Intensive Commercial Agriculture in Fragile Uplands of Vietnam: How to Harness its Poverty Reduction Potential while Ensuring Environmental Sustainability?

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Abstract

Markets for high-value agricultural commodities are growing and can contribute to reducing rural poverty. However, the poor may be unable to participate in such markets, and adverse environmental impacts may counterbalance short-term benefits. Hence, policies are needed that help reducing poverty while protecting the environment. We address this challenge using the case of commercial maize production for animal feed purposes in a marginal upland area of Vietnam. We identify determinants of farmers' degree of participation in maize production using regression analysis and assess farmers' awareness of soil erosion and their conservation practices. The poorest are particularly specialized in maize but depend on disadvantageous input supply and marketing arrangements to offset infrastructural and institutional deficiencies. High awareness of soil erosion is contrasted by lacking conservation practices due to high opportunity costs. Policies should foster the integration of livestock in the maize-based farming system and promote soil conservation technologies that produce feed.

Keywords: commercial agriculture, rural poverty, land degradation, tobit regression, Vietnam
JEL: O13, Q56

1 Introduction

Income growth and urbanization in developing countries have enlarged markets for high-value agricultural commodities, offering opportunities for poverty alleviation in rural areas if farmers are linked to such markets (WORLD BANK, 2007: 124). There are concerns, however, that lacking access to assets, infrastructure, and institutions limit the ability of the poor to participate in and benefit from such commercial agricultural activities (VON BRAUN, 1995; BARRETT et al., 2001; MINOT et al., 2006; WORLD BANK, 2007). Furthermore, there may be a trade-off between wealth enhancing effects of intensive commercial agriculture and adverse long-term effects on farmers' livelihoods due to natural resource degradation (WORLD BANK, 2007: 180). The World Development Report 2008 emphasizes that "policy interventions that reduce poverty and protect the environment are warranted in many less-favored areas" (WORLD BANK, 2007: 192), whereby the challenge lies in jointly achieving both goals (WORLD BANK, 2007: 193). We address this challenge using the case of commercial maize production in an ecologically fragile area of northern Vietnam, from which more general lessons for policy design for marginal areas of other fast-growing developing economies may be drawn.

Rapid economic growth and urbanisation in Vietnam in the past 15 years have led to a diversification of diets and, hence, to an increased demand for meat, eggs, and dairy products (MINOT et al., 2006). Rising from 15.8 to 49.9 kg, annual per-capita meat consumption increased by more than 215% between 1990 and 2009 (FAOSTAT, 2012). Maize (*Zea mays* L.) is the primary source of feed for Vietnam's rapidly growing livestock and poultry industry. Therefore, the demand for maize has grown dramatically and is expected to further increase in the future (THANH HA et al., 2004; DAO et al., 2002; THANH and NEEFJES, 2005). Consequently, maize production in Vietnam has sharply increased and is highly commercialized, especially since the government began to strongly support and promote maize hybrid technology in 1990. Since then, higher-yielding hybrid varieties have been widely adopted, and maize has become the second most important crop after rice (THANH HA et al., 2004; THANH and NEEFJES, 2005). Maize production increased from 671,000 metric tons in 1990 to 4,606,800 metric tons in 2010 – an increase by 587% - which was achieved by the combined effect of higher-yielding varieties and area expansion: mean yields increased by 164% from 1.55 Mg ha^{-1} in 1990 to 4.09 Mg ha^{-1} in 2010 while the area harvested grew by 161% from 431,800 ha to 1,126,390 ha during the same period (FAOSTAT, 2012). On the one hand, this development has the potential to reduce rural poverty by offering attractive income opportunities to farmers (DELGADO et al., 1999). On the other hand, it exposes farm households that used to be subsistence oriented to market related risks. Furthermore, this development promotes the expansion of agricultural cultivation into fragile hillside agro-ecological zones, often leading to deforestation, soil erosion, and subsequent soil degradation (DAO et al., 2002; WEZEL et al., 2002b; VALENTIN et al., 2008), thus posing a threat to farmers' livelihoods in the medium to long run. Hence, Vietnam's challenge will be to supply maize for an expanding market while ensuring sustainability of maize production through appropriate agricultural and rural development policy.

By investigating the determinants of smallholder farmers' degree of participation in hybrid maize production, their awareness of soil erosion, and their practice of related conservation measures, this study contributes to understanding farmers' land allocation decisions in a situation where there is a clear trade-off between short-term wealth enhancing effects of cash crop production on the one hand and increased market risk exposure and likely negative long-term effects on farmers' natural resource base on the other. The specific objectives of the study are (1) to investigate the level and patterns of income diversification of rural households, differentiated by wealth status; hereby, we are particularly interested in the degree to which the poorest participate in commercial hybrid maize production; (2) given the dominance of maize production in the area, to identify household and village level determinants of the scale of hybrid maize adoption using regression analysis; and (3) given the potential adverse environmental consequences of maize production in sloping areas, to explore farmers' awareness of soil erosion on upland plots and their practice of soil conservation measures, again differentiated by wealth status.

Recognizing that each country has characteristics that make it unique, we posit that from the evidence presented lessons can be learnt for the design of appropriate policies for ecologically fragile upland environments in other fast-growing developing economies of Asia, which may face similar pressures now or in the future: marginal rural areas will generally have to support increasing populations, leading to an expansion of the agricultural frontier (WORLD BANK, 2007: 181); the demand for meat and other animal products is expected to continue its rapid growth in major developing economies such as China and India (VERMA et al., 2008; MILLAR and PHOTAKOUN, 2008; NEO and CHEN, 2009), leading to a further increase in the demand for maize as animal feed. In addition, the demand for maize is forecast to further increase for biofuel purposes (WORLD BANK, 2007; OECD-FAO, 2010); while maize has been shown to foster soil erosion under various biophysical and climatic conditions of tropical upland environments (VALENTIN et al., 2008), maize prices are projected to increase substantially over the next decade (OECD-FAO, 2010), making it an attractive option for smallholder farmers. In addition to adverse long-term environmental consequences of maize production in fragile upland environments, also the short-term risks are likely to increase due to expected increases in extreme weather events (CRUZ et al., 2007: 476) and volatility of agricultural commodity markets (HEADEY et al., 2010).

The remainder of the paper is structured as follows: a brief description of the research area is provided in Section 2; Section 3 presents the methodology applied, while Section 4 describes the data and definitions of the variables used in the analysis; our findings are presented in Section 5 and discussed in Section 6; finally, our conclusions are summarized and recommendations are derived in Section 7.

2 Description of the Research Area

The area expansion and intensification of maize production has been particularly pronounced in the uplands of north-western Vietnam, where maize production almost quadrupled between 1990 and 2000, growing from 53,600 to 211,800 metric tons (DAO et al., 2002). Yen Chau is a mountainous district in Son La province in north-western Vietnam, which is one of the poorest provinces in the country (MINOT et al., 2006). Only patches of natural forest remain, mostly on mountain tops above 1,000 m a.s.l. Lowland villages benefit from easy access to infrastructure, such as markets, paved roads, and irrigation systems, and are relatively better-off than villages located at higher elevations. Farmers nowadays cultivate two main crops: rice, which is grown on irrigated paddy fields in the lowlands mainly for home consumption, and maize, which is grown in the uplands as a cash crop. Even steep slopes have been taken into cultivation, especially for maize production. Together with intensive ploughing and shortened fallow periods this has led to massive erosion and declining soil fertility (WEZEL et al., 2002b). While substantial efforts have been made since the mid 1990s to promote soil conservation technologies in the area (UNDP, 2000; VAN DER POEL, 1996), adoption rates have remained low (FRIEDERICHSEN, 1999; WEZEL et al., 2002b; SAINT-MACARY et al., 2010), whereby a major reason is the fear of adverse effects on maize production through competition for land, sunlight, and nutrients (SAINT-MACARY et al., 2010).

3 Methodology

3.1 Classification of Households into Wealth Groups

For our subsequent analyses we classify households into wealth groups using a linear composite index which measures the relative wealth status of a household within our sample. It is constructed by principal component analysis (cf. DUNTEMAN, 1994) from a range of indicator variables capturing multiple dimensions of poverty. Hereby, we combine longer-term and easily measurable wealth indicators related to housing, household demographics, and the official poverty classification in 2006[1] with detailed per-capita consumption expenditures in 2007, which were collected following the methodology of the Living Standards Measurement Study of the World Bank (LSMS, cf. GROSH and GLEWWE, 1998). Consumption expenditures are a widely used proxy of household income in studies assessing income poverty (cf. GROSH and GLEWWE, 2000). As there is a considerable degree of seasonality in agricultural production and

[1] Once a year, the local government classifies households into poor (i.e., below the official rural poverty line) and non-poor based on a set of criteria developed by the Ministry of Labor, Invalids, and Social Affairs (MOLISA).

incomes in Yen Chau district, these data were collected at two contrasting points in time during the agricultural cycle, namely the end of the dry season and the relatively affluent time after the sale of the main crop, maize. The average of the two observations enters our wealth index. By combining this wide range of indicators into one index we expect to achieve a reliable measure of households' relative wealth status. The application of principal component analysis for this purpose is described in detail by ZELLER et al. (2006). The index represents the households' scores on the first principal component extracted, which follows a standard normal distribution. Based on this index we create wealth terciles, i.e., groups representing the poorest, middle, and wealthiest thirds of the sample households for our subsequent analyses.

3.2 Measuring Cash Income Diversification

To measure the degree of cash income diversification of farm households we use the Simpson Index of Diversity (SID; SIMPSON, 1949) which takes into account both the number of income sources and the balance among them. The SID is defined as follows:

(1) $$SID = 1 - \sum_{i=1}^{n} P_i^2$$

where P_i is the proportion of cash income derived from source i. The value of the SID falls within the interval [0…1[; if there is only one source of cash income $P_i = 1$, hence SID = 0. As the number of sources increases, their shares decline, so that the SID approaches 1. The SID has been frequently applied to measure the diversification of farming systems in terms of area allocation to different crops (JOSHI et al., 2004) and income sources (MINOT et al., 2006).

3.3 Determinants of the Scale of Hybrid Maize Adoption

In their seminal paper on the adoption of agricultural innovations FEDER et al. (1985) review the literature on factors that have frequently been found to influence adoption. These are farm size, risk exposure, human capital, labor availability, credit access, tenure security, and access to commodity markets. Based on this review and drawing on the concept of livelihood resources as laid out in the sustainable livelihoods framework (CHAMBERS and CONWAY, 1992; SCOONES, 1998), we hypothesize the scale of hybrid maize adoption to be determined by households' resource endowment, including access to relevant services and commodity markets. These resources we subsume under four types of capital, namely (1) natural capital, (2) human capital, (3) financial capital, and (4) market access/infrastructure. We implicitly account for the issue of risk exposure: all households in our relatively small research area can be assumed to be exposed to very similar natural hazards and market related risks, so that their ability to cope with these risks will largely depend on the households' asset endowment (SCOONES, 1998), as captured by our analysis. Since poorer farmers tend to be more risk averse (MOSCARDI and DE JANVRY, 1977; MORDUCH, 1995), we would expect them to maintain a higher level of subsistence food production than wealthier farmers, resulting in a lower relative scale of hybrid maize adoption. The variables included in our model are described in detail in Section 4.

3.4 The Regression Model Employed

We measure the scale of hybrid maize adoption by the area share devoted to the crop at a particular point in time, which is appropriate in the case of a divisible technology (FEDER et al., 1985). This share is bound between 0 and 100%, and both limit values are observed in nine and ten cases, respectively (approx. 3% of observations each). Hence, the distribution of the dependent variable *Maize share* is censored at its minimum and maximum limit values, which has to be accounted for by the regression model employed. Due to the censored nature of the dependent variable an ordinary least squares (OLS) regression would yield biased estimates. Therefore, a model proposed by TOBIN (1958) is employed which accounts for the qualitative difference between limit and non-limit observations and uses the maximum likelihood (ML) method for parameter estimation. Awareness of a technology is the primary prerequisite to its adoption (FEDER and SLADE, 1984). Yet, given the widespread adoption of hybrid maize in the research area, it appears safe to assume that also the non-growers of maize are aware of the technology, so that there is no reason to expect our estimates to be affected by exposure bias (cf. DIAGNE and DEMONT, 2007). The tobit regression model expresses the observed outcome, *Maize share*, in terms of an underlying latent variable as follows:

(2a) $$y_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ji} + \varepsilon_i$$

(2b) *Maize share* = max (0, y_i*) and min (y_i*, 100), respectively

where

y^* = Latent dependent variable

i = Household index (i = 1,…, N)

x_j = Vector of explanatory variables (j = 1,…, k), as outlined in the previous section

β = Vector of parameters to be estimated

ε = N (0, σ^2) distributed random error term

Maize share = Observed dependent variable

The latent dependent variable y^* in equation (2a) satisfies the classical linear model assumptions; in particular, it has a normal, homoskedastic distribution with a linear conditional mean (WOOLDRIDGE, 2006: 596). Equation (2b) states that the observed dependent variable, *Maize share*, equals y^* if $0 \leq y^* \leq 100$, but it equals 0 if $y^* < 0$ and 100 if $y^* > 100$. As a remedial measure for potential heteroskedasticity in the tobit model, we compute the heteroskedasticity-consistent standard errors proposed by WHITE (1980). Furthermore, these robust standard errors are adjusted to account for the cluster sampling procedure applied in selecting the farm households (cf. DEATON, 1997: 51-56) which is described in Section 4.1.

4 The Data and Definition of Variables

4.1 Sampling Procedure and Data Collection

Data were collected in a survey of 300 randomly selected households in Yen Chau district in July 2007. A cluster sampling procedure was followed in which in a first step a village-level sampling frame was constructed encompassing all villages of the district[2], including information on the number of resident households. Next, 20 villages were randomly selected using the Probability Proportionate to Size (PPS) method (CARLETTO, 1999). In a second step, 15 households were randomly selected in each selected village using updated village-level household lists as sampling frames. Since the PPS method accounts for differences in the number of resident households between villages in the first stage, this sampling procedure results in a self-weighing sample (CARLETTO, 1999). A team of local enumerators collected the data in structured interviews using a carefully tested questionnaire.

4.2 Variables in the Regression Model

The dependent variable is the share of cultivable area allocated to maize in the main cropping season of 2007. The following paragraphs describe the explanatory variables x_j included in equation (2a) in detail, which, as elaborated in Section 3.3, we categorize into those related to households' endowment with natural, human, and financial capital, as well as market access and infrastructure; brief definitions and summary statistics are provided in Table 2 (Section 5.4).

Natural capital is reflected by the characteristics of the households' land endowment and a proxy of local climatic conditions. The variable *Land availability* measures the

[2] Except for the villages in four sub-districts bordering Laos, for which research permits are very difficult to obtain.

cultivable area per capita managed by the household in the main cropping season of 2007. We expect a positive relationship with *Maize share* since the area that may preferentially be devoted to food crops for home consumption becomes relatively smaller as the per-capita size of the farm increases. *Upland share* measures the share of land officially classified as 'upland' within the farm, i.e., it consists of non-irrigated and mostly sloping land. Since this is the type of land on which maize is typically grown, leading to the severe problems of soil erosion outlined in Section 1, we hypothesize a positive sign of the respective regression coefficient. *Upland distance* indicates the average distance between the homestead and a household's upland plots in walking minutes. We expect a positive coefficient since maize requires a comparatively low labor input making it suitable for relatively distant plots. *Paddy share* reflects the share of irrigable, terraced paddy land, which is sometimes used for growing maize but is usually reserved for irrigated rice. Thus, we expect a negative relationship with the dependent variable. According to the Vietnamese land classification, a farm can also encompass home gardens, perennial crop land, and fish ponds; hence, *Upland share* is not the complement to *Paddy share* and vice versa. While in Vietnam land is still owned by the state, farmers have received certificates from 1993 onwards (so-called Red Books) granting them a use right for specific plots for a period of 20 and 50 years for annual and perennial crop land, respectively (DO and IYER, 2008). We account for tenure security through the variable *Red Book share*, which measures the share of farm land for which the farmer holds a formal land use certificate. *Elevation* of the village centre above sea-level controls for differences in local climatic conditions that may be more or less favorable for maize and may, thus, affect the area allocation to the crop.

The variables capturing human capital are related to characteristics of the household head, ethnicity, and household demography. The age and sex of the household head as well as ethnicity dummies are included in the model as control variables which means that there are no explicit hypotheses regarding their influence on *Maize share*. Literacy of the household head is expected to have a positive influence. We assume that being literate is conducive to an adequate management and marketing of the crop. *Dependency ratio* is calculated as the number of household members aged younger than 18 and/or older than 64 relative to the total number of household members. In terms of risk management we hypothesize households with a high dependency ratio to prefer a low risk – low return crop portfolio, i.e., one that emphasizes the growing of low risk food crops, such as cassava. Moreover, *ceteris paribus*, a high dependency ratio means that less family labor is available for the proper management of the maize crop. We therefore expect a negative regression coefficient.

Financial capital is reflected by off-farm income and credit access. *Off-farm income* measures the share of total household income earned mainly in form of cash income from off-farm sources in 2006, i.e. prior to the land allocation decision. There are two controversial hypotheses regarding the direction of relationship with *Maize share*: on the one hand, if farming is clearly the dominant income source, supplementary off-farm income may be used to finance agricultural inputs such as hybrid maize seed and mineral fertilizers, implying a positive relationship. On the other hand, if off-farm income accounts for a major share of total income, households may prefer to devote a larger share of their cultivable area to food crops for home consumption and/or to crops with particularly low labor requirements, leading to a reduction of the area allocated to the cash crop maize. The linkages between non-farm income and farm investment and their conditioning factors are discussed in REARDON et al. (1994), DE JANVRY et al. (2005), and DAVIS et al. (2009), for example. To capture this ambiguous relationship we also include the square of *Off-farm income* into our model on which we hypothesize a negative regression coefficient. Following the methodology developed by DIAGNE et al. (2000), *Credit limit* is the respondent's assessment of the maximum amount of money the household could realistically borrow from formal and informal sources, including the amount presently borrowed. A positive sign of the regression coefficient is expected since a high credit limit facilitates the financing of inputs needed for maize production. However, the credit limit varies widely between wealth groups, ranging from 20.7 million VND in the poorest tercile to 69.4 million VND in the wealthiest tercile, on the average (Table 2, Section 5). Hence, credit access is likely to be a more binding constraint for the poorest farmers than for the wealthiest; we therefore allow the marginal effect of *Credit limit* to vary between wealth groups by including interaction dummy variables for the poorest and the wealthiest tercile (*Credit limit x poor* and *Credit limit x wealthy*), the middle tercile being the base group represented by the non-interacted *Credit limit* variable.

Finally, market access and infrastructural conditions deemed relevant for the cultivation of maize are reflected by the following five variables: *Maize price* is the price received for the maize harvest in 2006. We hypothesize a positive relationship with farmers' decision on how much land to allocate to the crop in 2007. Urea is a major input necessary for the cultivation of high-yielding maize varieties. Since the price of urea varies between 4 and 6 VND kg^{-1} in our sample villages we include *Urea price* as a potential influencing factor of *Maize share*, expecting a negative regression coefficient. Negative regression coefficients are also expected on the variables *Input distance* and *Road distance*, which measure the distance to the closest fertilizer store and the nearest paved road, respectively. The dummy variable *Good extension access* is based on farmers' perception of the quality of their access to agricultural extension on a scale from 1 (= very poor) to 5 (= very good). The dummy variable takes on the value of one if this score is above the median score of 3. A positive relationship with *Maize share* is hypothesized.

5 Results

5.1 Classification of Households into Wealth Terciles

Based on indicators related to households' asset endowment, housing condition, demography, consumption expenditures, and the official poverty classification in 2006[3] we construct a relative wealth index by principal component analysis (cf. Section 3.1). All signs of the component loadings conform to our theoretical expectations. Only indicators with an absolute loading greater than 0.4 are retained in the final model, as suggested by STEVENS (2002: 394). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is larger than 0.5 for all individual variables, as recommended by FIELD (2005: 642). Overall, the KMO statistic yields a value of 0.876, indicating a very distinct and reliable first principal component (FIELD, 2005: 640). The eigenvalues of two principal components extracted exceed the value of one and can therefore be considered meaningful (KAISER, 1960). Since the first principal component yields a much larger eigenvalue than the second (5.01 versus 1.36), explains a far greater share of variance in the data (41.7% versus 11.3%), and shows consistency in the signs of all component loadings we conclude that this is the component that reflects households' wealth status. Hence, the households' scores on this factor are used as the relative wealth index on which the classification of households into wealth terciles for the following analyses is based.

5.2 Sources and Diversity of Cash Income and Land Allocation to Crops

Table 1 lists on-farm and off-farm sources of cash income of our sample households, differentiated by wealth tercile, as well as the farm area shares allocated to the most important crops. Moreover, Simpson indices of cash income and cropping diversity are shown. With an overall cash income share from farming of approximately 83% households in Yen Chau are highly dependent on their own agricultural production. This applies to all wealth groups. Second, with an overall share of 65% of total household cash income (and 78% of cash income from farming), maize is by far the most important source of cash earnings. Hereby, the differentiation by wealth terciles reveals that at 73% the poorest third of households obtain a particularly large share of their cash earnings from maize. The share is significantly lower at 64 and 58% in the medium and wealthiest terciles, respectively. In the main cropping season of 2007, 97% of the sample households grew maize, and with an overall share of 73% of the cultivable area it clearly dominated the land use in the area. At 76% the share was

[3] Once a year, the local government classifies households into poor (i.e., below the official rural poverty line) and non-poor based on a set of criteria developed by the Ministry of Labor, Invalids, and Social Affairs (MOLISA).

significantly larger in the poorest tercile than in the wealthiest tercile (69%). Farmers sold 95% of their maize harvest, on the average, whereby there is no difference between wealth groups, and the median share sold is 100% in all groups. Hence, also the poorest tercile grew maize almost exclusively as a cash crop.

Table 1. Cash income sources and crop allocation in Yen Chau district, northern Vietnam, differentiated by wealth terciles

	Whole sample (N = 300)	Poorest tercile[1] (N = 100)	Medium tercile (N = 100)	Wealthiest ter. (N = 100)	Sign. level of diff.[2]
Estimated cash income share from farm activities in 2006 (%)[3]					
Maize	64.9	72.8[a]	63.8[b]	58.2[b]	***
Rice	1.1	0.7[a]	0.5[a]	2.0[b]	**
Vegetables	1.4	0.8[a]	2.0[ab]	1.5[b]	***
Fruit trees	3.0	1.8[a]	4.0[b]	3.3[b]	***
Livestock	9.0	5.8[a]	9.4[b]	11.9[c]	***
Total farm cash inc.	**82.8**	**83.7**	**83.3**	**81.3**	n.s.
Estimated cash income share from off-farm activities in 2006 (%)					
Agr. trade	1.1	0.5[a]	0.4[ab]	2.4[b]	*
Agr. wage	2.9	5.9[a]	2.3[b]	0.5[c]	***
Non-agr. wage	9.4	6.7	10.7	10.8	n.s.
Non-agr. business	2.5	0.6[a]	2.6[ab]	4.4[b]	*
Total off-farm inc.	**17.2**	**16.3**	**16.7**	**18.7**	n.s.
Simpson Index of cash inc. diversity[4]	**0.37**	**0.32[a]**	**0.35[a]**	**0.44[b]**	***
Land endowment and allocation to crops in June 2007					
Farm size (ha)	1.57	1.49[a]	1.35[a]	1.87[b]	**
Per-cap. farm size (ha)	0.35	0.31[a]	0.33[ab]	0.40[b]	**
Maize (%)	73.3	76.2[a]	74.6[ab]	69.2[b]	*
Rice (%)	11.9	13.1	10.8	11.8	n.s.
Fruit trees (%)	11.8	14.5	9.3	11.6	n.s.
Simpson Index of cropping diversity[4]	**0.35**	**0.30[a]**	**0.36[b]**	**0.40[b]**	***

*(**)[***] Differences statistically significant at the 10% (5%) [1%] level of error probability. Homogeneous subsets (a, b, c) are based on pair-wise Mann-Whitney tests and account for family-wise error.
[1] Wealth terciles are based on the index described in Section 3.1.
[2] Only income sources/crops accounting for >= 2% of income/total farm area in at least one tercile are listed.
[3] For reasons of simplicity, only the significance level of the difference between the poorest and the wealthiest tercile is shown.
[4] Based on all cash income sources/crops, also those not shown; see Section 3.2 for details.
Source: own survey

Regarding other sources of cash income, livestock is the second most important, whereby at 11.9% its contribution to total household cash income is twice as large in the wealthiest as compared to the poorest tercile (5.8%). The table further shows that all wealth groups allocate around 12% of their cultivable area to rice, but this crop contributes only minimally to households' cash income, indicating that it is mostly grown for home consumption. Considering all sources of cash income, the values of the Simpson index show that the poorest tercile are less diversified than the wealthiest tercile (0.32 versus 0.44, respectively; the difference is statistically significant at $P < 0.01$). The same is true with respect to the diversity of cropping activities.

5.3 Awareness of Soil Erosion and Related Conservation Practices

Maize in Yen Chau is mainly grown on sloping upland plots, and field measurements indicate a high degree of soil erosion with annual soil loss rates ranging from 21 to 132 Mg ha^{-1} (TUAN et al., 2010). Farmers are well aware of this problem: on a scale from 0 (= no erosion problem) to 10 (= very severe erosion problem) they assigned an average severity score of 4.4 to soil erosion on their maize plots, with no significant difference between wealth groups. We investigate whether there are differences in the practice of soil conservation measures between wealth terciles based on data used by SAINT-MACARY et al. (2010). The authors found that three-quarters of the sample farmers knew at least one soil conservation technique, and 53% applied at least one measure to reduce soil loss in 2007. Hereby, the digging of small ditches to channel run-off water off the plot was the most prominent practice (34% of households), followed by agroforestry (12%). Very few households practised any other soil conservation measures, such as the building of terraces (2%), or different forms of vegetative barriers to protect the soil against erosive rainfall (around 1% each). Interestingly, we find no significant difference between wealth groups neither regarding the awareness of soil conservation techniques nor the use of different measures.

5.4 Determinants of Land Allocation to Maize

The factors hypothesized to influence the area share of maize are summarized in Table 2. Since we are particularly interested in differences between wealth groups regarding these factors, apart from listing the overall mean of each variable the table also contains their means in the poorest and the wealthiest terciles and tests the difference for statistical significance.

Table 2. Hypothesized influencing factors of the farm area share allocated to maize production in Yen Chau district, northern Vietnam (hypothesized direction of relationship in parentheses), and their means, differentiated by wealth group[1]

Variable description			Mean values			Stat. sig.
			Whole sample (N=294)	**Poorest tercile[2]** (N=100)	**Richest tercile** (N=100)	
Dependent variable						
Maize share	=	Share of the cultivable area that was devoted to maize in the main growing season 2007 (%)	73.29	76.20	69.17	**/a
Natural capital						
Land availability (+)	=	Per capita cultivable area in the main growing season 2007 (hectares)	0.35	0.31	0.40	***/a
Upland share (+)	=	Share of land officially classified as 'upland' within the total cultivable area (%)	77.50	82.27	73.70	***/a
Upland distance (+)	=	Mean distance between homestead and upland plots (walking minutes)	39.28	50.93	36.24	n.s./a
Paddy share (-)	=	Share of paddy land within the total cultivable area (%)	12.28	9.84	13.56	***/a
Red Book share (?)	=	Share of total cultivable area under a formal land use certificate ('Red Book') (%)	72.97	59.11	84.07	***/a
Elevation (?)	=	Elevation of the village centre above sea level ('00 m)	5.19	6.71	4.35	***/a
Human capital						
Age HH head (?)	=	Age of the household head	43.22	38.54	46.62	***/a
Literacy HH head (+)	=	Dummy, = 1 if HH head is literate, 0 otherwise	0.77	0.55	0.94	***/b
Sex HH head (?)	=	Dummy, = 1 if HH head is female, 0 otherwise	0.08	0.09	0.03	*/b
H'mong (?)	=	Dummy, = 1 if HH head belongs to the ethnic group of the H'mong, 0 otherwise	0.15	0.44	0.00	***/b
Kinh (?)	=	Dummy, = 1 if HH head belongs to the ethnic group of the Kinh, 0 otherwise	0.08	0.08	0.06	n.s./b
Dependency ratio (-)	=	Number of HH members aged < 18 and/or > 64 relative to total number of members	0.41	0.52	0.31	***/c
Financial capital						
Off-farm income (+) / - squared (-)	=	Share of off-farm income in total HH income in 2006 (%)	15.83	16.26	18.73	n.s./a
Credit limit (+)	=	Logged maximum amount of credit available to the HH (million VND)[3]	42.67	20.68	69.35	***/a
Market access/infrastructure						
Maize price (+)	=	Maize price received in 2006 ('000 VND kg^{-1})	2.10	2.03	2.14	***/a
Urea price (-)	=	Mean village level price of urea in the cropping season 2007 ('000 VND kg^{-1})	5.08	5.28	4.99	***/a
Input distance (-)	=	Distance to the closest fertilizer store (km)	0.71	1.08	0.45	**/a
Road distance (-)	=	Distance to the next paved road (walking minutes)	16.00	23.45	11.30	**/a
Good extension access (+)	=	Dummy, = 1 if perceived access to agr. extension on a scale from 1 (= very poor) to 5 (= very good) is above the median score of 3	0.41	0.39	0.46	n.s./b

*(**)[***] Difference between means in the poorest and wealthiest terciles statistically significant at the 10% (5%) [1%] level of error probability based on /a Mann-Whitney test, /b Chi-square test, /c t-test.

[1] Means are based on a total of 294 cases without missing values for any of the variables.

[2] Based on the relative wealth index described in Section 3.

[3] Vietnamese Dong. 1 US$ = 16,000 VND (June 2007). For ease of interpretation, means are given for the unlogged variable.

Source: own survey

Table 3 presents the regression results and also displays Variance Inflation Factors (VIFs). Naturally, the VIFs are large for the variables *Off-farm income* and its squared term. Apart from these, the variables *H'mong* and *Elevation* yield relatively high values at 4.27 and 2.99, respectively, which is due to the fact that the H'mong reside in high-altitude villages only. High elevations are not only inhabited by H'mong people, however; it is therefore possible to disentangle potential elevation effects from ethnicity effects by the inclusion of both variables. All remaining variables yield VIFs ≤ 2.06 indicating that there is no cause for concern with regard to multi-collinearity among the explanatory variables. MYERS (1990) suggests that a value of 10 should not be exceeded.

Table 3. Tobit estimates of influencing factors of the farm area share allocated to maize production in Yen Chau district, northern Vietnam (N = 294)

Variable	Coefficient[1]	t-value[2]	Variance Inflation Factor
Constant	26.0303	1.20	
Land availability	11.3982	1.82*	1.45
Upland share	0.4300	7.51***	1.79
Upland distance	0.0153	4.18***	1.20
Paddy share	- 0.4472	- 4.87***	1.63
Red Book share	- 2.2925	- 0.91	1.31
Elevation	- 0.2177	- 0.32	2.99
Age HH head	- 0.0853	- 1.32	1.42
Literacy HH head	- 4.9336	- 2.87***	1.55
Sex HH head	13.3749	3.49***	1.28
H'mong	- 14.3476	- 3.08***	4.27
Kinh	13.6408	3.18***	1.62
Dependency ratio	- 10.0271	- 1.47	1.50
Off-farm income	0.2245	2.24**	9.22
Off inc. squared	- 0.0047	- 3.32***	10.46
Credit limit	3.4848	2.36**	1.46
Credit limit x poor	0.6320	2.65***	2.06
Credit limit x wealthy	- 0.2719	- 1.29	1.64
Maize price	4.3971	1.11	1.50
Urea price	- 4.4787	- 2.71***	1.43
Input distance	- 0.2332	- 0.63	1.28
Road distance	0.3069	7.01***	1.98
Good extension access	2.9872	2.26**	1.07
Log likelihood = - 1163.44			
Pseudo R^2 = 0.087			
% censored obs. at 0 = 3.1; % censored obs. at 100 = 3.4			

*(**)[***] Statistically significant at the 10% (5%) [1%] level of error probability.

[1] Dependent variable: Maize share. Coefficients are marginal effects on the latent (uncensored) dependent variable.

[2] Standard errors are heteroskedasticity-consistent (WHITE, 1980) and account for the cluster sampling procedure applied in selecting the farm households.

Source: own survey

Apart from *Red Book share*, *Elevation*, *Dependency ratio*, *Credit limit x wealthy, Maize price*, and *Input distance* all explanatory variables in our model have a statistically significant impact on *Maize share*. The exclusion of the insignificant variables leads to only minor changes in the size of the remaining regression co-efficients, confirming the robustness of the estimates. The discussion in Section 6 focuses on the most important findings based on the unrestricted model.

6 Discussion

In contrast to MINOT et al. (2006) who investigate income diversification in eight provinces of the Northern Uplands (one of them being Son La) using data of the VLSS[4] conducted in 1993, 1998, and 2002, we do not find that the poorer households in Yen Chau have more diversified cropping systems than the wealthier ones; the opposite is the case, the poorest tercile are particularly specialized in hybrid maize production. Since farmers in all wealth groups grow maize almost exclusively as a cash crop there is no indication that the poorer households are less commercially oriented than the wealthier ones, which is contrary to the findings of MINOT et al. (2006). However, the authors observed that households in all income categories had shifted toward commercial production over the period 1993 to 2002. Hence, while the poorer households may initially have lagged behind they may have caught up over time, explaining the divergence of our findings.

Farmers are well aware of adverse environmental consequences of maize cultivation on sloping land. Despite farmers' problem awareness and the promotion of soil conservation technologies in the area since the mid 1990s (cf. VAN DER POEL, 1996), the adoption rates of effective erosion control measures remain low, whereby there are no significant differences between wealth groups. The fact that maize is a highly profitable cash crop under the current conditions means that the establishment of soil conservation measures, such as contour hedgerows, incurs high opportunity costs in terms of land lost for maize production. Moreover, the fact that soil erosion entails a loss in soil fertility with negative consequences on maize yields may (still) be masked by the use of higher yielding maize varieties and high amounts of mineral fertilizer applied, as indicated by WEZEL et al. (2002a).

Regarding the determinants of the area share that households devote to maize production we find that their endowment with natural capital, both 'upland' and paddy area, has a highly significant influence. A one-percentage-point increase in *Upland share* entails an increase in *Maize share* by 0.43 percentage points. On the other hand,

[4] Vietnam Living Standards Survey

if *Paddy share* increases by one percentage point, *Maize share* is reduced by 0.45 percentage points. The magnitude and high level of statistical significance of the negative coefficient on *Paddy share* shows that farmers have a clear priority to use irrigable land not for maize but for the cultivation of rice. This suggests that they view it as too risky to rely on rice markets for the acquisition of their major food crop and are willing to pay a considerable risk premium (in terms of gross margin foregone on the more lucrative crop maize) for ensuring food security through home-produced rice. The statistically highly significant differences in *Upland share* and *Paddy share* between the poorest and the wealthiest tercile of farm households (Table 2) clearly work towards the poorest allocating a larger portion of land to maize. The signs of the coefficients on the variables *Upland distance* and *Land availability* conform to our hypotheses but indicate practically very small marginal effects on *Maize share*.

Concerning human capital, the model results confirm that the characteristics of the household head have important implications on the area allocation to maize. Contrary to our expectation, literacy of the household head reduces the area allocated to maize by 5 percentage points, which could be an indication that literate household heads are more aware of the phyto-sanitary need to diversify cropping patterns and/or that they are more aware of beneficial alternative crops. The statistically highly significant difference in the literacy rate between the poorest and the wealthiest tercile (55% versus 94%, Table 2) means that the poorest will be more likely to allocate a larger area share to maize. Surprisingly, we find that the portion of land devoted to maize is 13 percentage points larger if the household head is female. This may be explained by differences in land endowment: first, the total cultivable area available to female-headed households is significantly smaller than that of male-headed households (0.97 versus 1.63 ha, Mann-Whitney test significant at $P < 0.01$); and, second, female-headed households are less endowed with irrigable land allowing to grow rice for home consumption (269 versus 382 m^2 per person, Mann-Whitney test significant at $P < 0.1$). Both factors mean that the need to allocate land to a profitable cash crop is particularly pronounced for female-headed households to generate sufficient income for the satisfaction of food and other basic needs. We control for possible differences between ethnic groups and find that compared to the reference group of Thai households the H'mong devote a 14 percentage points smaller portion of land to maize whereas the Kinh allocate 14 percentage points more. This is likely to be due to differences in agricultural traditions and consumption or risk preferences. The ethnic minority of the H'mong tend to be very conservative of their cultural heritage and may be more cautious about allocating land to a modern cash crop that entails exposure to market related risks, preferring to devote a substantial area share to upland rice cultivation. The opposite is true in the case of the Kinh who are more market-oriented (cf. Neef et al., 2002).

Regarding the endowment with financial capital, the regression coefficient on *Off-farm income* is positive (0.225) and that on its squared term is negative (-0.005). In combination, these coefficients indicate that up to a share of 47% there is a positive but decreasing effect of off-farm income on the portion of land allocated to maize; beyond this threshold the effect becomes increasingly negative. This means that, if off-farm income is only supplementary, farm households are likely to use it to finance agricultural inputs, in our case hybrid maize seed and mineral fertilizers. If, however, off-farm income accounts for a major share of total income, households may prefer to devote a larger share of their cultivable area either to food crops for home consumption to reduce their exposure to market related risks, or to crops with particularly low labor requirements to free up labor resources to engage in their off-farm activities.

As expected, *Credit limit* yields a positive regression coefficient. Since this variable enters the model in its logged form, we conclude that a one *percent* increase in credit access leads to an expansion of the area share devoted to maize by 3.5 percentage points. We allow the marginal effect to vary between wealth groups by interacting *Credit limit* with dummy variables for the poorest and wealthiest terciles; *Credit limit* alone thus indicates the marginal effect on the middle tercile. *Credit limit x poor* yields a positive and statistically significant regression coefficient, showing that, at 4.1 percentage points, the marginal effect of a one percent increase in credit access on *Maize share* is 18% larger for the poorest tercile than for the middle tercile. The sign of the coefficient on *Credit limit x wealthy* is negative, as would be expected, but not statistically significantly different from zero. Furthermore, it is important to note that currently especially the poor rely on credit from informal lenders such as shopkeepers or traders, which is typically supplied at comparatively high interest rates: while the wealthiest tercile of households pay on average 0.93% interest per month, the poorest tercile pay 1.64%. Hence, for the poorest tercile credit is on the average 76% more expensive (Mann-Whitney test statistically significant at $P < 0.001$).

The regression coefficient on the maize price received in the cropping season 2006 carries the expected positive sign but is not significantly different from zero. This may be due to a lack of alternative cash crops that are able to compete with maize, even though the price received in a particular location and under a specific marketing arrangement (see below) may be comparatively low. As hypothesized, we find a statistically significant negative influence of the urea price on the area allocation to maize: for a price increase of 1,000 VND per kg our model predicts a decrease in *Maize share* of 4.5 percentage points. Hence, based on the means of the two variables, a 20% increase in the price of urea would entail a 6% reduction in maize area (elasticity = -0.30), indicating that farmers do respond to input price signals.

With respect to physical input and output market access, an influence of the distance to the closest fertilizer outlet is not supported by our data. Contrary to our expectation the portion of land devoted to the cash crop maize *increases* with increasing distance to the nearest paved road, by 0.3 percentage points for an increase by one walking minute, which is statistically highly significant. Both findings can be explained by the fact that many villages have established marketing contracts with maize traders who collect the produce at the farm gate. These traders also supply the farmers with the necessary inputs. Especially in remote locations maize may be the only viable cash crop because the transaction costs involved in cultivating and marketing alternative crops, such as fruits or vegetables, may be prohibitive. The marketing arrangements with maize traders come at a cost, however: in the two most remote research villages that rely on such arrangements the maize price received was 23 and 28% lower than in the remaining villages in 2006 and 2007, respectively (Mann-Whitney test significant at $P < 0.001$). Moreover, as mentioned above, especially the poor receive in-kind credit in the form of seeds and fertilizers from these traders at comparatively high interest rates, which is reflected in the significantly lower output price that the poorest tercile receive and the significantly higher price they have to pay for urea (Table 2). Another important source of upfront provision with agricultural inputs on credit are village- and district-level institutions, such as the so-called farmers' union and the agricultural extension service, which organize their supply at the village level. Although farmers are free to use these inputs on whichever crop they like, the timing of supply and repayment are strongly tied to the cropping cycle of maize. This relatively easy supply with in-kind credit makes it much more comfortable for farmers to engage in maize production than to choose an alternative, less commonly grown crop.

Finally, maize, as the dominant crop in the area, is also the main focus of agricultural extension activities. Consequently, *Good extension access* is found to increase the area share devoted to maize by 3 percentage points. Since 41% of households enjoy good extension access by our definition, one can conclude that there is scope for the agricultural extension service to influence land use decisions in the area.

7 Conclusions and Policy Recommendations

We find that hybrid maize is by far the most important cash crop in Yen Chau district, covering most of the uplands and generating the lion's share of households' cash income. The poorest households allocate a particularly large portion of their land to maize which they use almost exclusively as a cash crop, as do the wealthier households. Apart from the availability of upland area, farmers' area allocation to maize is mainly determined by the households' endowment with human and financial capital. Infrastructural conditions, such as easy access to paved roads and markets, are found not to play a significant role, which is probably due to marketing and input supply arrangements with maize traders who collect the produce in the villages. Our first main conclusion, therefore, is that maize is attractive to farmers from all social strata, notably the poor. Not only are there no barriers preventing the poorest households from participating in commercial maize production, but they are even particularly specialized in this enterprise.

Furthermore, our results indicate that an increase in credit access has a particularly large effect on the area allocation to maize in the poorest tercile. It is comparatively easy for them to obtain in-kind credit in terms of seed and fertilizer from maize traders, but the cost of these arrangements manifests itself in significantly higher input and lower output prices as compared to the wealthiest tercile of farmers. From this we conclude that, while enhancing the access of the poor to low-interest formal rural credit may promote their specialization on maize even further, it would enhance the profitability of maize production in this stratum and therefore contribute to poverty alleviation. Through moderate interest rates the risk of becoming indebted and caught in a poverty trap would be reduced. This risk is considerable given the currently extremely high shares of maize in overall production and cash income, coupled with input and output price fluctuations and possible yield depressions due to maize pests or diseases, adverse climatic conditions, and soil degradation. Regarding the latter, we find that although farmers in all wealth groups are well aware of soil erosion on their maize plots, effective soil conservation measures are rarely practised. The fact that currently maize is a highly profitable cash crop means that the establishment of soil conservation measures incurs high opportunity costs in terms of land lost for maize production. Hence, we conclude that soil conservation measures have to yield more immediate economic benefits in addition to the reduction of soil erosion if they are to be adopted at any significant scale.

Due to the trade-off between potential short-term wealth enhancing effects of maize production and lacking longer-term sustainability we propose a two-pronged rural development policy approach: on the one hand, the potential of maize production to alleviate poverty should be harnessed. This means that the poor should become less dependent on the relatively disadvantageous input supply and marketing arrangements offered by maize traders who service remote villages. Appropriate policy measures encompass public investments in the rural road network, maize storage facilities, and enhanced access of the poor to formal credit at moderate interest rates. Moreover, an effective market information system should be established, whereby the use of modern information technology such as short message services (SMS) should be promoted to reduce transaction costs (cf. WORLD BANK, 2007: 121). On the other hand it is crucial to make maize production in the uplands ecologically more sustainable, and it is desirable to foster a diversification of land use and income sources in the longer run to reduce the risks associated with the specialization in maize.

To address these issues, the promotion of non-farm income sources through the establishment of small and medium rural enterprises is a crucial development strategy element, offering considerable scope for rural poverty reduction, especially when linked to fast-growing urban markets (REARDON et al., 2007; DE JANVRY et al., 2005; XU and TAN, 2001). Non-farm income can also promote agricultural productivity growth by relaxing credit constraints for farm investments (DAVIS et al., 2009; REARDON et al., 1994; DE JANVRY et al., 2005). To enhance the sustainability of farming, interdisciplinary research needs to identify land use options that are able to compete with the prevailing cropping activities and serve a soil conservation purpose at the same time. Since livestock related products continue to be relatively income elastic in developing economies (ZHENG and HENNEBERRY, 2011), and mixed crop-livestock systems offer various advantages to smallholder farmers, such as provision of manure, draft power, and greater resilience in case of crop failure (HERRERO et al., 2010), livestock may be particularly suitable as a means for rural households to benefit from urban-based economic growth. We find that the contribution of livestock to households' cash income is still small, especially in the poorest tercile. Therefore, priority should be given to assessing the potential for upland areas to expand animal husbandry activities – especially the keeping of ruminants – and soil conserving land use options that produce feed and are easily combined with the current production of maize, such as contour strips of fodder grasses or leguminous cover or relay crops. There is evidence from upland areas in Lao PDR that the introduction of forages for cattle fattening has had positive effects on poverty alleviation (MILLAR and PHOTAKOUN, 2008). In Vietnam, there is evidence of an increasing demand among affluent urban dwellers for high-value meat, such as pork from local *Ban* pigs. Protein-rich feed derived from soil conservation techniques may facilitate the expansion of smallholder *Ban* pig rearing in upland areas and, hence, allow farmers to benefit from such niche markets. However, institutional prerequisites, such as the development of respective breeding and supply chain systems, must be taken care of at the same time (HEROLD et al., 2010). The agricultural extension service should emphasize the dissemination of information on adverse environmental long-term effects of maize production on sloping lands and any identified promising agricultural activities to counteract these effects. Our results indicate that there is scope for the agricultural extension service to influence land use decisions. Enhanced access of the poor to formal rural finance as well as non-farm income would then facilitate the diversification process.

Nevertheless, the immediate monetary benefits provided by fodder producing soil conservation techniques may not fully outweigh their opportunity costs in terms of maize yield foregone and/or additional labor requirements for their maintenance.

Hence, in addition to the development, testing, and promotion of economically attractive soil conservation techniques, payment for environmental services (PES) schemes have to be considered as a complementary measure to boost the adoption of soil conserving land use practices. Soil conservation is a public good, since its benefits do not only extend to upland farmers, but also to society as a whole in terms of water safety, food security, and sustainable rural development. This justifies the use of direct payments to farmers in order to compensate for the opportunity costs incurred by soil conservation practices in the uplands.

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