling potential, we consulted the provincial Masterplan and land use plans for 2015-2020 [20,21].

Qualitative data. Participatory focus group activities in each village resulted in detailed information: (i) Timeline of major development trends and extreme weather events in the village; (ii) Annual calendar of farming systems and natural hazards; (iii) Village sketch maps of actual land use, soil, and natural hazards to complement the low resolution (topography, soil, land use) maps and agriculture census data. Villages in Vietnam rarely have defined borders, however if such can be established the village maps can be transferred a commune map; (iv) Transect walks with key informants were used to assess current farming systems and start discussing potential interventions in the field. [16]. Three half-day focus group discussions were conducted in each village. The fieldwork was conducted between May 2015 and July 2016, the effective time estimated for the fieldwork was three weeks. Some information has been re-confirmed in 2017.

2.4. CSA Indicators

Drawing on the information generated in steps i-iii above, the participatory CSA prioritisation can be summarised in the following steps: (1) Description of the farming system(s), what crops are grown, and how they are managed (Baseline characterization); (2) Decide what problems to solve (Problem identification and target indicators from the CSA longlist [9]); (3) Design a farming system that aims to be climate-smart within 5-10 years, (Plan and design the system). Step (4) includes implementation, testing and adjustment, though it is not included in the scope of this study. In consultation with key informants, the following shortlist of CSA indicators were selected:

Food security and livelihoods. Crop yields (ton ha^{-1} year^{-1}), income from agriculture products sold (million VND ha^{-1} year^{-1}) and costs for labour and agriculture inputs, such as seed(lings), fertiliser and herbicide (million VND ha^{-1} year^{-1}). Profit (million VND ha^{-1} year^{-1}) is calculated as costs subtracted from revenue.

Adaptation. The risk of crop failure was assessed through participatory ranking and mapping exercises [16], where farmers were asked to evaluate potential extreme weather event(s) and prioritise appropriate interventions, as to avoid overestimating the ability of any single practice to mitigate all risks. Yield stability and the added risks when accounting for the climate change scenarios were not rated but based on local perceptions and discussed in qualitative terms [22].

Mitigation potential and ecosystem services. Farmers generally have a clearer understanding of environmental functions than greenhouse gas emissions [23]. Here, a combined assessment of an intervention's contributions to environmental services as temporal duration (months year^{-1}), canopy strata (number of vertical layers), and vegetation cover (% canopy cover per unit area annually). Longer planting periods and higher vegetation cover are assumed to reduce negative environmental effects, although this is debated in the case of clear-felling [6]. Soil nutrient status is viewed as ability to reduce soil degradation (erosion and/or nutrient depletion). Due to the apparent misuse of inorganic pesticides and herbicides which had resulted in reduced soil organic matter and hardpans, local authorities requested the research team to also recommend feasible alternatives.

Scaling potential of the practice. The household's preference for a farming system was based on farmers' qualitative assessment of its compatibility with their needs, capacity and desire to expand the practice. Desire is influenced by farmers' (realistic and unrealistic) perceptions of market opportunities. The market and spatial scaling potential at the commune or district levels were based on land use plans, supporting policies and consultations with expert representatives from Farmer's Union, Department of Agriculture and Rural Development (DARD), agriculture university and research institutes (representing an agronomist, forester, mitigation expert, and ecosystem assessment modeler).

3. Results

3.1. Climate Impacts on Farming Systems

Figure 2 presents general temperature and rainfall patterns for Ky Anh district, and highlights decadal increases in monthly average temperatures, particularly from November to March, and June. Two seasonal shifts in rainfall stand out: the pre-onset (locally referred to as 'The Golden Rain') moved from June to May. Overall, the rainfall reduced during the main rainy season, and redistributed to a slight increase in the early part (July-August) and decrease in the latter part (October-November), compared to the previous two decades.

Table 2 illustrates the timing of extreme events throughout the year. Farmers in Ky Trung experienced droughts, hot spells with dry hot foehn winds, so-called Lao winds (with recent notably strong events in 2009, 2012, 2014, 2015), rain storms with flash floods (2006, 2008, 2011, 2016), and cold spells with rain (typically drizzle, Dec 2009-Jan 2010, Dec 2011-Jan 2012, Jan 2015).

The farming calendar for key crops including rice, peanuts, cassava, tea, and timing of extreme events are presented in Table 2, and this data is used for planning interventions (see next section). Management includes the most common perennial trees species, i.e. orange, acacia and pine.

Similar to My Loi CSV, the study sites have a constant exposure to natural hazards throughout the year (see also section 'Adaptation' Table 5a-e). Paddy rice is particularly vulnerable due to its location and extended planting season, during which growth is affected by droughts, storms and cold rains. Peanuts and tea are particularly affected by droughts and hot spells, and cassava by droughts. Acacia, due to its brittle stems, is sensitive to storms.

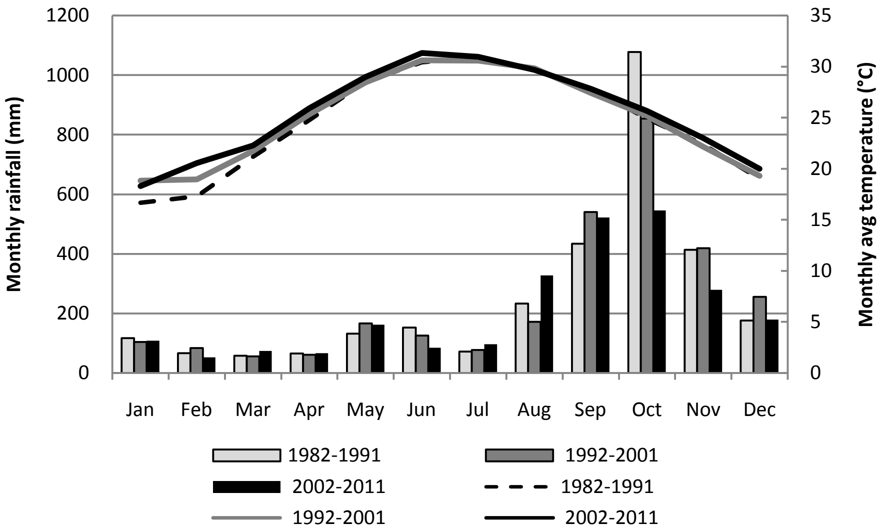

Figure 2. Decadal variability in monthly rainfall and average temperature in Ky Anh district, 1982-2011

Table 2. Typical timing of extreme weather events and farming calendar for Dat Do (DD), Dong Son (DS) and Truong Son (TS) villages, Ky Trung commune, Ky Anh district

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DD	COLD		DROUGHT			DROUGHT, LAO WIND		TROPICAL STORM			COLD SPELL & RAIN	
DS	COLD			DROUGHT, LAO WIND					TROPICAL STORM		COLD SPELL & RAIN	
				HOT SPELL								
TS	COLD		DROUGHT, LAO WIND					FLOODING				COLD SPELL & RAIN
							TROPICAL STORM					
DD, TS	Rice 1 (cont'd) – spring harvest					Rice 2 - autumn harvest					Rice 1	
DS												R1
DD, TS	Peanut											
DS		Peanut										
DD, TS	Cassava											
DS		Cassava										
DD		Tea harvest 1					Tea harvest 2					Pruning
DS				Tea harvest 1				Tea harvest 2				Pruning
TS			Tea harvest 1					Tea harvest 2			Prun.	

Source: Focus group discussions; Authors' fieldwork October 2015.

The RCP8.5 climate change scenarios for North-central Vietnam project an 1-1.5°C increase in winter and summer temperatures by the 2050s. Furthermore, decreasing frequency but increasing intensity of hurricanes is expected. Although no particular trends are projected for rainfall, with more heat waves and prolonged droughts, increasing inter-annual variations can be anticipated [18]. Without appropriate adaptation measures, we hypothesise that current farming systems may be unfit for future weather patterns, thus increasing the risk of crop failures in the near future.

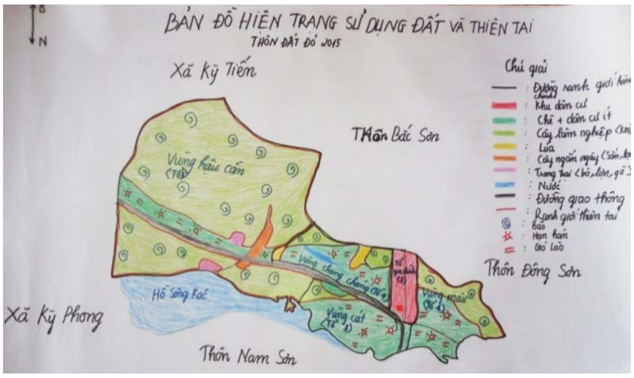

Figure 3. Land use and hazard map, Dat Do Village. Source: focus groups, October 2015

When presented with the climate change scenarios, farmers believe the impacts of current extreme events will worsen, particularly cold winter rains, droughts and storms (Table 3). They expect that rice (specifically the spring crop) will be most negatively affected. Increased frequency and length of droughts will reduce rice and tea production, and more intense storms will affect the brittle acacia stems and reduce the flower and/or fruits on fruit trees. Farmers' perception that winters will likely get colder even under warmer temperatures, seems influenced by unusual cold surges in recent years. While light rain helps germination of rice, cold temperatures with high humidity or rain may kill peanut and cassava buds and reduce growth. The fieldwork was undertaken during a major El Nino phase that lasted from the autumn of 2014 to the spring of 2016, which may have diverted attention toward droughts and away from flood risks.

Table 3. Participatory ranking of perceived impacts of extreme weather events on future cropping systems in Ky Trung commune

Extreme weather event	Rice	Tea	Acacia	Fruit
Drought	2	2	0	1
Hot spell	0	1	0	1
Storm	1	1	2	2
Rain, cold spell	2	1	0	1

Ranking: 0: Not affected; 1: Negatively affected; 2: Significantly negatively affected. Source: focus group discussions, 2016.

3.2. Potential CSA interventions

Five farming systems were identified for incremental interventions towards a proposed CSA practice (Table 5): (a) rice, (b) annual crops, (c) tea, (d) acacia, and (e) low-diversity/low-quality fruit garden. Most interventions are based on an initial monoculture system, and designed to address drought as the main limiting climatic factor. (Table 2 and Table 4).

3.2.1. Livelihoods

The traditional staple crops generated low incomes and minor livelihood contributions (see section 'Livelihoods' in Table 5a-e). Rice, despite being impacted by various weather events, was considered indispensable as a food source (Table 5a). Cassava was planted on the poorest soils and viewed as less sensitive to adverse weather impacts than e.g. peanut (Table 5b). Acacia trees were often planted twice as dense as the recommended spacing, to reduce the risk of storm damage. Consistent data for fruit trees, acacia and pine tree yields are missing. The total acacia production in the commune in 2015 was 3,360 tonnes (for a 4-6 year rotation), which would give approximately 58 t ha^{-1} yr^{-1}. For a market price at VND600,000-700,000 per metric ton, each rotation would return approximately VND35-40 million ha^{-1}. Pine trees produced about 2.6 kg gum per tree annually, sold at VND6,000-7,000 kg^{-1}.

The farmers' primary concerns when evaluating a new practice were labour input and time until return on investment (economic efficiency, see section 'Farmers' comments' in Tables 5a-e). Acacia plantations (Table 5d) represented a comparatively high economic return requiring little labour inputs. Given the short rotations, clear-felling resulted in soil degradation compared with long-term plantations, such as tea hedgerows. Tea (Table 5c) differed most among the practices both in terms of management and sensitivity to weather. Overall, tea yielded higher profits than acacia but required more investments. Interestingly, some households were open to developing business from tree diversification. This many involve new high-value fruit trees, timber and non-timber forest products, that can balance the double uncertainty of markets and weather with adaptation and mitigation benefits.

3.2.2. Adaptation and Mitigation Synergies

Irrigation was the main constraint for introducing shorter-term rice varieties. While water conservation/ harvesting methods were seen as necessary, water pits and ponds on small plots competed for valuable growing space and drip irrigation was deemed inhibitively expensive. Without groundwater irrigation, which was too expensive an investment, the tea would remain drought sensitive in more exposed areas, especially on plateaus. Furthermore, the driest soils with hardpans in tea plantations coincided with continuous herbicide applications, whereas weedy areas (with reduced herbicide usage) held more moisture and were less compacted. Adding one or more vegetative layers was expected to diversify production (and/or incomes) and reduce drought-related yield loss by regulating microclimate through shade, reducing evaporation and enhancing soil moisture storage, thus addressing both above- and below-ground carbon indicators (See sections 'Adaptation' and 'Mitigation' in Tables 5a-e). Intercropping cassava with peanut for double yields was common practice in the district, while adding maize for the autumn rotation had not been tried in Ky Trung (here maize was monocultured and covered small areas), a practice that was shared from My Loi CSV (Table 5b).

Table 4. Characteristics of farming systems in Ky Trung commune with respect to climate-smart agriculture indicators

	Food security and livelihoods					Adaptation	Mitigation & Environmental services			Scaling potential
Current practice	*Yield ($t\ ha^{-1}\ year^{-1}$)*	*Input cost (million VND $ha^{-1}\ year^{-1}$)*	*Income (million VND $ha^{-1}\ year^{-1}$)*	*Profit (million VND $ha^{-1}\ year^{-1}$)*	*Consumption*	*Climate risk*	*Duration m=months y= years*	*Soil status*	*Household acceptance*	*Perceived market potential*
Rice	9	52	81	29	home	drought, cold rain	10 m	rich	medium	low
Rice	5	26	45	19	home	drought, cold rain	4 m	medium	medium	low
Peanut	2-2.4	30	38	9	home, sale	low	4 m	rich	medium	low
Cassava	20-30	28	36	8	home, sale	low	11 m	poor	medium	medium
Tea	10-12	55	78	23	sale	drought	20 y	medium	high	high
Acacia	58[2]	1	8	7	sale	storm	4-6 y	poor	high	high

Source: Key informant interviews and group discussion. Authors' fieldwork October 2015.
[2]Average acacia yield is estimated based on commune total production in 2015.

Table 5 a-e. Current farming systems and identified steps towards climate-smart agriculture interventions for (a) rice, (b) annual crops, (c) tea, (d) acacia, and (e) fruit-tree based systems. ***For CSA indicators the '-' sign denotes current or remaining issues, and '+' anticipated improvements. The comment sections below the practices were identified through focus group discussion with farmers and key informant discussions with CSA-experts and policy makers.***

(a) Rice and sustainable intensification

		Current practice 1	Current practice 2 (example in Dong Son)	CSA practice 3
Practice	Technology	Monoculture: 1 crop per year (spring) + fallow Inputs: herbicide, pesticide, inorganic fertilizer Rainfed	Intensified monoculture: 2 crops per year Inputs: as Practice 1 Rainfed (partly irrigated during rainy season in some fields)	Intensified rotation: 2 crops per year Input: inorganic inputs and/or conversion to organic inputs (IPM), compost Rainfed (some partly irrigated during rainy season) (Climate services)
Practice	Component	Rice 120 day-variety (Dec-Apr)	Rice 120 day-variety (Dec-Apr) and 90 day-variety (May-Jul) or 2 crops of 90-day variety	Rice (Dec-Apr) and/or Legumes or Legumes intercropped with maize (autumn), see Table 5b
CSA indicators	Livelihood	Productivity: 5 $t\ ha^{-1}\ year^{-1}$ Selling at: 45 million VND $year^{-1}$ -Food shortage	Productivity: 9 $t\ ha^{-1}\ year^{-1}$ Selling at: 81 million VND $year^{-1}$ +Yield increase +Diversified income	+Diversified production, income, and nutrient intake +Resource use efficiency +Reduced costs for inputs
CSA indicators	Adaptation	-Sensitive to drought, storm, cold spells -Sensitive to pests	As Practice 1	+Potential to improve soil water use efficiency (Apr-Jul) (+ Seasonal forecast for varietal selection and timing with hazard risk)
CSA indicators	Mitigation	-Soil degradation -GHG (methane)?	-As Practice 1 possibly higher total GHG emissions but reduced GHG efficiency (methane)	+Expected: improved soil status (soil carbon, biota and retain nutrients) +Expected: some reduction in GHG emission
Farmers' comments		Benefits: Some evidence of benefits by shifting to rotations with legumes (green bean and peanut) and increasing to two crops per year Risks: Some reluctance to two staple crops per year (Practice 2-3), saying productivity too low due to water shortage and not worth the labour inputs (compared to tea)		
Experts' comments		Specific solutions are needed to deal with drought periods (Apr-Jul). SRI is inappropriate without controlled irrigation. For winter-spring rice: Apply compost before transplanting/broadcasting to improve soil fertility and water holding capacity and reduce need for inorganic fertilisers. Nitrogen control when rice is affected by pest and disease. For summer-autumn rice: Select varieties/crops to avoid flooding and storm risk (Jul-Sep). If sufficient irrigation, test short-term varieties planted in Dong Son in other locations with similar geographical conditions. For rainfed fields: change to drought-tolerant leguminous crops (peanut and mung bean), or intercrop peanut/bean with maize for retaining soil moisture and weed control. Plant directly after harvesting spring rice to utilize remaining soil moisture and reduce drought risk during the hot months (Jun-Jul); alternatively shift to perennial plantations (e.g. Table 5e).		
Scalability potential		Main limitation is irrigation, water sources dry up (Apr-Jul), restricting the area for double rice crops. Of the 46 ha currently used for Practice 1, intercropping could be an alternative (see Practice 3, Table 5b and 5e). Permissions for conversion to permanent plantations (Table 5e) may be required.		

(b) Monoculture to sustainable intensification of annual crops

		Current practice 1	Current practice 2	CSA practice 3	CSA practice 4 (examples in My Loi)
Practice	Technology	Monoculture Input: chemical herbicides pesticides; inorganic fertilizer Rainfed	Monoculture As Practice 1	Intercropping Input: As Practice 1 and 2 except for inorganic fertiliser/compost Rainfed	Intercropping, rotation Input: biological herbicide and pesticide; organic fertilizer/compost Rainfed
	Component	Cassava (Jan-Nov)	Peanut (spring, 1 crop)	Intercrop Practice 1 and 2	Peanut (spring) in rotation with maize (autumn) intercropped with cassava
CSA indicators	Livelihood	Productivity: 20 – 30 t ha^{-1} $year^{-1}$ Selling at VND24 – 36 million ha^{-1} $year^{-1}$	Productivity: 2 – 2.4 t ha^{-1} $year^{-1}$ Selling at VND 32 – 38 million ha^{-1} $year^{-1}$	Yield and price as Practice 1 and 2 together	+Diversified production and income +Increased incomes +Animal feed +/-More stable yield, if drought risk is controlled
	Adaptation	-Sensitive to drought -Pest prone	-Sensitive to drought -Pest prone	+Cover crop, reduces soil evaporation -Pest prone	+Increased cover with peanut regulating soil moisture and drought risk -Fewer pests expected
	Mitigation	-Soil degradation	+Legume (N-fixing), lower greenhouse gas emission than cassava	+As Practice 2, possibly slightly less efficient	+As Practice 3 +Reduced GHG emission (N)
Farmers' comments		Benefits: Expectation that diversified systems will increase income and/or animal feed, e.g. there is little difference in productivity between monoculture practice 1 and 2 compared with intercropping Practice 3. Multistrata and cover crop can reduce some drought impacts. Risks: Annual staple crops generally provide low price, fluctuating markets, especially for maize and cassava. Some reluctance to intercrop on small plots. Drought risks remain high as annual crops are not irrigated. More weeds with manure and/or without chemical herbicides.			
Experts' comments		The proposed CSA practice 4 exists at small-scale in the district and is recognised for diversified yields, thus farmers could visit such demonstration models. If practices are truly biological, they should be marketed as such. Improved climate information services will help farmers adjust farming calendar, select appropriate varieties, etc to minimize crop failures.			
Scalability potential		Some of the drought-affected rice area can add non-rice autumn crop(s) (46 of 68 ha). About 40% of the current cassava area is intercropped with peanut, and could integrate maize for household consumption (food and feed). Market potential to expand cassava could increase as factory in the district is expected to reopen in 2018.			

(c) Tea monoculture to tea agroforestry systems

		Current practice 1	Current practice 2	CSA practice 3 (examples in Truong Son and Dong Son)
Practice	Technology	Hedgerows, monoculture Input: herbicide, pesticide and inorganic fertilizer Rainfed	Hedgerows with shade trees Input: As Practice 1	Hedgerows with shade trees and cover crops. Harvest (Mar – Oct) Input: biological herbicide and pesticide, organic fertilizer (compost, manure*)* Rainfed
	Component	Tea	Tea Shade tree (*Senna siamea*, *Aquilaria crassna)*	As Practice 2 with green bean 60-70 days (Mar-Nov) or grass (Dec-Feb)
CSA indicators	Livelihood	Productivity: 10 – 12 t ha^{-1} $year^{-1}$ Selling at VND 65 – 78 million ton^{-1}	+Negligible difference in tea productivity to Practice 1 +Additional income/benefits from shade trees, e.g. oil, fodder, nuts, manure from litterfall	+Increased and diversified income +Food for household consumption +Additional animal feed/green manure +Replace labour inputs for weeding with bean/grass - Competing harvests (tea/crop) after 3^{rd} year
	Adaptati on	-Sensitive to drought and hot spells -Surface runoff (no ground cover)	-Shade, reduce impacts of hot spell -/+Potential to reduce soil evaporation, remains drought sensitive	+Micro-climate regulation: Shade and ground cover expected to reduce evaporation
	Mitigation	-Soil nutrient degradation	-Soil nutrient degradation +C-sequestration potential through permanent trees	+Improved soil quality: soil carbon, nutrients and water holding capacity, N-fixing (*S. Siamea*), litterfall +Reduced NO_x-emissions +C-sequestration (above and below ground) +Manure management
Farmers' comments		Benefits: Some households that had gone to Practice 3, considered biological pest controls and grass efficient in replacing labour inputs for weeding with more outputs (grass and green bean). Shade trees with non-timber products provide additional income and decomposing litterfall that build up soils Risks: Some households having shifted from Practice 2 to 3, experienced more weeds with organic fertilizer Shade trees could increase the occurrence of certain pests under the (increasing and slowly decomposing) litter from *A. crassna* (large leaves) and *S.siamea* (many leaves) Annual crops can be intercropped with tea by pruning the lower canopy of shade trees, however farmers considered such labour inputs higher than the economic return		

Experts' comments	When the tea plants reach 3 years, the harvesting of tea and crop need to be timed; c.f. Dat Do, where tea was harvested all-year round, could follow the other two villages and intercrop between Nov-Feb with tea harvest Mar-Oct. To control weeds, a limited amount of livestock could graze tea plantations, planting fodder grasses for cut & carry, or planting mung beans for the first 3 years. Pests risk associated with shade trees should be identified, to select appropriate tree species and identifying biological measures, e.g. attractor or repellent plants. New organic inputs can be tested on small scale before promoting widely.		
Scalability potential	Suitable for major part of the tea plantations (160ha) that are treeless or when aged shade trees are replaced, and for some land with peanut and cassava (100 ha). See Figure 5.		

(d) From fast-growing acacia monoplantation to diversified tree plantation			
		Current practice 1	Current CSA practice 2
Practice	Technology	Monoculture Dense short-term plantations with clear-felling (spacing 1.7m by 1m, 1.4m by 1.4m, i.e. 5,000 – 6,000 trees ha^{-1}) Harvest every 4-6 years	Permanent mixed stands Diversification, enrichment with higher value timber or multifunctional tree species Sequential harvest
	Component	*Acacia auriculiformis*	*Acacia auriculiformis* *Talauma spp*, *Centrolobium spp* (Canarywood) Jackfruit
CSA indicators	Livelihood	Each 4-6 year cycle generates about VND 600.000-700.000 ton^{-1} $harvest^{-1}$ or VND35-40 million ha^{-1}	+Diversified and increased income +/-Market potentials to be explored
	Adaptation	-Sensitive to storm fell	+Gradually reduced sensitivity to storm fell
	Mitigation	-Soil degradation (nutrient and quantity) is high after clear-felling -Low biodiversity	+C-sequestration: increased above and below ground -Slow decomposition rate of litter? +Increased biodiversity
Farmers' comments		Benefits: After having started high-quality tree plantations, farmers saw potentials for timber products and small-scale business development Risks: Two factors restricting tree diversification are (i) that monoculture is seen more labour efficient, in particular with lower costs for clearcutting than selective felling; (ii) lack of apparent markets, investment capital and technical capacity, including access to high-quality seedlings and harvest methods. Extension advice is needed to determine combinations and succession for mixing tree species.	
Experts' comments		To shorten the period for return on investment, there are two possibilities: permanent mixed stands with grafted fruit trees, or temporary intercrop annual crops (taungya). Acacia spaced 1.8-2 m allows cassava up to two years, while denser spacing (1x1 m) may reduce the risk for storm damage, but would only allow cassava for one year. Acacia is not recommended for soil erosion if acacia stumps are uprooted during felling.	
Scalability potential		There is currently 1,317 ha production forest (primarily acacia monoculture) and 429 ha natural forest, with varying potential for enrichment and diversification. Some of the 100 ha upland with peanut and cassava, and 152 ha tea plantations with low productivity, could be improved with higher value trees / agroforestry systems. (See Figure 5).	

(e) Fruit garden to multistory garden				
		Current practice 1	Current practice 2	CSA practice 3 (example in Truong Son)
Practice	Technology	Monoculture or mixed fruit trees Inputs: none Rainfed	Intercropping: Fruit trees with sporadic tea Inputs: As Practice 1	Intercropping, diversification: Fruit trees with grass or vegetables Inputs: biological herbicide and pesticide, organic fertiliser (compost) Management: thinning branches and leaves Irrigation: water pit or pond, drip irrigation
	Component	Pomelo (Phuc Trach), jackfruit, litchi and/or orange	Litchi, longan Tea	Pomelo (Phuc Trach), jackfruit, litchi and/or orange. Grass, sunflower. Vegetables (autumn-spring season, e.g. green bean, *Brassica juncea*, *Ipomoea aquatic*, *I. batatas*, *Colocasia esculenta*)
CSA indicators	Livelihood	Fruits sells at VND5 -7 million $tree^{-1}$ $year^{-1}$	+Diversified income -Declining yields (competition for nutrients in the root zone) +More efficient use of home garden area	+Diversified production, income and nutrient intake +Increased yield/income +Animal feed -Investment cost/land loss for water
	Adaptation	-Sensitive to drought, storm and pest	- Sensitive to drought, storm (litchi, longan) and pest + Shade and soil moisture interactions	+Irrigation and improved management is expected to reduce drought and storm damage +Grass cover may regulate soil moisture (reduce direct evaporation) +Microclimate regulation (shade, wind shield)

	Mitigation	+C-sequestration above and below ground -Declining soil nutrient as no fertiliser is added	+/-Similar to practice 1	+Increased C-sequestration above and below ground +Biological pest management, increased biodiversity +Compost recover some soil nutrient loss
Farmers' comments		**Benefits:** Tree diversification has contributed to improved food and feed habits. By integrating fruit trees and grass or improving management, such as thinning and pruning, some farmers had reduced storm damage. Some households envisioned business opportunities. **Risk:** Some farmers expected more weeds with organic fertilisers and/or without inorganic herbicides. Diversification is limited due to absent longer-term investment capital, technical skills and equipment and high quality seedlings.		
Experts' comments		Practice 3 opens up for context-specific variations. If natural grasses are part of the system, weeds need not be a problem, such as enclosed systems for small grazing animals, cut & carry for larger livestock with manure for compost/biogas. Consider putting fish or duck in water-harvesting ponds to compensate part of the lost area; establishing farmer-cooperative nursery to ensure local supply of improved tree seedlings.		
Scalability potential		Fruit tree diversification and improved management is possible in most home garden areas. If the prescribed land use for agriculture (rice) could be altered to allow perennial land use, there is potential to convert some of the most drought-affected rice fields (68 ha), peanut and cassava (100 ha), and/or tea plantations (~160 ha) in the commune.		

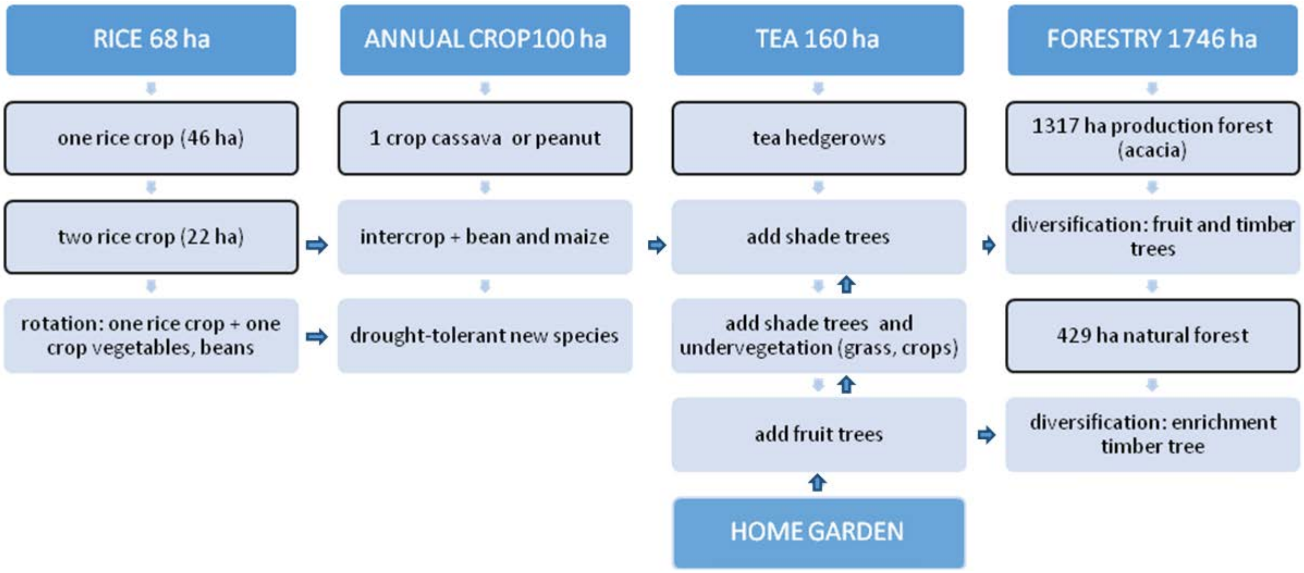

Figure 4. Vertical (land use change) and horizontal (land conversion) pathways towards intensified climate-smarter land uses in Ky Trung commune. The four columns represent current key land use types, and cells with black borders are existing baseline practices

Addressing the persistent perceived need for inorganic pesticides and herbicides remained a challenging topic throughout all 'improved' practices. Many farmers used inorganic inputs for weed and pest control saying they experienced less weeds, thus higher yields. However, it was unclear what alternatives had been tested. The drought risk, which poses a slow-onset and comparatively predictable hazard, highlights the need for improved climate services (seasonal and updated weather forecast) that can be tied to concrete management advice to enable more effective use of inputs. For example, avoiding fertilizer/pesticide application on rainy or hot, sunny days. Concrete recommendations for gradual conversion from chemical to biological inputs can be developed in farmer learning groups using approaches similar to Integrated Pest Management (IPM), with on-farm control-and-experiment plots to evaluate the resource-use efficiency also for producing e.g. animal feed, green manure and compost.

3.2.3. Scaling Potential

The potential for diversifying and scaling out some practices in the commune is limited by policies on designated land uses, especially for rice and for fruit trees on forestland. Moreover, many areas have insufficient surface water for irrigation, due to distance and limited natural open water sources. For sustainable drought management, three options were discussed: (a) expanding new surface water harvesting systems to avoid groundwater replenishment linked to drip irrigation systems – an option that would require public investment; (b) green solutions for microclimate regulation, i.e. multi-storey systems, shade trees, intercropping, and avoiding bare soils through cover crops, mulch and no-tillage - multiple options that can be developed within several existing projects and support programs, with direct and indirect contributions to mitigation targets; (c) drought tolerant species – in collaboration with the province extension department.

Given the seedling support for reforestation and limited support for other products than pulp, farmers perceived the dense acacia plantation to be a financially viable and comparatively storm-resilient option. In fact, preliminary estimates from the province indicate that dense short-term acacia stands (1x1 meter for four years) could store about the same amount of above-ground carbon annually as if planted more sparsely and left twice the time (3x3 meter for eight years), discounting the trade-off between build-up of soil and below-ground carbon storage that is lost during harvest, and risk for storm-fell [24]. With Ha Tinh being a pilot province for REDD+, enabling policies are in place for integrating reforestation efforts into existing programs with support for forest protection, carbon markets, PFES-mechanisms and to integrate higher-level CSA-indicators in green accounting reported to Nationally Determined Contributions (NDC).

Based on consultations with farmers, agriculture experts and policymakers, Figure 4 outlines some spatial possibilities to advance pathways for CSA in the commune. The provincial land use plan (Figure 5) indicates several opportunities for scaling of CSA. Notably, between 2015 and 2020, tea and citrus are planned to expand by 50% and forest plantation by 6,300 ha. At the time of the study, latex prices had been plunging for several years, hence rubber planting was stalled and existing trees were cut down. Given the uncertain trends, rubber was not considered here so the land areas were instead allocated for other agroforestry systems.

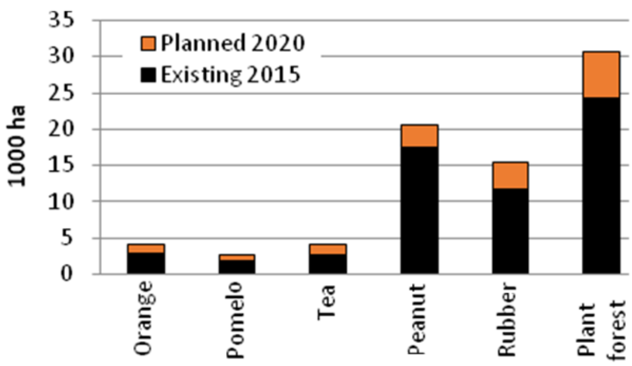

Figure 5. Areas planted in 2015 and planned by 2020 [20] for flagship crops in Ha Tinh province' Masterplan [21]

4. Discussion

4.1. Farmer Adoption of CSA

This study highlighted the potential to scale CSA and promote more resource-efficient farming systems. To gain farmers' acceptance, CSA practices were identified and prioritised based on the knowledge and experiences of farmers to address certain (perceived) barriers and changes at the farm and landscape levels [2,25]. In short, the considerations that farmers weigh before adopting new practices can be clustered around the three basic factors of production [26]: labour, land, and capital. With an average household size of 4-5 persons, Vietnamese households need to plan farming activities well or hire labour. This is particularly necessary during harvest times, and in the case of hiring loggers for timber harvest, clear-felling is cheaper despite its negative environmental impacts. Secondly, for a household to make sufficient income from 4-6 small scattered fields, in total covering some 0.5-1.5 ha, planning is required. Given there is a diversity of seedlings available, small and scattered fields may theoretically encourage agrobiodiversity at the landscape scale. In contrast, some farmers perceive small and scattered fields as economically ineffective that prevent them from investing in permanent mixed higher-value, typically more labour-intensive stands. In countries like Vietnam, where some agricultural land uses are regulated, impacts on ecosystem functions (including adaptation and mitigation potentials) are important to investigate prior to scaling out.

Enabling conditions. The proposed pathways towards elevated CSA (Figure 4, Table 5) build on local knowledge and diversification mainly using existing crops. Overall, rather than agro-technical knowledge, common bottlenecks to solve for implementing CSA practices were (i) the required upfront investments and years without return for establishing new technologies; and (ii) uncertain factors involved in 'new' untested components. In particular, long-term investments on small plots were not deemed worthwhile. Enabling conditions could be provided through (1) gradual introduction of integrated CSA-practices that provide some income during the establishment phase; (2) policy support for converting unproductive agriculture land into mosaics of permanent agroforestry; (3) access to investment or loans with low interest rate and longer return period; and (4) new drought-tolerant varieties and crops.

Due to the uncertainty, an incidental, or risk fund, may be established to cover potential losses when introducing new crops. Revolving village funds could kick-start such investments. There is scope for awareness-raising on the appropriate use of chemical agriculture inputs, and to broaden the use of IPM and Good Agriculture Practice (GAP). Authorities and farmer organisations expressed interest in creating links between farmer-groups and market opportunities. Farmers and extension officers may work out 5 to 10-year plans for developing and maintaining CSA practices based on the economic viability of various farm practices. Considering on-farm resource-use efficiency can improve financial returns by reducing the needs for external inputs, such as fertiliser, pesticide and herbicide.

4.2. Motivation for Scaling

We note two different angles of interest in CSA: policymakers focused on land use targets broadly, i.e. 'what to' plant, while farmers and extension focused on specific implementable practices that would bring economic return, i.e. 'how-to' to use land efficiently. Thus, for generating farmers' acceptance and adoption as well as assessing the potential scalability of complex integrated farming systems, both aspects were easily discussed about when 'practices' were separated into the more generic, potentially scalable 'how-to' [technology] from the context-specific 'what-to' [components] do, or grow: i.e. selecting the landscape design and the right tree-crop combinations. Using this modified approach for exploring CSA options and scalability, is considered an improvement to the initial modes tested in the CSV [9,12,14].

Ensure the need for CSA. Perhaps the most challenging part was to encourage local stakeholders to 'innovate' their practices. In other words, local stakeholders were encouraged to consider CSA practices not as stagnant solutions, but as starting points to be continually improved based on local needs and contexts to address productivity, adaptation and, particularly for achieving concrete contributions to mitigation. This may be interpreted as CSA being knowledge-intensive [4]. Some extension workers and farmers have the capacity to build upon current practices and by themselves evaluate economic and environmental impacts, including unwanted side-effects. However, some guidance may be needed for prioritising what indicators to monitor where and for what practices. For example, reducing greenhouse gas emissions from low-input rice cultivation in rainfed uplands should not be a priority.

For the purpose of clarifying trade-offs in CSA, the researchers organised a training for provincial and district stakeholders. This training included field visits wherein participants were encouraged to critically evaluate practices using CSA metrics and recommend improvements to achieve productivity, adaptation and mitigation objectives. This exercise was intended to encourage leaders who could become future advisors to farmers and champion CSA practices [27]. The same approach was used to map and prioritise 'climate-smarter' practices in this study, confirming that the exercise can be made with minor budgets. With substantial budgets, landscape modelling tools could considerably improve the evaluation of different options, but would require more training to officials at departments of agriculture and environment. Some adaptation strategies require Government infrastructure or public-private partnerships, such as climate services. Here, access to weather forecasts and agroadvisories can result in better adaptation strategies.

This research contributes to a portfolio of practices for the province, with information about how to implement each practice, minimum requirements (biophysical, training and investment) and potential support from ongoing projects and policies. Based on the experiences from this study in explaining and demonstrating CSA at farmer and policy-maker scales, it is clear that the 'climate-smart' practices have a considerable potential for addressing food security, adaptation, and climate change mitigation in tandem. These innovations must be viewed as an ongoing, collaborative process of continual improvement.

5. Conclusion

Local knowledge can speed up acceptance for CSA. The practices generated from farmers' knowledge highlights that some CSA practices are neither new nor necessarily science-technology-knowledge intensive, therefore generally readily accepted.

CSA-priorities can be determined low-tech low-cost. Prioritising 'climate-smarter' practices can be done by local stakeholders on minor budgets, by considering two steps: a scalable how-to and a context-specific what-to do, building on enabling conditions.

Monitor and follow up contributions to CSA targets. A 5 to 10-year monitoring and evaluation plan with self-selected indicators for follow up, can be developed with technical expertise.

Build on factors that enable scaling. When designing CSA interventions, limiting and supporting factors need to be considered, such as policies. Learning events, experiments, cross-visits, and clear guidelines can motivate and trigger innovative climate-smart farming systems and business cases.

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