Economic Analysis of Improved Smallholder Paddy and Maize Production in Northern Viet Nam and Implications for Climate-Smart Agriculture

Giacomo Branca, Aslihan Arslan, Adriana Paolantonio, Romina Cavatassi, Nancy McCarthy, N. VanLinh, and Leslie Lipper

Abstract Adoption of improved agricultural practices is shown to vary based on rainfall variability and long-term average maximum temperature, and although such practices increase productivity and profitability on average, their impacts also vary based on climatic conditions. This paper presents a case study on impacts and implications for adoption of Climate Smart Agriculture (CSA) solutions in the Northern Mountainous Region (NMR) of Viet Nam. We use primary data collected through *ad hoc* household and community surveys to conduct profitability estimates of comparative technologies using crop financial models based on partial budget analysis and a study of the determinants of adoption and of yields. In particular, we find that the majority of farmers in NMR rely on 'conventional' farming despite indications that sustainable land management practices such as Minimum Tillage (MT) applied to upland maize production, and Fertilizer Deep Placement (FDP) and Sustainable Intensification for Paddy (SIP) production are more profitable. Adoption of MT is greater where long-term variation in rainfall during critical growing periods for maize is higher; FDP and SIP adoption is greater in places where the long-term

G. Branca (✉)
Department of Economics, University of Tuscia, Viterbo, Italy
e-mail: branca@unitus.it

A. Arslan • A. Paolantonio • R. Cavatassi
International Fund for Agriculture Development (IFAD), Rome, Italy
e-mail: a.arslan@ifad.org; a.paolantonio@ifad.org; r.cavatassi@ifad.org

N. McCarthy
Lead Analytics Inc., Washington, DC, USA
e-mail: nmccarthy@leadanalyticsinc.com

N. VanLinh
Food and Agriculture Organization of the United Nations (FAO), Hanoi, Viet Nam

L. Lipper
ISPC-CGIAR, Rome, Italy
e-mail: leslie.lipper@fao.org

L. Lipper et al. (eds.), *Climate Smart Agriculture*, Natural Resource Management and Policy 52, DOI 10.1007/978-3-319-61194-5_23

average of maximum temperatures is higher during critical periods for rice growth. Finally, these improved practices have higher labour and input costs compared to conventional practices, which may prevent or slow adoption.

JEL Classification Q12 • Q16 • Q54 • Q55 • O33

1 Introduction

Viet Nam is forecasted to be among the countries hardest hit by climate change (CC) with expected negative effects on agricultural production, caused mainly by changes in rainfall and temperatures and rising sea levels (Yu et al. 2010). The Northern Mountainous Region (NMR) is a particularly challenging region (FAO 2011) and has poverty rates among the highest and most widespread in the country.[1] CC is expected to exacerbate the instability of food production in the region, where agriculture is the main employer of rural labour force. Unfortunately, region-specific evidence of vulnerability to CC and its impacts is scarce.

An important question for the NMR is thus the extent to which improving agricultural practices may mitigate the negative impacts of CC and further improve resilience indicators. The literature on sustainable agricultural practices indicates that improved farming practices could increase food production without degrading soil and water resources – important elements towards adaptation to CC (World Bank 2006; Pretty 2008; Woodfine 2009). In reviewing 160 studies with field data on yield effects, Branca et al. (2013) found that adoption of Sustainable Land Management (SLM) generally leads to increased yields, although the magnitude and variability of results varies by specific practice and agro-climatic conditions. Many of these practices can also deliver co-benefits in the form of reduced greenhouse gas emissions, enhanced carbon storage in soils and biomass, increased soil fertility and water storage capacity, and strengthen the mechanisms of elemental cycling. Thus, sustainable farming technologies may be Climate-Smart Agriculture (CSA) options for smallholders in fragile environments like NMR.

To assess the possible role of adoption of sustainable farming technologies in the NMR, detailed analyses on their production costs and profitability as well as on the determinants and impacts of adoption are needed (see FAO 2010). This chapter presents a case study conducted in the provinces of Yen Bai, Son La and

[1] Poverty rates change, depending on the methodology employed, but in every event, suggesting poverty is the highest and more widespread in the North West, the area of our interest. The head-count ratio suggests that the poor residing in the North West Mountains of Viet Nam ranges from 60.1% from the General Statistics Office of Viet Nam and the World Bank to 39.1% from official estimates (World Bank 2012).

Dien Bien located in the NMR of Viet Nam. It uses primary data coupled with historical climate information using partial budget and econometric analyses. Special attention is paid to the impact of long- and short-term climate variations during critical periods for key food crops in the area, namely maize and rice, during their growing period. The study:

1. documents the type of practices and technology systems used by farmers in NMR for different crops and agro-ecologies;
2. estimates productivity and profitability of improved versus ‘conventional’ agriculture systems;
3. analyses the determinants of practices’ adoption; and
4. assesses the potential of sustainable farming technologies as adaptive response to changes in climate.

2 Background

The NMR region of Viet Nam (see Fig. 1) is 103,000 km^2, about one third of the country area, and hosts about 12 million people, corresponding to 15% of the national population, living in more than 2000 communes (administrative villages), with a large share consisting of ethnic minority groups (Tran 2003). The region is almost exclusively highland, ranging between very steep (slopes of greater than 25°) and steep (slopes ranging between 15 and 20°), where the former covers 62% and the latter 16% of cultivable land (Le Ba Thao 1997). Due to the varied and fractured topography, there is a wide range of ecosystems (Tran 2003) with a series of mountain ranges and several large intermountain basins. The NMR is affected by the tropical monsoon climate, characterized by hot rainy summers and dry cold winters.

The NMR has poor infrastructure and is less urbanized and more dependent on agriculture than any other region of the country. Almost all farmers are smallholders, which diversify production to some degree. Mechanization is not yet broadly developed and is currently mainly practiced for rice threshing, land preparation in big plain areas, and occasionally for tea and coffee harvesting and/or processing.

Smallholder cropping systems in the study provinces include both rainfed and irrigated annual crop production. The upland environment provides a range of agro-ecological conditions that allow farmers to grow rice, maize, millet, peanuts, vegetables, beans and cassava. Beans, peanuts and vegetables are mainly produced for self-consumption. Cassava and maize are generally produced as cash crops. Rice is the primary staple crop in NMR as in the rest of the country, which is produced both for self-consumption and cash income. Lowland irrigated rice (paddy) plays a major role in most households’ food security (Castella and Erout 2002).

Farmers grow rice in the intermountain basins, river valleys, and bunded terraces as wetland/lowland paddy, as well as on the sloping uplands as direct seeded upland rice.

Fig. 1 The provinces in the NMR

Paddy rice is intensively cultivated in plains, where two cropping seasons per year can be grown. After harvesting the second crop of paddy, upland food crops (potato, sweet potato, legumes, and vegetables) can also be produced in some areas of these plains. Upland rice system still persists in areas under slash-and-burn practices (shifting cultivation). The substantial increase in the productivity of irrigated rice, combined with the ban on slash-and burn cultivation, have brought about a major decrease in upland rice cultivation. In spite of progressively declining upland yields due to shortening fallow periods (Husson et al. 2000) upland rice remains the primary food production strategy for a number of households.

With increasing scarcity of good quality land, farmers are turning upland rice to other food crops (maize, soybean, cassava). Maize is one of the most important cash crops, especially in Son La province, and is now the dominant upland crop (Castella et al. 2002). This is mainly attributable to an increase in the demand for maize from the feed industry, increase in yields and profitability of maize due to the use of improved varieties, and decrease in upland rice yields (Wezel et al. 2002; Doanh and Tiem 2001). Tea and coffee are the most widely produced perennial crops in the area. Tea is grown in all three provinces, but mostly in Yen Bai. Arabica coffee is produced only in Son La and Dien Bien. Regenerated forests of acacia and eucalyptus are common on steep slopes at high altitudes, mostly at places where soil fertility is low, for their value in generating timber.

Climatic patterns are characterized by (i) cold winters, with diurnal temperatures between 12 and 14 °C and hoarfrost on high belts, and (ii) early summers relative to other regions, with night temperatures increasing to 30 °C in March and reaching their maximum in June (41.1–42.5 °C). The region has two monsoons during the wet season from April to October. Total annual rainfall is about 2000 mm (over 85% falls during the rainy season), and its temporal and spatial distribution is highly unevenly (Nguyen 2006). Thus, the role of climate on adoption decision and cropping patterns focuses on rainfall regime and temperature variability.

We analyse the differences of climate depending on crop type and its "critical" growing periods. A critical growing period for maize is the 10-day period after sowing when too little rain would prevent seed germination. This corresponds to late March or early April in our case.[2] Climate data show that Son La historically receives much higher rainfall during the 10-day period after maize sowing than Yen Bai and Dien Bien. In 2013, while Son La experienced higher than average rainfall during this period, Dien Bien and Yen Bai received much less rainfall than their historical average and were more vulnerable to unpredictable rain during this period than Son La.

A second "critical period" is the heading stage of paddy rice when too high temperatures can damage production (Zhu and Trinh 2010). In our case, this corresponds to late May or early June. While Dien Bien has historically lower temperatures during this period, it experienced much higher maximum temperatures in 2013 compared to its long-term average. The other two provinces experienced lower temperatures during this critical period in 2013. The long-run variation in this variable is much higher in Dien Bien, in spite of the fact that it has more favourable temperatures on average, underlining the importance of monitoring the differences in both levels and long-term trends between and among different locations to assist farmers in dealing with various shocks.

3 Data Sources

3.1 Survey Design and Primary Data Description

A survey at the household and community level in the study area was conducted in 2014, using Stratified Random Sampling (SRS) with purposively designed strata on an *ad hoc* universe of households and communities to ensure all relevant data could be collected. A qualitative analysis was conducted through literature review, key informants interviews and stocktaking of data and information related to projects and interventions that included adoption and dissemination of potential CSA. Communes where such interventions had been conducted were included in the sampling frame in parallel with comparable communities where no interventions or projects of such types had been conducted. In each commune a full list of households was obtained, including farmers practicing both improved and 'conventional'

[2] "Critical periods" for the two crops of concern in the present study have been identified through deep analysis from literature but above all from discussion with experts in the study area.

agriculture.[3] In the process of generating the list of households to be interviewed, an effort was made to stratify respondents according to specific farming practices (or a combination of practices and crops) in order to have a balanced number of observations for each target practice. Disproportionate stratified sampling procedure was used.[4] Actual respondents were randomly selected within each strata to be interviewed.

Questionnaires were designed to collect detailed primary data on benefits and costs of agricultural practices at household and community levels in addition to other relevant socio-economic and agriculture related data. Agricultural data refers to the 2013–2014 production year. Data was geo-referenced to enable merging with climatic information at commune level, as well as institutional data collected at provincial level (see Branca et al. 2015).

The sample covers 900 farmers in 25 communes distributed across the three provinces as follows: 235 in Dien Bien, 314 in Son La, and 351 in Yen Bai. Data collected include key crop production variables[5] related to smallholders (average land size in the sample is between 1 and 2.65 ha) practicing SLM and 'conventional' farming practices. The main crops considered include paddy, upland rice, maize, cassava, coffee and tea.

A list of improved farming practices with CSA potential (see Pham et al. 2014) was developed after literature review and through consultations and validation with the Viet Nam Ministry of Agriculture and Rural Development (MARD) and scientists from the local partner institute Northern Mountain Agriculture and Forestry Science Institute (NOMAFSI). These include:

1. sustainable intensification for paddy (SIP), i.e. transplanting young seedlings according to specific distance or space between plants using straight-row method and irrigation management to increase production efficiency[6];

[3] This includes: the Viet Nam Household Living Standards Surveys (VHLSS), conducted by The World Bank and the General Statistics Office of Viet Nam, constituting a panel dataset for the years 2002, 2004 and 2006; and the Viet Nam Access to Resources Household Surveys (VARHS), conducted by the Central Institute for Economic Management (CIEM).

[4] Disproportionate stratified sampling is a stratified sampling procedure in which the number of elements sampled from each stratum is not proportional to their representation in the total population. Given the sometimes low rate of improved farming adoption, using proportionate stratification could have caused the sample size of a stratum to be very small. Proportionate allocation may have not yielded sufficient number of observations for a specific farming technology applied to different crops making it difficult to meet the objectives of the study. The solution was to oversample the small or rare strata; oversampling creates a disproportional distribution of the strata in the sample when compared to the population.

[5] Data contain information on: farmland use, inputs (hybrid and open-pollinated variety seeds, chemicals, organic fertilizer, water for irrigation) quantities and unit costs, labour use in different management activities, labour costs estimated at the prevailing wage rate, inputs acquisition sources and subsidized prices, investment and establishment costs, crop yields, and output prices. The questionnaire includes specific sections on cropland management to capture key information about the agriculture management practices adopted (including sustainable land management practices).

[6] Farmers may apply different subsets of other more well-known and promoted systems such as

2. Fertilizer Deep Placement (FDP), i.e. use of potassium and nitrogen fertilizers mixed and compressed into larger fertilizer granules that are physically placed under the soil surface[7];
3. minimum tillage (MT), i.e. direct sowing without mechanical seedbed preparation and with minimal soil disturbance after harvest of the previous crop;
4. intercropping, i.e. cropping of different legumes (black beans, mung beans, rice beans, soybeans, groundnuts) or other crops (e.g. pumpkins) together with coffee or tea;
5. mini-terracing, i.e. vegetative strips created in sloping fields in order to allow growing a crop on a single row on each terrace to reduce soil erosion.

Based on the qualitative analysis, we define "conventional agriculture" as: fields are ploughed (tillage system), plant residues are piled and burnt or cleared out of the field, and no specific control method for input use is adopted. These practices are a source of land degradation exacerbated by soil erosion and sediment loss due to surface runoff in response to rainfall patterns especially in steep slope areas, such as the NMR (Tran 2003). Further, these practices reduce both productivity and resilience of the system.

The household level survey captured the socio-economic structure of the household as well as the agricultural production including costs, benefits, inputs and technology used by crop and plot. The community questionnaire collected relevant information at village and/or commune level including: (i) average costs of labour, (ii) average time required to perform field tasks, (iii) input sources and prices, (iv) seed types, sources and prices, (v) input subsidies provided to farmers, (vi) output prices at local markets, (vii) access to infrastructures, to extension and to information services, and (viii) perceptions on rainfall and temperature patterns.

The surveys were conducted immediately after harvest in order to minimize recall errors. Annex 1 provides detailed information on the structure of the household and community questionnaires.

System of Rice Intensification (SRI), Integrated Crop Management (ICM) and Integrated Pest Management (IPM). These agro-ecological methodologies are supposed to increase the yield of the rice produced in irrigated farming by changing the management of plants, soil, water and nutrients. They are based on a combination of practices aimed at increasing the efficiency of paddy productivity and reducing the use of resources and inputs (choose appropriate varieties and use quality seeds, improve transplanting modalities, balance chemicals and fertilizer application, control water irrigation use). However, since almost no farmer in the three regions applies the whole set of practices that form these systems, for the purpose of the study a new category has been identified under the name of 'SIP' (Sustainable Intensification for Paddy) in order to represent these sets of practices and prevent confusion with other systems.

[7] This is an innovative technique aimed at reducing fertilizer losses and increasing efficiency of fertilizer use.

Table 1 Critical periods for rainfall and temperature shocks for maize and paddy in Dien Bien, Son La and Yen Bai

Variable name	Critical periods for maize
maize_first10d_rain	First 10 days after sowing: too little rain prevents seed germination (the most critical period for maize)
maize_flower_rain	Flowering stage: too much rain is damaging (spring and autumn)
maize_midseason_rain	Between 60 and 80 days after sowing: 20 days of good rainfall is necessary
	Critical periods for paddy
rice_midseason_tmin	50–60 days after planting too low temperatures are damaging (only in the spring season)
rice_heading_tmax	Heading stage: 70–80 (50–70) days after planting in spring (autumn) too high temperatures are damaging
rice_harvest_rain	Ripening stage: 30 days before harvest heavy rains are damaging

Source: Own elaboration based on expert consultations, May 2015

3.2 Climate Data

Household data have been complemented with commune-level data on historical rainfall and temperature patterns from the European Centre for Medium Range Weather Forecast (ECMWF) in 10-daily intervals for the period of 1989–2013.[8] Using the ECMWF ERA-Interim data, a comprehensive set of variables to control for impacts and role of key climatic variables were created, including "critical growing periods" of agriculture and food security in the season of interest. These key climatic variables reflect crop- and province-specific within season shocks and were created during an interactive workshop with experts from the MARD and DARD from all study provinces. These variables are considered to provide a detailed representation of location- and phase-specific shocks for the provinces and crops of interest compared to general findings based on intensively managed experimental stations in the literature (Welch et al. 2010). Table 1 summarizes the variables used to measure long-term trends as well as within-season shocks specifically created.[9]

Long-term coefficients of variation in these variables shape farmer incentives to adopt practices that may help them dealing with climate shocks, and hence are

[8] ERA-Interim is the latest global atmospheric reanalysis produced by the ECMWF with a resolution of 0.25° (~28 km) in 10-day intervals. Re-analysis is a process by which model information and observations of many different sorts are combined in an optimal way to produce a consistent, global best estimate of the various atmospheric, wave and oceanographic parameters.

[9] Growing seasons for rice and maize may vary, but they mostly are as follows: (i) Maize. Spring-summer season: sowing from late February to March, and harvesting in July-August. Summer-autumn season: sowing from late July to early August, and harvesting in October- November; (ii) Rice. Spring-summer season: cropping period goes from March-April to June-July. Summer-autumn season: cropping period goes from June-July to September.

used as determinants in adoption analysis. The shocks specific to the crop seasons covered by the primary data are used in yield analyses, since they affect yields directly as well as indirectly (through interactions with the effects of various practices).

4 Empirical Analyses

4.1 Gross-Margin Analysis

The comparative profitability of the different technologies is estimated using crop financial models based on partial budget analysis (Brown 1980, Swinton and Lowenberg-DeBoer 2013).[10] The following assumptions have been made: (i) cost of the land is not taken into account since it is a fixed production cost and it does not vary depending on the different practices; (ii) farm-gate prices of inputs and outputs are those prevailing during the production season covered by the study and are assumed to be equal for all farmers; (iii) all quantitative information (input and output quantities and prices) are computed on-farm; (iv) economic results are obtained at the farm-gate level.

Profitability outcomes used in the comparison include: gross margin (GM), net income, production costs per unit of output, returns to capital, returns to labour and incremental value-cost ratios. These indicators have been estimated for each combination of crop and technology over the time frame of a 1-year production cycle per 1 hectare of land, using the following equations:

$$TR_{jT} = P_j Q_{jT} \tag{1}$$

$$TVC_{jT} = \sum_{n}^{i=1} P_{X_i} X_{ijT} \tag{2}$$

$$GM_{jT} = TR_{jT} - TVC_{jT} \tag{3}$$

$$TC_{jT} = TVC_{jT} + LC_{jT} \tag{4}$$

$$NI_{jT} = TR_{jT} - TC_{jT} \tag{5}$$

$$UC_{jT} = TC_{jT} / Q_j \tag{6}$$

[10] This is a short-term analysis. Resources and technologies are assumed to be fixed, and management decisions are made among existing alternatives which may be limited in the selected time-frame. Long-term changes in the technologies, policies, availability and productivity of the natural resource-base are not taken into account and are out of the scope of this analysis.

$$RC_{jT} = TR_{jT} / TVC_{jT} \tag{7}$$

$$RL_{jT} = TR_{jT} / Total\, labor_{jT} \tag{8}$$

$$L_{jT} = Q_j / Total\, labor_{jT} \tag{9}$$

$$BCR_{jT} = \left(TR / TVC\right)_{jT} \tag{10}$$

Where:

TR_{jT} = total revenue ($/ha) for crop *j* under technology *T*
P_j = farm-gate price of crop *j* ($/kg)[11]
Q_{jT} = yield of crop *j* under technology *T* (kg/ha)
TVC_{jT} = total variable costs ($/ha) for crop *j* under technology *T*
P_{X_i} = farm-gate price of input *i* ($/unit)
X_{ijT} = quantity of input *i* (per ha) used in production of crop *j* under technology *T*
GM_{jT} = gross margin ($/ha) for crop *j* under technology *T*
TC_{jT} = total costs ($/ha) for crop *j* under technology *T*
LC_{jT} = cost of family labour ($/ha) for crop *j* under technology *T*
NI_{jT} = net income ($/ha) for crop *j* under technology *T*
UC_{jT} = production costs per unit of output ($/kg) for crop *j* under technology *T*
RC_{jT} = returns to cash capital ($/$) for crop *j* under technology *T*
RL_{jT} = returns to labour ($/person day) for crop *j* under technology *T*
L_{jT} = labour productivity (kg/person day) for crop *j* under technology *T*
BCR_{jT} = benefit-cost ratio for crop *j* under technology *T*.

Total variable costs are those directly applicable to the crop on each field and include all cash inputs (e.g. seeds and seedlings, fertilizers, manure, herbicides, insecticides, fungicides). Costs of depreciation of fixed assets, land, labor, and capital costs (e.g. interest) are excluded from GM calculations, because they are either negligible or no inputs, other than family, are used.[12] However, labour costs are taken into account in computing total costs at an imputed agricultural wage rate (unit cost of hired labour) estimated on the basis of field data and kept equal for all

[11] Allowance should be made for the time of selling, as price fluctuates throughout the year. However, since it has been verified that among smallholders interviewed almost all sales happen immediately after harvest time, a stable 'average' price is used in the analysis.

[12] Land is seen as a household resource, with different productive activities competing for its use. Including the cost of land in the analysis would make all GMs lower, but would not affect the relative attractiveness of the different crops and technologies. Also, it should be noted that in Viet Nam smallholders in rural areas do not pay a rent for the land. Although it is true that the cost of land will become increasingly important for smallholders in densely populated areas and in areas close to urban centres, this element falls out of the boundaries of the analysis.

crops grown. Since the study concerns small family farms, fixed costs in our analysis only include family labour.[13]

In principle, net income represents the return to the farmer for management and interest on land and capital (i.e. what accrues to management, capital and land). Since we are considering smallholders who have very limited capital invested (the only capital available is the cash used for input purchase), net income is what accrues to land and farm management. However, since farmers do not pay for land, net income is mostly remuneration of management activities.

Production cost per unit of output is one of the most important components of short-term economic results of agricultural activity. Comparing per unit production costs for a given crop and practice is a good indicator of the inherent suitability of a certain practice in a given area.

Return to capital is constructed from the ratio of total revenues to cash inputs. For example, a return to capital ratio of 3.5 means that for each Vietnamese Dong (VND) invested, 3.5 VND are obtained. Return to labour is constructed by the ratio of GM (excluding all costs of labour) or net income to total labour input. The parameter indicates how much is earned for each day of work attributed to the farm, irrespective of who provided labour. When the return to labour is lower than the prevailing wage rate of daily labour, hiring labour implies that the costs outweigh the returns. Labour productivity is calculated by the ratio of crop yields over the total amount of labour needed for that crop under the specific technology used.

4.2 Determinants of Adoption and Yield Impacts

We employ econometric analysis of the determinants of adoption and yield implications of the sustainable agricultural practices to address the following questions:

1. What are the determinants of/barriers to adoption of practices deemed to be profitable by the above analysis?
2. What are the marginal effects of practices on yields controlling for all other factors that affect yields?
3. Do the yield implications differ under different climatic shock conditions?

The following estimating equations are used to understand the determinants of adoption, and the effects of practices on yields, with specific focus on the climatic shock variables (see Sect. 3.2):

$$A_{ij} = \alpha_1 + \beta_1 X_i + \gamma_1 W_c + u_i \tag{11}$$

[13] This approach will apportion only family labour costs related to field operations in crop production, overcoming, to some extent, the limitations of gross margins which fail to take into account fixed cost changes when comparing different farming practices. Other fixed costs that have to be borne regardless of production (e.g. depreciation, interest payments, administration) are not considered.

$$Y_i = \alpha_2 + \beta_2 X_i + \gamma_2 W_c + \delta A_{ij} + \epsilon_i \tag{12}$$

A_{ij} is the indicator variable for the adoption of SLM practices: it equals one if the household i adopted practice j (i.e. MT, FDP or SIP) on at least one plot for the crop in question (maize and paddy) during the 2014 growing season. X_i is a vector of variables that affect households' incentives to adopt a specific SLM practice including demographic characteristics, wealth indicators, access to credit, extension and other types of government support. Y_i is the productivity per hectare of maize or rice for household i. u_i and ε_i are normally distributed error terms of the adoption and yield models, respectively. W_c is a vector of variables defined based on the climatic shock variables in Table 1, which vary between adoption and yield analyses.

In estimating the adoption probabilities (i.e. Eq. 11), W_c includes long-term coefficients of variation of the variables in Table 1 in order to capture the effects of long-term trends in shocks on incentives to adopt sustainable agricultural practices. We expect, in general, that higher long-term variation of shock variables increase incentives to adopt practices that are perceived/promoted to help deal with these shocks. Adoption of MT, for example, would be positively correlated with increased variability of average rainfall during critical periods. This is because MT has the potential to buffer crops from water stress. In case of SIP/FDP however, the expectations are ambiguous as these practices are not necessarily promoted to deal with shocks but rather to increase yields as captured in the yield equations used in this analysis.

In estimating the productivity model (i.e. Eq. 12), W_c includes the values of the specific shocks during the cropping seasons covered by our data in order to capture the direct yield effects of these shocks. We estimate Eq. (12) for maize and rice using two specifications: one simple specification including the climatic shock variables, and one with interaction variables between adoption indicators and climatic shock variables relevant for the crop. The interaction model helps us investigating whether and how the adoption of SLM practices changes the effects of shocks on yields (Arslan et al. 2015). We expect the direct effects of the shocks on yields to be positive (negative) if the specific shock definition indicates lower (higher) values to be detrimental to crop growth. The signs of interaction variables vary depending on the shock and practice combination, but overall the detrimental effects of shocks are expected to be mitigated by those practices that provide adaptation benefits.

5 Results and Discussion

5.1 Gross Margin Analysis

Diffusion of farming practices by type among farmers in the sample is reported in Table 2. Of note, the vast majority of surveyed farmers mainly rely on 'conventional' farming systems, especially for upland rice production.[14] Some households,

[14] It should be noted that these figures do not reflect the overall adoption shares in these provinces, as the sample selection was such to ensure enough numbers of adopters and a corresponding number of non-adopters in each commune to be able to conduct some analysis (both from "intervention" communes and 'comparable' communes).

Table 2 Diffusion of sustainable farming and 'conventional' practices among farmers in the sample

Practice surveyed	Details of the practice	% of Households adopting				Avg. nr. of years of adoption
		Dien Bien	Son La	Yen Bai	Total	
Sustainable paddy production intensification	FDP	0	0	40	16	2.12
	SIP	9	20	5	11	2.34
MT	(with or without any residue management)	0	47	39	32	4.63
Agronomy	Intercropping	15	24	17	19	3.35
	Crop rotation	3	4	1	3	4.25
Soil and water conservation structures	Mini-terracing	17	18	8	14	6.11
Agroforestry	Agroforestry	4	9	23	13	3.73
Conventional	None of the above	94	91	79	87	

Source: Branca et al. (2015)

however, also apply a combination of sustainable farming practices to various crops. More specifically, MT applied to upland maize production is the most common among the sustainable farming practices surveyed (32% of adopters located in Son La and Yen Bai provinces). FDP and SIP methods are used in irrigated rice production. FDP is adopted only in Yen Bai province where 40% of the sampled farmers reported its use, whereas SIP is found in all three provinces though with a much higher incidence in Son La (20% of adopters compared to 9% in Dien Bien and only 5% in Yen Bai).

In terms of agronomic practices, crop rotation shows very limited diffusion (only 3% of adopters) whereas intercropping is a more common principle with 19% of households associating different crops. Soil and water conservation (namely mini-terracing) and agroforestry show similar adoption rates in our sample (14 and 13% of adopters, respectively). The first one is applied to perennial crops such as coffee and tea on sloping lands and it is found in all three provinces (with a lower share of adoption in Yen Bai). On the other hand, agroforestry diffusion is much higher in Yen Bai (23%) compared to Son La and Dien Bien (9 and 4%, respectively).

GM analysis finds that FDP and SIP on irrigated rice and MT on rainfed maize are the most profitable practices (see Fig. 2).

Gross margins and profitability indicators described in Eqs. (1 to 10) for improved and 'conventional' practices for paddy in both growing seasons (spring-summer and summer-autumn seasons, denoted as season 1 and 2, respectively) are reported in Tables 3a and 3b. FDP, which is practiced mostly in Yen Bai, is more profitable than 'conventional' paddy production in both seasons (see columns A and B). SIP (column C), which is found in all three provinces albeit with a much more limited diffusion compared to 'conventional' systems, generates higher yields than both 'low' and 'high' intensity 'conventional' practices in both seasons (columns D and E). SIP and 'conventional' high intensive systems (columns C and E) are also more profitable than low intensity ones (column D). However, cash input costs are higher

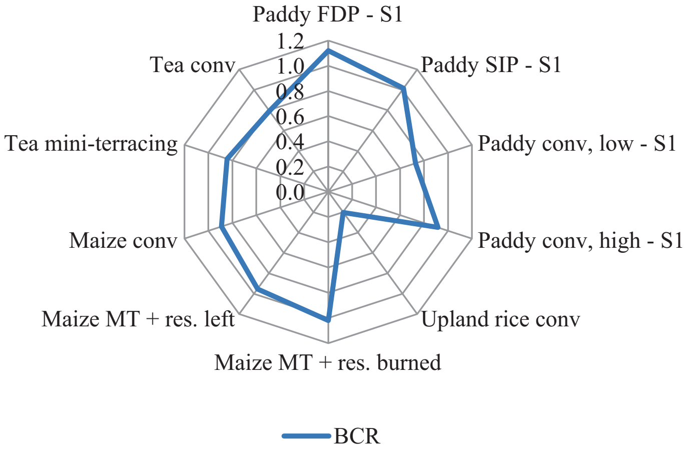

Fig. 2 Benefit-Cost Ratio (BCR) comparison between different crops and management options (Note: S1 denotes season 1 (*i.e.* spring-summer season); *Source:* Branca et al. (2015))

under SIP (columns C and E) and FDP compared to 'conventional' high intensity systems. In particular, SIP requires more fertilizer, which is partially offset by fewer seeds, and FDP requires more labor and fertilizer in the preparation of FDP briquettes. Combined though, the increased yields of SIP and FDP still guarantee higher gross margins.

Table 4 presents the results of gross margins and profitability indicators for maize grown on uplands, also providing a comparison with rice. Results show rather clearly that upland rice is not a profitable crop (see column A); whereby maize provides much better outcomes in terms of profitability, returns, BCR, and overall production costs, especially under MT systems (columns B and C). MT on upland maize requires less cash inputs and family labour than 'conventional' systems (column D). MT on maize is a labour-saving technology suitable in areas where labour availability is a binding constraint for rural households like the area under study (Castella et al. 2002). It is important to consider that MT would be more profitable and sustainable if combined with residue management as results from Column C indicate. However given the higher labour required in managing residues, MT is mostly (57% of households in our sample) combined with crop residue burning (column B).

The evidence from our study suggests that, on average, households that mechanize both land preparation and post-harvest processing activities gain higher yields compared to those performing these activities manually.[15] Specifically, mechanization allows an average savings of about 20 person-days of family labour per hectare for

[15] Different hypotheses on the mechanization scenarios, however, revealed the results on conventional systems to be much more robust whereas in the case of FDP, for instance, mechanization did not always prove to be an effective choice in terms of net income from paddy gains compared to manual production.

Table 3a Paddy, gross margins and profitability indicators: comparison between 'conventional' and improved practices, spring-summer season

Paddy, manual, flood irrigated	Season 1, Yen Bai		Season 1, Yen Bai, Dien Bien and Son La		
	FDP – Transplanting, high intensity	Conventional – Transplanting, high intensity	SIP – Transplanting, high intensity	Conventional – Broadcasting, low intensity	Conventional – Transplanting, high intensity
	(A)	(B)	(C)	(D)	(E)
Yield (kg/ha)	5713	4899	5404	3519	4929
(1) Total revenue ($/ha)	2177	1867	2059	1341	1879
(2) Cash inputs ($/ha)	479	416	492	312	396
(3) Gross margin ($/ha)	1698	1451	1567	1029	1482
Cost of family labour ($/ha)	1466	1369	1536	1526	1654
(4) Total costs ($/ha)	1945	1785	2028	1838	2050
(5) Net income ($/ha)	232	82	31	−497	−172
(6) Production costs per unit of output ($/kg)	0.34	0.36	0.38	0.52	0.42
(7) Returns to cash capital ($/$)	4.55	4.49	4.18	4.29	4.74
Total family labour (person days/ha)	256	239	269	267	289
(8) Return to family labour ($/person day)	6.62	6.06	5.83	3.85	5.12
(9) Labour productivity (kg/person day)	22.28	20.46	20.11	13.18	17.04
(10) BCR	1.12	1.05	1.02	0.73	0.92

Source: Branca et al. (2015)

Table 3b Paddy, gross margins and profitability indicators: comparison between 'conventional' and improved practices, summer-autumn season

Paddy, manual, flood irrigated	Season 2, Yen Bai		Season 2, Yen Bai, Dien Bien and Son La		
	FDP – Transplanting, high intensity	Conventional –Transplanting, high intensity	SIP – Transplanting, high intensity	Conventional – Broadcasting, low intensity	Conventional – Transplanting, high intensity
	(A)	(B)	(C)	(D)	(E)
Yield (kg/ha)	4783	4326	4280	3268	3542
(1) Total revenue ($/ha)	1823	1649	1631	1246	1350
(2) Cash inputs ($/ha)	462	428	442	318	363
(3) Gross margin ($/ha)	1361	1221	1189	927	986
Cost of family labour ($/ha)	1454	1380	1569	1452	1573
(4) Total costs ($/ha)	1916	1808	2011	1770	1936
(5) Net income ($/ha)	−93	−159	−380	−524	−586
(6) Production costs per unit of output ($/kg)	0.40	0.42	0.47	0.54	0.55
(7) Returns to cash capital ($/$)	3.95	3.86	3.69	3.91	3.72
Total family labour (person days/ha)	254	241	274	254	275
(8) Return to family labour ($/person day)	5.35	5.06	4.33	3.65	3.59
(9) Labour productivity (kg/person day)	18.80	17.92	15.60	12.87	12.88
(10) BCR	0.95	0.91	0.81	0.70	0.70

Source: Branca et al. (2015)

Table 4 Upland rice and maize, gross margins and profitability indicators: comparison between ‘conventional’ and MT practices

Upland rice, all three provinces Maize, Son La and Yen Bai provinces	Upland rice, local	Maize, hybrid		
	Conventional	MT, residues burned	MT, residues left on field	Conventional, residues burned
	(A)	(B)	(C)	(D)
Yield (kg/ha)	1246	4475	4710	4768
(1) Total revenue ($/ha)	475	1173	1234	1249
(2) Cash inputs ($/ha)	207	342	408	378
(3) Gross margin ($/ha)	268	831	826	871
Cost of family labour ($/ha)	2136	807	886	1025
(4) Total costs ($/ha)	2343	1149	1294	1403
(5) Net income ($/ha)	−1868	23	−60	−153
(6) Production costs per unit of output ($/kg)	1.88	0.26	0.27	0.29
(7) Returns to cash capital ($/$)	2.29	3.43	3.02	3.31
Total family labour (person days/ha)	374	141	155	179
(8) Return to family labour ($/person day)	0.72	5.88	5.33	4.86
(9) Labour productivity (kg/person day)	3.33	31.69	30.39	26.6
(10) BCR	0.2	1.02	0.95	0.89

Source: Branca et al. (2015)

land preparation and about 15 person-days for post-harvesting. However, the costs of mechanization can be very high (about 6 million VND) and are not affordable for poor smallholders. Figure 3 shows the returns to family labour per person day, corresponding to each crop and technology.

Innovative farming technologies such as FDP and SIP for paddy in both seasons as well as MT with rainfed maize can improve labour productivity (addressing food security) and increase returns to labour. Under these systems, hiring external labour is feasible (e.g. labour productivity is higher than average wage rate to hire external labour) addressing the labour availability constraint, and allows resource-constrained smallholders to expand farm activity and improve their overall productive potential.

Results from partial budget estimates suggest different results for the crops of interest. With regard to paddy rice most of the SLM practices seem to perform better in terms of yields in each of the provinces and seasons. Nonetheless, there is not widespread adoption possibly due to lack of knowledge diffusion and to access to

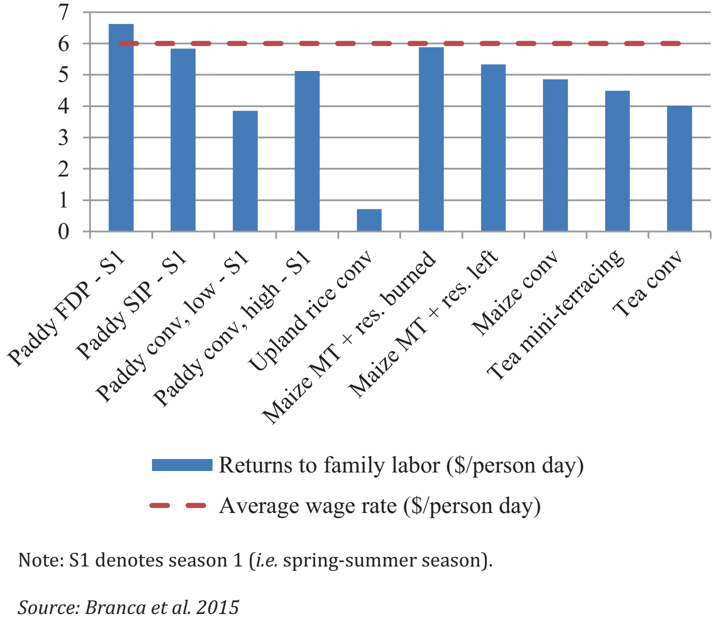

Fig. 3 Returns to family labour, comparison between different crop and management options (Note: S1 denotes season 1 (*i.e.* spring-summer season); *Source:* Branca et al. (2015))

inputs. On the other hand, results for maize show limited difference across adoption of technologies possibly due to the fact that MT is not combined as it should be with proper residue management, likely due to labour constraints and lack of knowledge. Whereas knowledge could be increased through a more effective and widespread extension service, labour constraints remain an issue not easy to address given mechanization and labour costs.

5.2 *Econometric Analyses*

The next analytical step aims at examining the effect of weather patterns during "critical periods" on the productivity and adoption of the various practices, which is key to assessing the climate smart characteristics of the practices. This econometric analysis complements the GM analysis, which could not control for detailed consideration of climatic shocks in the region.[16] In fact, one of the novel features of this analysis is the specific attention paid to the creation of context specific rainfall and

[16] Regression results presented here should be interpreted as representative of the provinces where the data come from. Regression results on Yen Bai restricted sample are not reported for reason of space, and are available upon request.

Table 5 Rainfall and temperature during critical periods for maize and rice by province

	Dien Bien	Son La	Yen Bai	Total
Rainfall				
maize_first10d_rain	23.82	79.96	22.69	42.27
maize_flower_rain	64.65	65.93	27.87	50.17
maize_midseason_rain	205.05	206.49	207.30	206.44
LT CV of maize_first10d_rain	0.94	0.32	0.81	0.68
LT CV of maize_flower_rain	0.52	0.51	0.58	0.54
LT CV of maize_midseason_rain	0.30	0.35	0.31	0.32
rice_harvest_rain, season 1	62.63	212.29	295.88	207.61
rice_harvest_rain, season 2	86.54	116.22	347.79	202.46
LT CV of rice_harvest_rain, season 1	0.32	0.23	0.32	0.29
LT CV of rice_harvest_rain, season 2	0.38	0.54	0.24	0.38
Temperature				
rice_midseason_tmin, season 1	14.55	16.79	19.50	17.31
rice_heading_tmax, season 1	29.63	25.93	25.56	26.74
rice_heading_tmax, season 2	26.87	25.65	29.72	27.61
LT CV of rice_midseason_tmin, season 1	14.27	5.40	9.10	9.19
LT CV of rice_heading_tmax, season 1	12.28	5.86	6.62	7.82
LT CV of rice_heading_tmax, season 2	2.59	3.09	3.03	2.94

Note: LT CV denotes the long-term (1989–2013) coefficient of variation
Source: own elaboration

temperature shocks during critical crop growth periods. Table 5 summarizes the "critical period" climatic variables both in levels during the 2013 season and their long-term coefficients of variation (LT CV) by province.

During the 2013 season, Son La had the highest rainfall amount (79.96 mm) and lowest variability of rainfall over years (LT CV of 0.32) during the critical period for maize. On the other hand, Son La also reported very high rainfall amount during flowering season (65.93) when it can damage crop growth.

Yen Bai experienced very high rainfall during the 30-day period before harvest in both rice seasons (295.88 and 347.79 mm in season 1 and 2, respectively), which imply high probability of damaging rice. During the heading stage of rice in the spring-summer season (season 1), Dien Bien recorded the highest average temperatures (29.63 °C), whereas in summer-autumn season (season 2) Yen Bai had the highest temperatures (29.72 °C). Dien Bien shows the highest across-year variability in terms of low and high temperature shocks that matter for rice during the spring-summer season (LT CV of 14.27 and 12.28, respectively). Long-term measures of variability of these variables are used in adoption models, and their 2013 values are used in yield models.

Table 6 presents average sample values of the dependent and independent variables used in our analyses by province. Forty per cent of maize plots in our sample is under MT (only in Son La and Yen Bai provinces). Paddy rice plots on which

Table 6 Averages of dependent and independent variables by province

	Dien Bien	Son La	Yen Bai	Total
Dependent variables				
% of maize plots under MT	0	47	51	40
% of paddy plots under FDP	0	0	51	21
% of paddy plots under SIP	10	31	5	14
Crop/Land characteristics				
Total land operated throughout year (ha)	0.45	0.8	0.48	0.58
Nr. of seasons	1.28	1.12	1.53	1.33
Plot slope (weighted)	2.61	2.51	2.15	2.39
Dummy household has certificate of land	0.47	0.98	0.75	0.76
Altitude (m asl)	780.28	555.92	359.25	534.01
Nr. of crop units (plots/seasons)	1.87	1.79	2.07	1.93
Socio-economic characteristics				
Age of household head	41.23	43.25	45.01	43.45
Education of household head	3.22	2.57	2.76	2.83
Dummy female headed household	0.03	0.07	0.13	0.08
Nr. adults working on farm	2.28	3.09	2.56	2.66
Nr. children working on farm	0.02	0.01	0.04	0.03
Dummy Kinh ethnicity	0.07	0.00	0.38	0.17
Dummy Thai ethnicity	0.82	0.72	0.22	0.54
Dummy H'mong ethnicity	0.10	0.06	0.20	0.13
Institutions				
Dummy household received ext. advice on MT	0.22	0.45	0.54	0.43
Dummy household received ext. advice on FDP/SIP	0.89	0.38	0.82	0.72
Dummy participation to farmer union	0.83	0.67	0.75	0.74
Dummy support for fertilizer received in 2013	0.08	0.01	0.02	0.03
Dummy support for seeds received in 2013	0.33	0.04	0.11	0.14
Dummy access to formal credit	0.73	0.44	0.22	0.43
Wealth/Income				
Dummy household has income from other sources	0.28	0.19	0.20	0.22
Household asset index	0.04	0.44	–0.32	0.03
Tropical Livestock Units (TLU) owned	2.08	1.55	1.40	1.63

Source: own elaboration

farmers use FDP account for 21% (only in Yen Bai), whereas SIP rice is adopted in all three provinces on 14% of paddy plots.

With respect to independent variables, average sample values show that households have operated 0.6 hectares of land throughout the year during 1.3 seasons, three-fourths of the households have a land-use certificate (almost 100% in Son La), and Dien Bien has the lowest share of those with a certificate and the highest weighted plot slope.

We control for ethnic group due to higher rates of poverty that are expected to affect the adoption of new technologies. Kinh households (the dominant ethnic group in Nam) represent only 17% of our sample, Thai minority is 54% (mostly located in Dien Bien), and H'mong is 13% (mostly located in Yen Bai).

In terms of institutions, 43% of households in the sample have received advice on MT and 72% on FDP and/or SIP. Seventy-four per cent of households have a member that belongs to a farmer union. Only 3% of the households received any support for fertilizers; 14% received seed support (more than 1/3 in Dien Bien); and 43% had access to formal credit, with the highest concentration in Dien Bien (73%). Also, distribution of wealth indicators differ across provinces. Dien Bien has the highest percentage of households with income sources other than agriculture and livestock measured by Tropical Livestock Units (TLU), whereas Son La has the highest asset index.[17]

Table 7 reports the results of the analysis on the determinants of adoption of MT in maize systems (columns A and B), and FDP and SIP in rice systems (columns C to F), using probit specifications as per Eq. (11). We estimate two different specifications for each model: one includes the long-term coefficients of variation (LT CV) of climatic variables (columns A, C and D), and the other includes also long-term averages (LT AVG) (columns B, E and F). These variables capture the potential impact of long-term average values of climatic variables that cannot be obtained from the standardized value of variation using CV.

Results from columns A and B suggest: (i) households that operate plots on higher slopes are significantly more likely to adopt MT; (ii) none of the household socio-economic characteristics significantly affects adoption, suggesting adoption is very much driven by agronomic indicators; (iii) extension advice is significantly and positively correlated with higher probability of adoption as expected; (iv) a positive relation between the share of households adopting MT and the relative diffusion of MT in the same communes is a sign of positive spillovers of effective adoption; (v) access to formal credit significantly and positively affects adoption, which is especially important for ethnic minorities with limited access to credit (and extension) compared to the Kinh majority (Do and Nguyen 2015); and (vi) having received support for improved seeds is negatively associated with the probability of adoption of MT.

Controlling for long-term averages in rainfall shocks that matter for maize (column B), we find that the probability of adoption is significantly lower in places where the variation in rainfall during the first 10 days of maize season is higher. On the other hand, the probability of adoption is significantly higher where the long-term variation in rainfall during the flowering season is higher, indicating that farmers' incentives to adopt MT are more sensitive to long-term variation in rainfall when excessive rain can damage the crop and could be particularly problematic in high slopes.

[17] The household asset index is constructed using principal component analysis. It includes key agricultural assets owned by the household.

Table 7 Determinants of adoption of sustainable crop management practices

	Maize		Paddy rice			
	MT(A)	MT w/LT AVG(B)	FDP(C)	SIP(D)	FDP w/LT AVG(E)	SIP w/LT AVG(F)
ln(Total area operated throughout year)	−0.013	−0.011	0.039	0.002	0.031	0.002
	(0.038)	(0.038)	(0.040)	(0.005)	(0.038)	(0.003)
Plot slope (weighted)	0.187***	0.204***	−0.058*	−0.010*	−0.053*	−0.006*
	(0.054)	(0.054)	(0.030)	(0.005)	(0.029)	(0.003)
Dummy household has certificate of land	−0.074	−0.122	0.070	0.026	0.063	0.013
	(0.097)	(0.101)	(0.067)	(0.019)	(0.069)	(0.011)
ln(Age of household head)	0.070	0.067	−0.271	0.066**	−0.298	0.033*
	(0.114)	(0.115)	(0.200)	(0.031)	(0.200)	(0.018)
Years of Education of household head (median)	0.014	0.013	0.153**	−0.003	0.159**	−0.003
	(0.037)	(0.037)	(0.067)	(0.011)	(0.064)	(0.007)
Dummy female headed household	−0.098	−0.108	0.102	−0.010	0.080	−0.003
	(0.102)	(0.099)	(0.140)	(0.015)	(0.141)	(0.010)
Nr. adults working on farm	−0.000	0.007	−0.040	−0.008	−0.033	−0.005
	(0.027)	(0.027)	(0.049)	(0.008)	(0.049)	(0.005)
Nr. children working on farm	0.117	0.078	0.210	0.123***	0.182	0.072***
	(0.116)	(0.115)	(0.206)	(0.027)	(0.196)	(0.016)
Dummy Kinh ethnicity	−0.030	−0.106	−0.274**	0.222***	−0.245**	0.165***
	(0.125)	(0.114)	(0.122)	(0.060)	(0.105)	(0.047)
Dummy Thai ethnicity	0.116	0.191**	0.229**	−0.008	0.343***	−0.001
	(0.093)	(0.091)	(0.111)	(0.015)	(0.133)	(0.008)

Dummy H'mong ethnicity	−0.066	0.072	−0.532***		−0.717***	
	(0.178)	(0.181)	(0.161)		(0.236)	
Dummy household received ext. advice on MT/SIP	0.561***	0.566***	0.454***	0.083***	0.432***	0.049***
	(0.056)	(0.060)	(0.108)	(0.014)	(0.107)	(0.009)
Dummy participation to farmer union	−0.059	−0.069	0.057	−0.044*	0.067	−0.027*
	(0.065)	(0.062)	(0.099)	(0.022)	(0.095)	(0.014)
Dummy support for fertilizer received in 2013	0.060	0.140	−0.357**	−0.018	−0.336*	−0.013
	(0.097)	(0.095)	(0.175)	(0.041)	(0.174)	(0.020)
Dummy support for seeds received in 2013	−0.189***	−0.216***	0.473***	−0.002	0.485***	−0.002
	(0.067)	(0.068)	(0.153)	(0.037)	(0.150)	(0.021)
Dummy access to formal credit	0.158**	0.160**	0.072	0.011	0.088	0.005
	(0.070)	(0.067)	(0.093)	(0.021)	(0.091)	(0.012)
Dummy household has income from other sources	0.035	0.027	−0.051	0.006	−0.056	0.005
	(0.072)	(0.072)	(0.084)	(0.023)	(0.085)	(0.014)
Household asset index	−0.043	−0.050	0.092	0.000	0.101	−0.001
	(0.034)	(0.035)	(0.068)	(0.010)	(0.066)	(0.006)
Tropical Livestock Units (TLU) owned	0.022	0.023	−0.002	0.001	0.003	0.000
	(0.019)	(0.019)	(0.016)	(0.003)	(0.018)	(0.002)
Share of households adopting MT in the community	1.120***	1.133***				

(continued)

Table 7 (continued)

	Maize		Paddy rice			
	MT(A)	MT w/LT AVG(B)	FDP(C)	SIP(D)	FDP w/LT AVG(E)	SIP w/LT AVG(F)
	(0.231)	(0.242)				
LT CV of maize_first10d_rain	0.022	−0.118**				
	(0.020)	(0.054)				
LT CV of maize_flower_rain	−0.010	0.704*				
	(0.042)	(0.400)				
LT CV of maize_midseason_rain	0.014	−0.173				
	(0.060)	(0.381)				
LT AVG of maize_first10d_rain		−0.445				
		(0.581)				
LT AVG of maize_flower_rain		0.196				
		(0.306)				
LT AVG of maize_midseason_rain		0.334				
		(0.363)				
LT CV of rice_heading_tmax, season 1 and/or season 2			0.003	0.003	−0.054	0.004
			(0.142)	(0.003)	(0.121)	(0.003)
LT CV of rice_harvest_rain, season 1 and/or season 2			−0.008	−0.000	−0.117	−0.000
			(0.061)	(0.001)	(0.107)	(0.001)
LT CV of rice_midseason_tmin, season 1 and/or season 2				−0.040*		−0.019
				(0.023)		(0.013)

LT AVG of rice_heading_tmax, season 1 and/or season 2					0.253**	0.010**
					(0.113)	(0.005)
LT AVG of rice_harvest_rain, season 1 and/or season 2					−4.677*	−0.032
					(2.798)	(0.038)
LT AVG of rice_midseason_tmin, season 1 and/or season 2						0.032
						(0.023)
Number of observations	504	504	697	1458	697	1458
Pseudo R^2	0.43	0.44	0.41	0.42	0.43	0.43
Log-Likelihood	−198.47	−195.47	−283.19	−331.45	−274.19	−324.88

Notes: Standard errors clustered at commune level in parentheses. Paddy rice analysis is done at plot-season level
Source: own elaboration
Significance levels: .01 – ***; .05 – **; .1 – *

In terms of adoption incentives for technologies in rice cropping (columns C to F), we find that FDP adoption is positively correlated with education and Thai ethnicity, while it is negatively correlated with Kinh and H'mong ethnicities. Kinh ethnic group, on the other hand, is significantly more likely to adopt SIP. Having received extension advice on improved rice management technologies is positively and significantly associated with both FDP and SIP adoption. FDP adoption is sensitive to support on fertilizers and seeds: fertilizer support significantly decreases it (this was expected as FDP is also a fertilizer saving technology); and seed support increases probability of adoption significantly.

Long-term coefficients of variation in rain and temperature shocks are not significantly correlated with the adoption of rice technologies (columns C and D); however, the higher the long-term average of maximum temperatures during the heading season, the higher the probability of adoption of both technologies (columns E and F). This suggests that farmers may perceive them as potential adaptation measures for high temperatures. We also find that the higher the long run average of rainfall during the rice harvest season, the lower the adoption of FDP.

Table 8 shows the results of the yield models specified in Eq. (12) used to investigate the effects of climatic shocks, sustainable practices and their interactions on maize and rice yields. Column A suggests that the effect of MT adoption on yields depends on the length of implementation period. Contrary to expectations, we find that the square of the duration variable is negatively correlated with yields. Upon closer inspection, we find that the average duration in our sample is more than 10 years. Discussions with experts suggested that after a very long time of MT, application yields may decline as the soils lose fertility in the absence of mulching (which is common in our sample). With respect to paddy rice, column C shows that SIP is positively correlated with a yield increase of 8%; and the use of high yielding varieties is associated with an increase of 10%. FDP seems to have no effect on rice yields when the regression model is run on the three provinces sample. However, when restricting our sample to Yen Bai (the only province where sampled farmers adopt FDP for paddy), we find that the use of FDP is significantly associated with an increase of about 6% in paddy yields.

We also find that yields are significantly affected by excess rainfall and high temperatures: 10% more rain in the first 10-day period after sowing is associated with a more than 30% increase in maize yields; 10% more rain during flowering is negatively correlated with maize productivity leading to a decrease of about 30% in yields (column A); higher maximum temperature during heading stage of paddy is associated with slightly lower yields (about 1% decrease) (column C).

The effects of some of these shocks interact significantly with the effects of adoption, which is analysed using interaction variables (in columns B and D). While the positive effect of rainfall during the first 10 days of maize is amplified for MT practitioners, the negative effects of rainfall during maize flowering are worsened under MT (column B). Looking at paddy rice, we find that the negative effects on paddy rice yields of excessively high temperatures are ameliorated by the practice of SIP (column D). On the other hand, the interaction variable between rice tech-

Table 8 Maize and rice yield models with adoption and interaction variables

	Maize		Paddy rice	
	MT(A)	MT w/ interactions(B)	FDP/ SIP(C)	FDP/SIP w/ interactions(D)
Dummy MT in at least one plot/season	−0.070	0.398		
	(0.060)	(0.328)		
Years of MT use for those who used in 2013	0.047***	0.043**		
	(0.015)	(0.017)		
Years of MT use for those who used in 2013	−0.005***	−0.005***		
	(0.001)	(0.001)		
Dummy FDP			0.049	2.106***
			(0.032)	(0.796)
Dummy SIP			0.087*	−0.080
			(0.047)	(0.428)
Years of FDP use for those who used in 2013			0.005	−0.008
			(0.012)	(0.012)
Years of SIP use for those who used in 2013			−0.002	0.004
			(0.012)	(0.010)
maize_first10d_rain	0.398*	0.348*		
	(0.206)	(0.202)		
maize_flower_rain	−0.295*	−0.202		
	(0.155)	(0.161)		
Dummy MT*maize_first10d_rain		0.148*		
		(0.085)		
Dummy MT*maize_flower_rain		−0.270**		
		(0.130)		
rice_midseason_tmin, season 1 and/or season 2			0.003	
			(0.002)	
rice_heading_tmax, season 1 and/or season 2			−0.011*	−0.010
			(0.006)	(0.008)
rice_harvest_rain, season 1 and/or season 2			0.099	0.142*
			(0.079)	(0.079)
SIP*rice_heading_tmax, season 1 and/or season 2				0.032**
				(0.013)

(continued)

Table 8 (continued)

	Maize		Paddy rice	
	MT(A)	MT w/ interactions(B)	FDP/ SIP(C)	FDP/SIP w/ interactions(D)
FDP*rice_heading_tmax, season 1 and/or season 2				0.002
				(0.009)
SIP*ln(rice_harvest_rain, season 1 and/or season 2)				−0.142***
				(0.044)
FDP*ln(rice_harvest_rain, season 1 and/or season 2)				−0.366**
				(0.145)
Inputs use per ha (seeds, fertilizer, labour)	Yes	Yes	Yes	Yes
Controls for crop/land characteristics	Yes	Yes	Yes	Yes
Controls for socio-economic characteristics	Yes	Yes	Yes	Yes
Controls for institutions	Yes	Yes	Yes	Yes
Controls for wealth/income	Yes	Yes	Yes	Yes
Constant	6.547***	6.415***	7.086***	6.902***
	(0.872)	(0.888)	(0.534)	(0.536)
Number of observations	465	465	1604	1604
Adjusted R2	0.28	0.29	0.38	0.39
Log-Likelihood	−137.33	−135.42	69	84.25

Notes: Standard errors clustered at commune level in parenthesis. Paddy rice analysis is done at plot-season level
Source: own elaboration
Significance levels: .01 – ***; .05 – **; .1 – *

nologies and the rainfall during the harvest time (when it is damaging) is significant and negative, suggesting that these practices do not generate adaptation benefits. This finding suggests a potential trade-off between higher yields and stability of yields under this type of climatic shock, underlining the importance of integrating ways to address climatic patterns and risk in extension programmes in areas where these practices are promoted.

There are some caveats in interpreting the econometric analysis results. Given the non-random and cross-sectional nature of the sample, results have to be cautiously interpreted as correlations rather than causations, since potential endogeneity in data can only be controlled using instrumental variables, quasi-experimental or panel data techniques. Another caveat is related to our climate data source. Even though re-analysis data from ECMWF offer advantages over collected data in regions with sparse stations with long-term coverage, it relies on the assumptions of climate models, which can be restrictive. Future research should conduct similar analyses using various validation methodologies to improve the robustness of evidence. In spite of these caveats, the strong correlations between adoption of sustainable practices and expected increased yields, as well as potential adaptation benefits documented here underline the importance of such studies for agricultural policy to improve food security accounting for climate.[18]

6 Conclusions

Our analyses show that while sustainable farming practices improve productivity and profitability on average, the timing and variations of climatic conditions significantly impact results, and are even shown in some cases to have a negative impact. This means that achieving adaptation benefits for individual households requires sufficient understanding of specific climate patterns, particularly during "critical growing periods" of crops. Our results indicate the high returns to including climate change effects directly into agricultural development planning and investments. The findings of this study imply that NMR agricultural policies should prioritize MT for upland maize, especially where the rainfall at the beginning of the season is a constraint, and SIP on paddy in more productive irrigated flat lands especially where high temperatures during heading stage are a limiting factor. However, sustainable practices often have higher upfront capital and labour requirements, which may prevent or impede adoption.

Our findings suggest the importance of local climate and socio-economic contexts in determining which practices will actually be climate-smart. In some cases we find that sustainable land management practices will be the best CSA option – however in others this is not the case. For example, SIP generates benefits under high temperatures, but is not a good option in places where the long-term average of maximum temperatures during critical periods for rice growth is high. MT is effective under low rainfall conditions and thus could reduce the negative impact of changes in rainfall variation at critical stages of maize cropping. These results indicate the importance of using climate information for targeting the promotion of improved practices, and building adaptive capacity amongst the farming population.

Another important finding of this work is the role of extension. Access to extension information is among the major enablers of adoption identified in the analysis. The results suggest that extension is found to have important spillover effects as adoption is higher where the proportion of adopters in the commune is higher. Returns to extension investments could be quite high in terms of increasing adoption and adaptive capacity of farmers.

[18] Further analysis using climate modeling and taking into account the expected changes in weather shocks would significantly strengthen the results of our analysis. This may be taken into consideration for future research work.

Some caveats about the current study are warranted. Our results confirm the importance of credit and labour constraints in impeding adoption in the NMR, implying the need for a regional approach. Nevertheless, related economic and institutional issues are omitted here. Also, sustainable practices are expected to generate environmental benefits (mitigation, water savings, reduced erosion). These benefits are in the form of positive externalities generated by (upstream) farmers toward (downstream) farmers and all of society. Some of these practices show synergies with food security goals. For example, in paddy production, SIP could help reduce overuse of irrigation, which is lowering groundwater levels, and FDP may hold further environmental benefits. It is also worth noting that paddy production is highly dependent on secure water flow availability, which is not a limiting factor. However, foreseen climatic changes may alter this equilibrium and make water-saving techniques (e.g. SIP) more convenient. While we have not explicitly considered these environmental issues and externalities in the analysis, they are clearly important aspects to be considered at the policy level.

Acknowledgments This work has been conducted within the FAO Project "Climate Smart Agriculture (CSA): capturing the synergies between adaptation, mitigation and food security", funded by the European Commission over the 2012–15 period and conducted by FAO in partnership with the Viet Nam Ministry of Agriculture and Rural Development (MARD) and the Northern Mountainous Agriculture and Forestry Science Institute (NOMAFSI). The authors wish to thank Pham Thi Sen and her team of enumerators from NOMAFSI for their support with data collection and preparation. The study has also benefited of various comments received during technical meetings and of continuous support provided by all members of the FAO-EPIC Programme.

Annex 1: Structure of the Household and Community Questionnaires

Questionnaire sections	Key data collected
Household questionnaire	
Household identification	Location (Province, District, Commune, Village) and contacts
Socio economic status of household	Demographic characteristics, assets, access to resources and food security status, access to input support and extension
Inventory of fields cropped and collection of data on cropland use and management, by household/field/cropping season	Field and farm size, crops cultivated (annual and perennial), management practices, irrigation, land characteristics, quantity of inputs used, crop yields, input and output prices, family and hired labour use for different practices,
Input acquisition	Sources of access to seeds and other inputs
Agroforestry, soil and water conservation	Typology of interventions, tree species, labour and input costs, revenues from sales

Questionnaire sections	Key data collected
Livestock (cattle, buffaloes, poultry, pigs) and forage production	Stock inventory and dynamics (acquisition, sales), feeding and health, labour use, grass production (feed) and grazing management
Other income sources and access to credit	Incomes from self-employment and wages, other income sources (pension, rental, external support), credit and loans
Institutions and extension	Membership of associations, access to extension services
Community questionnaire	
Community identification	Location (Province, District, Commune, Village) and contacts
Village labour costs	Unit costs of hired manual labour, animal draft power, mechanical power, land (rental)
Average crop management inputs	Average time required to perform field activities for different management types
Access to input and output markets	Input sources and prices; seed types used, purchase source and price; input subsidies provided to farmers; output prices at local market level (village or commune)
Access to services and infrastructures	Access to extension and information services, service providers, dissemination methods, access to other services and infrastructures
Climate-related information	Perception about rainfall and temperature patterns

Source: Branca et al. 2015

References

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., and Kokwe, M. (2015). Climate Smart Agriculture? Assessing the adaptation implications in Zambia. Journal of Agricultural Economics, 66(3): 753–780.

Branca, G. et al. (2015). Benefit-cost analysis of sustainable farming practices for CSA systems in Northern Mountainous Region of Viet Nam. Final report. FAO-CSA Project. June.

Branca, G., McCarthy N, Lipper L, Jolejole MC. (2013). Food security, climate change and sustainable land management. A review. Agronomy for sustainable development, 33:635–650, doi: 10.1007/s13593-013-0133-1

Brown, M.L. (1980). Farm budgets: from farm income analysis to agricultural project analysis. World Bank Staff Occasional Papers, International Bank for Reconstruction and Development 1980. ISBN 0-8018-2387-0

Castella, J.C., Erout A. (2002). Montane paddy rice: the cornerstone of agricultural production systems in Bac Kan Province, Vietnam. In: (J.C. Castella and Dang Dinh Quang eds.) Doi Moi in the Mountains. Land use changes and farmers' livelihood strategies in Bac Kan Province, Vietnam. The Agricultural Publishing House, Ha Noi, Vietnam. 175–195.

Castella, J.C., Boissau S., Nguyen H.T., Novosad P. (2002) Impact of forestland allocation on agriculture and natural resources management in Bac Kan Province, Vietnam. In: (J.C. Castella and Dang Dinh Quang eds.) Doi Moi in the Mountains. Land Use Changes and Farmers' Livelihood Strategies in Bac Kan Province, Vietnam. The Agricultural Publishing House, Ha Noi, Vietnam. 197–220.

Do, X.L., Nguyen T.L. (2015) Credit Access in the Northern Mountainous Region of Vietnam: Do Ethnic Minorities Matter? International Journal of Economics and Finance; Vol. 7, No. 6; 2015

Doanh, L.Q., Tiem L.V. (2001). Feasible solutions for sustainable land use in sloping areas. Project Review and Planning Meeting, 10–14 December 2001, Hanoi, Vietnam.

FAO (2010) "Climate-smart" agriculture. Policies, practices and financing for food security, adaptation and mitigation. Food and Agriculture Organization of the United Nations, Rome

FAO (2011). Strengthening Capacities to Enhance Coordinated and Integrated Disaster Risk Reduction Actions and Adaptation to Climate Change in Agriculture in the Northern Mountain Regions of Vietnam. Project UNJP/VIE/037/UNJ. Hanoi, 2011.

Husson, O., Tuan H.D., Lienhard P., Tham D.H. (2000). Development of "direct sowing" techniques as alternatives to slash-and-burn practices in the mountainous areas of North Vietnam. Preliminary results of SAM – Cropping Systems project. EC workshop on sustainable rural development in the Southeast Asian mountainous region. Hanoi, 28–30 November 2000

Le Ba Thao (1997). Vietnam, the country and its geographical regions. The Gioi Publishers, 1997. Hanoi.

Nguyen, T.M. (2006) Country Pasture/Forage Resource Profiles: Vietnam. FAO: Rome. http://www.fao.org/ag/agp/AGPC/doc/Counprof/PDF per cent20files/Vietnam.pdf

Pham, T.S., Nguyen Q.T., Branca G. (2014). A review of sustainable farming practices in Yen Bai, Son La and Dien Bien provinces of Vietnam. Final report. FAO-EPIC. Rome

Pretty, J.N. (2008) Agricultural sustainability: concepts, principles and evidence. Phil Trans R Soc London B 363(1491):447–466. doi: 10.1098/rstb.2007.2163

Swinton, S.M., Lowenberg-DeBoer J. (2013). Evaluating the Profitability of Site-Specific Farming. Journal of Production Agriculture Vol. 11 No. 4, p. 439–446. doi: 10.2134/jpa1998.0439

Tran, D.V. (2003). Culture, Environment, and Farming Systems in Viet Nam's Northern Mountain Region, Southeast Asian Studies, Vol. 41, No. 2: 180–205, September 2003.

Welch, J. R.; Vincent, J. R., Auffhammer, M., Moya, P. F., Dobermann, A. and Dawe, D. (2010). Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures, PNAS: 107 (33), pp. 14562–14567; doi:10.1073/pnas.1001222107

Wezel, A., *et al*. (2002). Temporal Changes of Resources Use, Soil Fertility and Economic Situation in Upland Northwest Vietnam. Land Degradation & Development 13 (2002): 33–44.

Woodfine, A. (2009) The potential of sustainable land management practices for climate change mitigation and adaptation in sub-Saharan Africa. Food and Agriculture Organization of the United Nations, Rome.

World Bank (2006) Sustainable land management: challenges, opportunities, and trade-offs. The World Bank, Washington.

World Bank (2012) Poverty assessment Report Vietnam : Well Begun, Not Yet Done: Vietnam's Remarkable Progress on Poverty Reduction and the Emerging Challenges, The World Bank, Washington.

Yu, B., Zhu T., Breisinger C., Manh Hai N. (2010). Impacts of Climate Change on Agriculture and Policy Options for Adaptation. The Case of Vietnam. IFPRI Discussion Paper 01015. August 2010.

Zhu, T., Trinh M.V. (2010). Climate Change Impacts on Agriculture in Vietnam. In: Proceedings of the International Conference on Agricultural Risk and Food Security, June 11–12, 2010, Beijing.