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Maize boom in the uplands of Northern Vietnam: economic importance and environmental implications

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Discussion papers in this series are intended to stimulate discussion among researchers, practitioners and policy makers. The papers mostly reflect work in progress. This paper has been reviewed internally by Dr. Pepijn Schreinemachers and externally by Dr. Miet Maertens (University of Leuven, Belgium) and Dr. Franklin Simtowe (Africa Rice Center (WARDA), Benin) whom we thank for their valuable and pertinent comments.

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Abstract

In Vietnam, the demand for meat products has grown dramatically due to rapid economic growth and urbanisation and is expected to further increase in the future. Being the primary source of feed for the country's livestock and poultry industry, maize has become the second most important crop after rice. While this maize boom has the potential to reduce rural poverty, it promotes the expansion of agricultural cultivation into fragile agro-ecological zones, often leading to deforestation and soil degradation, especially in the uplands. Using empirical evidence from mountainous Yen Chau district in north-western Vietnam, the objective of this paper is to investigate the current economic importance and environmental implications of maize cultivation. Furthermore, particular emphasis is placed on the identification of factors influencing farmers' decision how much area to allocate to maize in order to derive research and policy recommendations. Maize is the dominant crop in Yen Chau, covering most of the uplands and generating the lion's share of households' cash income. Although farmers are well aware of soil erosion on their maize plots, effective soil conservation measures are rarely practiced. Maize is attractive to farmers from all social strata, notably the poor, and through marketing arrangements with traders its cultivation is also not constrained by poor infrastructural conditions. Access to low-interest credit should be enhanced to mitigate farmers' risk of being caught in a poverty trap when maize revenues plummet due to pests, diseases, price fluctuations, or adverse weather conditions. To address the problem of soil degradation in the maize-dominated uplands, research is needed on soil conservation options that are economically more attractive than those promoted thus far.

Key words: Maize area expansion, environmental sustainability, Tobit regression, Vietnam

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1 Introduction

Since the 1970s, massive increases in the global demand for food of animal origin have been fuelled by population growth, urbanization, and income growth in developing countries, aptly being coined the 'livestock revolution' (Delgado et al. 1999). In Vietnam, for example, the agricultural sector has undergone dramatic changes in the past 20 years as the country shifted from a centrally planned to a state regulated market-oriented economy. The cooperative and state-farm based agricultural production has been replaced by a system where production decisions are predominantly made by individual farm households based on market signals (Thanh Ha et al. 2004). At the same time rapid economic growth and urbanisation have led to a diversification of diets and, hence, to an increased demand for meat, eggs, and dairy products. Rising from 16 to 30 kg, annual per capita meat consumption almost doubled between 1990 and 2003 (FAOSTAT 2008). 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 (Dao et al. 2002, Thanh Ha et al. 2004). Consequently, maize production in Vietnam has increased sharply, 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). While this development has the potential to reduce rural poverty by offering attractive income opportunities to smallholder farmers (Delgado et al. 1999), it promotes the expansion of agricultural cultivation into fragile agro-ecological zones, often leading to deforestation, soil erosion, and subsequent soil degradation, especially in the uplands (Dao et al. 2002, Wezel et al. 2002). In concert with climate change, both periods of excessive rainfall and drought are forecast to become more severe and occur more frequently in Vietnam in the future (Chaudhry & Ruysschaert 2007, Cruz et al. 2007: 476). This will have two consequences: first, it can be expected that high-intensity rainfall events will further aggravate the problem of soil erosion on sloping lands. And, second, drought-induced depressions of maize yields are likely to occur more often, making smallholder farmers who specialize on maize production particularly vulnerable. Vietnam's challenge, thus, will be to supply maize for an expanding market under these adverse conditions, while ensuring environmental and economic sustainability of maize production through appropriate agricultural and rural development policy.

Using empirical evidence from a random sample of 300 households in Yen Chau district in the Northern Mountain Region of Vietnam, the objectives of this paper are (1) to assess the extent to which farmers engage in maize production in the area, (2) to explore farmers awareness of soil erosion on upland plots and the practice of soil conservation measures, and (3) to identify determinants of farmers' area allocation to maize in order to derive research and policy recommendations. The remainder of the paper is structured as follows: a description of the research area is provided in Section 2; Section 3 develops the analytical framework applied and outlines the methods used in sampling and data collection; our findings are presented in Section 4 and discussed in Section 5; finally, our conclusions are summarized and recommendations derived in Section 6.

2 Description of the research area

Figure 1 illustrates the drastic growth in maize production in Vietnam as a whole. Production increased from 671,000 metric tons in 1990 to 4,312,500 metric tons in 2007 – an increase by 543% - which was achieved by the combined effect of higher-yielding varieties and maize area expansion: mean yields increased by 141% from 1.55 Mg ha^{-1} in 1990 to 3.75 Mg ha^{-1} in 2007 while the area harvested grew by 166% from 431,800 ha to 1,150,000 ha during the same period (FAOSTAT 2008). 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) while at the national scale it 'only' tripled during the same period (cf. Figure 1).

Yen Chau is a mountainous district in Son La province in north-western Vietnam. 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. The largest ethnic groups in the district are the Thai (Black Thai) with about 55% of the district's population, followed by the H'mong (20%), and the Kinh (13%). The Thai and the Kinh were the first settlers in the area and occupied the lowlands, while later arrivals, such as the H'mong, settled mainly in the highlands (Neef et al. 2002). Farmers nowadays cultivate two main crops: rice, which is grown on irrigated paddy fields in the lowlands mainly for own consumption, and maize, which is grown in the uplands as a cash crop. The area allocated to maize has more than tripled over the past 20 years while the area allocated to upland rice has decreased by 27%, according to the district statistical office. According to the same source, at an annual growth rate of 2.4% the districts' population rose by 50% between 1988 and 2006, which is around twice the national growth rate (GSO 2007). Due to this population increase 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. 2002). While substantial efforts have been made since the mid 1990s to promote soil conservation technologies in the area (van der Poel 1996, UNDP 2000), adoption rates have remained extremely low (Friederichsen 1999, Wezel et al. 2002).

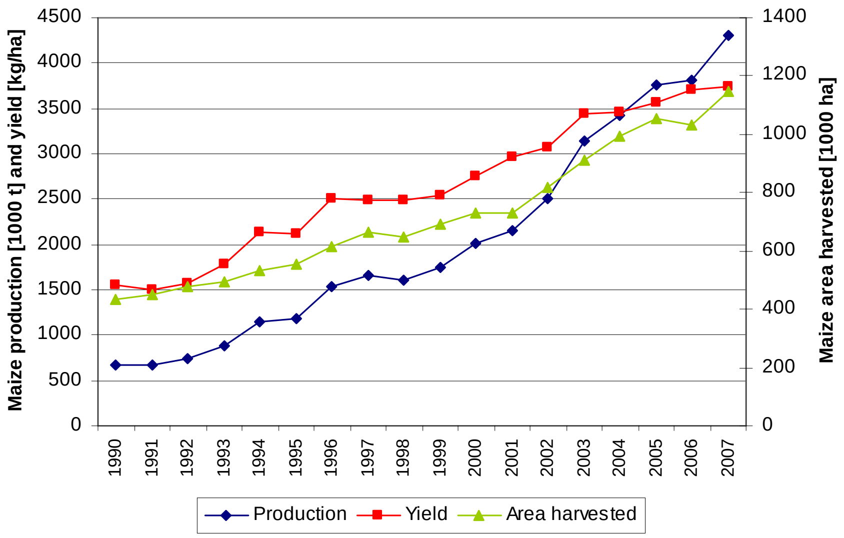

Figure 1: The development of maize production in Vietnam from 1990 to 2007, differentiating yield and area harvested. Source: Based on FAO data (FAOSTAT 2008)

3 Research methodology

The regression model employed

We measure the extent to which a farm household engages in maize production as the share of cultivated area which was allocated to maize in the main cropping season in 2007. This share is bound between 0 and 100%, and both limit values are observed in nine and eight cases, respectively (approx. 3% of observations each). Hence, the distribution of the variable *Maize share* is censored at its minimum and maximum limit values. When using this variable as the dependent variable in a regression model to investigate its determinants this censored nature has to be accounted for. 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. The 'Tobit' estimation procedure requires that the dependent variable be such that it is possible for it to take on values close to the limit. Furthermore, the assumption must be realistic that the equation determining whether an observation is at the limit is the same as the equation determining the value of a non-limit observation (Kennedy 2003: 283-284). In the case of the upper limit this requirement is certainly met in the maize share model. Regarding the lower limit one could argue that the yes/no decision whether to grow any maize at all may be influenced by additional factors as compared to the choice of the scale of the maize activity. However, since the group of 'non-growers' of maize encompasses nine observations only, a model differentiating between the two cases, such as the two-step Heckman procedure (Heckman 1979), can not be estimated. Knowledge of a technology is the primary prerequisite to its adoption (Feder & Slade 1984). Given the widespread adoption of maize in the research area, it appears safe to assume that also the non-growers of maize are aware of this technology, so that there is no reason to expect our estimates to be affected by exposure bias (cf. Diagne & Demont 2007).

The Tobit regression model expresses the observed outcome, *Maize share*, in terms of an underlying latent variable as follows:

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

Maize share = max (0, y_i*) and min (y_i*, 100), respectively (1b)

where

y^* = Latent dependent variable

i = Household index (i = 1,…, N)

x_j = Vector of explanatory variables (j = 1,…, k)

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 (1a) satisfies the classical linear model assumptions; in particular, it has a normal, homoskedastic distribution with a linear conditional mean (Wooldridge 2003: 566). Equation (1b) states that the observed dependent variable, *Maize share*, equals y^* if $0 \leq y^* \leq 100$, but *Maize share* = 0 if $y^* < 0$ and *Maize share* = 100 if $y^* > 100$.

The Tobit estimates are the marginal effects of the x_j on the latent dependent variable. These are the estimates that are of interest in our study since we assume that farmers who grow maize on their entire cultivated area would expand this area further if they were able to[4].

An important assumption of the classical linear regression model is that the disturbances ε_i in equation (1a) are homoskedastic, i.e., that the variance of each disturbance term, conditional on the values of the explanatory variables, is some constant number equal to σ^2. If this condition is not fulfilled, the estimated coefficients remain unbiased but their variances may be underestimated or overestimated, so that any conclusions drawn with respect to their statistical significance may be misleading (Gujarati 2003: 399). As a remedial measure for potential heteroskedasticity in the Tobit model, the heteroskedasticity-consistent ('robust') standard errors proposed by White (1980) were applied in the analysis, as recommended by Gujarati (2003: 418). 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).

Determinants of the extent of maize cultivation

We hypothesize the area share allocated to maize (the variable *Maize share* as defined in the previous section) to be determined by households' resource endowment, including access to services and relevant infrastructure. Drawing on the sustainable livelihoods framework (Scoones 1998, Siegel & Alwang 1999), we subdivide the relevant components of a household's asset base into natural, human, economic and financial, as well as infrastructural capital. The following paragraphs describe the explanatory variables x_j included in equation (1a) in detail; brief definitions and summary statistics are provided in Table 3. It should be noted that our analysis is based on cross-sectional data; hence, the effects of price changes over time cannot be captured.

Natural capital is reflected by the farm size, the shares of upland area as well as irrigated paddy land in total farm land, and by a variable reflecting farmers' security of access to their land resources. The variable *Farm size* measures the total cultivable area managed by the household in the main cropping season of 2007. We expect a positive relationship with *Maize share* since the area devoted to food crops for home consumption becomes relatively smaller as the farm size increases. *Upland share* measures the share of land that is officially classified

[4] If the observed dependent variable is the variable of interest, the estimated parameters cannot be interpreted directly; to derive the marginal effects in that case the values of the regression coefficients have to be multiplied by an adjustment factor which depends on the values of all explanatory variables and parameters. For the derivation of the adjustment factor which is bound between zero and one see Wooldridge (2003), for example.

as ‘upland’ within *Farm size*, 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 drastic problems of soil erosion outlined in Section 1, we hypothesize a positive sign of the respective regression coefficient. Conversely, *Paddy share* reflects the share of irrigable, terraced paddy land within *Farm size*, 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, apart from upland plots and paddy land, *Farm size* can encompass home gardens, perennial crop land, as well as fish ponds. Since the official end of collective farming in Vietnam in 1988, a series of land reforms have been implemented (cf. Do & Iyer 2008). While land is still owned by the state, farmers have received certificates (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. We account for tenure security through the variable *Red Book share*, which measures the share of *Farm size* for which the farmer holds a formal land use certificate.

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 (*Age HH head, Sex HH head*) as well as ethnicity dummies (*H’mong, Kinh*) 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 (*Literacy HH head*) is expected to have a positive influence. Apart from the marketing of the produce we assume that being literate is conducive to an adequate management of the crop that typically involves the application of mineral fertilizers (cf. Table 1, Section 4). *Dependency ratio* is calculated as the number of household members aged younger than 18 and/or older than 60 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.

Economic and financial capital is reflected by a wealth index, off-farm income, and credit access. *Wealth index* is a linear composite index indicating the relative wealth status of a household within the sample. It is constructed from a number of indicator variables using principal component analysis and represents the households’ scores on the first principal component extracted[5]. The index is scaled to range from 0 (= poorest household in the sample) to 1 (= wealthiest household in the sample). We hypothesize a positive relationship with *Maize share* since maize is predominantly grown as a cash crop using relatively high levels of cash inputs as compared to other crops. *Off-farm income* measures the share of total household income derived from off-farm sources. There are two controversial hypotheses regarding the direction of relationship with *Maize share*: on the one hand, off-farm income can be used to finance agricultural inputs such as hybrid maize seed, mineral fertilizers, and pesticides, 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 perennial crops with particularly low labor requirements, leading to a reduction of the area allocated to the cash crop maize. 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.

Finally, infrastructural conditions deemed relevant for the cultivation and marketing of maize are reflected by the following four variables: *Maize price* is the price received for the maize harvest in 2006. We hypothesize that this will influence farmers' decision on how much land to allocate to the crop in 2007 and therefore expect a positive relationship with *Maize share*. *Extension access* is the farmer's perception of access to agricultural extension on a scale from 1 (= very poor) to 5 (= very good). A positive relationship with *Maize share* is hypothesized. Negative regression coefficients are expected on the variables *Input distance* and *Road distance*, which measure the distance to the closest fertilizer store and the nearest paved road, respectively.

Sampling procedure and data collection

Data were collected in a survey of 300 randomly selected households conducted in Yen Chau district in July 2007. In selecting the households, a cluster sampling procedure was followed

[5] The variables used are: size of dwelling in square meter per capita; exterior wall is made of bamboo (yes = 1); floor is made of earth (yes = 1); share of children in the household, value of cupboard (logged); value of living room set (logged); household was classified as poor in 2006 by the village (yes = 1). The first principal component yields an Eigenvalue of 3.6 and explains 44% of the total variance in the data. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yields a value of 0.82, indicating compact patterns of correlations between the variables and, hence, a distinct and reliable first principal component.

where at first a village-level sampling frame was constructed encompassing all villages of the district[6], including information on the number of resident households. In a first step, 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 of these villages 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. The composition of the team was such that interviews could be conducted in local languages when this facilitated the communication with the respondents.

4 Results

Maize production in Yen Chau district

In the main cropping season of 2007, 97% of our sample households grew maize on 1.16 ha on the average (median 0.97 ha), representing 71% of the total farmed area and 84% of the area available for annual crops at that time[7]. The two next most important crops grown in that season were rice, accounting for 11% of the total farmed area, and cassava (1.4%). Ninety-seven percent of the maize growers sell (most of) their maize, which accounts for 65% of total household cash income and 76% of agricultural cash income, on the average. The next most important agriculture-related income sources are agricultural wage labor and livestock production, each accounting for around 9% of total household cash income. It can thus be concluded that maize cultivation is by far the most important source of cash income in the research area. Based on recall data on the main cropping season 2006[8], Table 1 provides statistics on input use, yields, and gross margins attained in maize production in Yen Chau. The table shows that large amounts of mineral fertilizer are applied, whereas the use of pesticides is virtually non-existent. At 6.17 Mg ha^{-1} the yield level is high, and the small difference between the mean and median values, both with regard to yield and gross margin, indicates that the means are not inflated by relatively few large values only. The calculated gross margin considers the costs of seeds, mineral fertilizer, and pesticides, as shown in the table.

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

7 Perennial crops grown are various kinds of fruit trees and tea.

8 At the time of the survey the maize of the growing season 2007 had not yet been harvested.

Table 1: Input use, yields, and gross margins in maize production in Yen Chau district, Northern Vietnam (N = 404 maize plots)

	Mean	Std. Dev.	Median
Inputs:			
Maize seeds (kg ha^{-1})	22.5	12.7	20.0
NPK (kg ha^{-1})	369.8	383.5	333.3
Urea (kg ha^{-1})	170.5	177.1	127.1
Pesticides ('000 VND[a] ha^{-1})	1.6	10.8	0.0
Output:			
Maize yield (kg ha^{-1})[b]	6,172.9	2,338.1	6,000.0
Gross margin 2007[c] (US$ ha^{-1})	1,059.1	490.9	1,019.6

[a] Vietnamese Dong. 1 US$ = 16,000 VND (June 2007).
[b] Production data refer to the cropping season 2006.
[c] Gross margin is based on production data from 2006, but household-level output prices and means of village-level input prices from 2007.

Soil conservation practices in Yen Chau district

Maize is mainly grown on erosion-prone sloping upland plots, and farmers are well aware of soil erosion on these plots: on a scale from 0 (= no erosion) to 10 (= severe erosion) they assigned a severity score of 4.4 to soil erosion on their maize plots, on the average[9]. The steeper the slope, the more severe is the erosion problem perceived[10]. Table 2 summarizes our empirical findings regarding farmers' awareness of various soil conservation technologies (SCTs), the practice of these technologies, the perceived effectiveness, and the major adoption constraints cited. Three-quarters of the sample farmers know at least one SCT, and 53% currently practice at least one technique to reduce soil loss, whereby the digging of small ditches to channel run-off water off the plot is the most prominent (34% of households). Most other SCTs, such as the establishment of vegetative strips along the contour lines, the use of cover crops or mulch to protect the soil against erosive rainfall, or the building of terraces are virtually not practiced at all, although they are known by some and are also judged to be quite effective in reducing soil loss. Apart from a lack of labor for the establishment of terraces or the application of mulch, major reasons stated for not practicing SCTs are adverse effects on maize production through competition for land, sunlight, and nutrients.

[9] N = 294. Household-level values are means of plot-specific ratings weighted according to the plot size.

[10] The slope was assessed on a scale from 1 (= level) to 5, using a graph for illustration. This variable is strongly positively correlated with the severity score of soil erosion (Pearson correlation coefficient = 0.63, $P < 0.01$).

Table 2: Knowledge and practice of soil conservation technologies in Yen Chau district, Northern Vietnam

Soil conservation technology (SCT)	**Knowing SCT** (% of all HH[a])	**Currently using SCT** (% of all HH)	**Mean effectiveness score** (users only; 0 = no effect, 10 = very effective)	**Knowing but not using** (% of HH knowing)	**Adoption constraint most frequently cited**
Ditches or channel	56.2	34.2	5.7	39.0	Not effective
Agroforestry	42.5	11.6	6.7	72.6	No access to seedlings
Terrace	20.9	2.1	7.0	90.2	Lack of labor
Contour ploughing	20.2	17.8	6.1	11.9	No erosion
Cover crop	12.7	1.4	7.3	89.2	Lack of land
Vegetative strips	5.8	0.7	6.0	88.2	Lack of land
Mulching	3.4	0.7	5.7	80.0	Lack of labor
Other SCT	5.1	3.4	5.8	33.3	-
Total (at least one SCT)	**74.7**	**53.4**	-	-	-

[a] HH = households, N = 292 (non-farm households and those cultivating paddy land only are excluded).

Determinants of the extent of maize cultivation

The factors hypothesized to influence the area share of maize, as described in detail in Section 3, are summarized in Table 3. The regression results are provided in Table 4, whereby both Tobit estimates and, for comparison, the estimates derived from an OLS specification are shown. The difference is that the first are based on an uncensored latent dependent variable and the latter on the censored observed dependent variable (see Section 3). Moreover, the Variance Inflation Factors (VIFs) are listed which attain a maximum value of 2.83, indicating that there is no cause for concern with regard to multicollinearity among the explanatory variables. While there are no hard rules with respect to a critical VIF value, Myers (1990) suggests that a value of 10 should not be exceeded. Since the Breusch-Pagan test (Breusch & Pagan 1979) rejects the null-hypothesis of homoskedastic errors in the OLS regression, heteroskedasticity-consistent standard errors are used in both model specifications that also account for the cluster sampling procedure (see Section 3).

Table 3: Hypothesized influencing factors of the farm area share allocated to maize production in Yen Chau district, Northern Vietnam, and their summary statistics (hypothesized direction of relationship in parentheses)

		Variable description	Mean	Std. Dev.
Dependent variable				
Maize share	=	Share of the entire cultivable area that was devoted to maize in the main growing season 2007 (%)	**71.36**	20.99
Natural capital				
Farm size (+)	=	Total cultivable area in the main growing season 2007 (hectares)	**1.59**	1.17
Upland share (+)	=	Share of land officially classified as 'upland' within the total cultivable area (%)	**77.50**	21.33
Paddy share (-)	=	Share of paddy land within the total cultivable area (%)	**12.28**	10.48
Red Book share (?)	=	Share of total cultivable area under a formal land use certificate ('Red Book') (%)	**72.97**	36.17
Human capital				
Age HH head (?)	=	Age of the household head	**43.22**	12.66
Literacy HH head (+)	=	Dummy, = 1 if the household head is literate, 0 otherwise	**0.77**	0.42
Sex HH head (?)	=	Dummy, = 1 if the household head is female, 0 otherwise	**0.08**	0.27
H'mong (?)	=	Dummy, = 1 if the household head belongs to the ethnic group of the H'mong, 0 otherwise	**0.15**	0.36
Kinh (?)	=	Dummy, = 1 if the household head belongs to the ethnic group of the Kinh, 0 otherwise	**0.08**	0.27
Dependency ratio (-)	=	Number of household members aged < 18 and/or > 60 relative to total number of members	**0.41**	0.22
Economic/financial capital				
Wealth index (+)	=	Relative wealth index constructed by Principal Component Analysis[b]	**0.59**	0.21
Off-farm income (?)	=	Share of off-farm income in total household income (%)	**15.83**	23.62
Credit limit (+)	=	Logged maximum amount of credit available to the household (1,000 VND)[c]	**42,666.61**	47,243.56
Infrastructure				
Maize price (+)	=	Maize price received in 2006 (VND kg-1)	**2,100.30**	248.65
Extension access (+)	=	Perceived access to agr. extension on a scale from 1 (= very poor) to 5 (= very good)	**3.10**	1.06
Input distance (-)	=	Distance to the closest fertilizer store (km)	**0.71**	1.75
Road distance (-)	=	Distance to the next paved road (walking minutes)	**16.00**	19.19

[a] Summary statistics are based on 294 cases without missing values for any of the variables.

[b] The index is the household's score on the first principal component based on the following wealth indicators: size of dwelling in square meter per capita; exterior wall is made of bamboo (yes = 1); floor is made of earth (yes = 1); share of children in the household, value of cupboard (logged); value of living room set (logged); household was classified as poor in 2006 by the village (yes = 1). The index was scaled to range from 0 (= poorest) to 1 (= wealthiest).

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

Table 4: Parameter estimates of influencing factors of the farm area share allocated to maize production in Yen Chau district, Northern Vietnam (N = 294)

Variable	Tobit estimates		OLS estimates		
	Coefficient[a]	t-value[c]	Coefficient[b]	t-value[c]	VIF[d]
Constant	14.8856	0.82	23.3020	1.61	
Farm size	1.1410	1.47	1.2110	1.55	1.39
Upland share	0.4635	8.33***	0.4336	7.56***	1.68
Paddy share	- 0.3396	- 2.92***	- 0.3363	- 3.09***	1.50
Red Book share	- 3.5648	- 1.40	- 2.6480	- 1.09	1.32
Age HH head	- 0.0630	- 0.63	- 0.0584	- 0.59	1.58
Literacy HH head	- 6.3590	- 3.42***	- 5.9090	- 3.60***	1.52
Sex HH head	14.8777	3.58***	12.9382	3.28***	1.23
H'mong	- 16.2758	- 4.90***	- 15.4493	- 5.19***	2.79
Kinh	12.1237	2.14**	10.7146	2.30**	1.39
Dependency ratio	- 14.6329	- 2.13**	- 13.2797	- 2.00*	1.53
Wealth index	- 23.6084	- 2.37**	- 20.5535	- 2.13**	2.83
Off-farm income	- 0.1239	- 1.49	- 0.1098	- 1.45	1.30
Credit limit	3.6138	3.17***	2.5584	5.23***	1.47
Maize price	0.0060	1.26	0.0061	1.30	1.47
Extension access	0.6182	0.78	0.8424	1.11	1.08
Input distance	- 0.3448	- 0.92	- 0.4004	- 1.06	1.16
Road distance	0.2635	7.33***	0.2528	7.14***	1.84
	F-value = 223.56*** Log likelihood = - 1175.28 Pseudo R^2 = 0.079 % censored obs. at 0 = 3.1 % censored obs. at 100 = 2.7		F-value = 273.31*** R^2 = 0.486 Root MSE = 15.508		

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

[a] Dependent variable: Maize share. Coefficients are marginal effects on the latent (uncensored) dependent variable based on a Tobit regression.

[b] Dependent variable: Maize share. Coefficients are marginal effects on the observed (censored) dependent variable based on an Ordinary Least Squares (OLS) regression.

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

[d] Variance Inflation Factor.

Both specifications identify the same influencing factors on *Maize share*. The signs of all coefficients are identical and the t-values are similar. In general, the OLS coefficients are slightly smaller than their Tobit counterparts; this conforms to our expectations since the OLS regression does not account for the censored nature of the dependent variable and, hence, tends to underestimate the marginal effects of the explanatory variables (see Kennedy 2003: 282). However, since at 5.8% the share of censored observations is quite small this effect is not very pronounced, i.e., both specifications produce similar estimates.

Most of the explanatory variables in our model are found to have a statistically significant impact on *Maize share*. Five variables (*Red Book share*, *Age HH head*, *Maize price*, *Extension access*, and *Input distance*) have no significant influence, two variables (*Farm size* and *Off-farm income*) are close to the 90% confidence level. A likelihood ratio test shows that, in combination, these seven variables do have some explanatory power[11]. However, the exclusion of these variables leads to no loss of statistical significance and only very minor changes in the size of the remaining regression coefficients, which confirms the robustness of the estimates. The following discussion of the results is based on the unrestricted Tobit specification.

5 Discussion

Maize cultivation dominates the upland areas in Yen Chau district. Farmers apply large amounts of mineral fertilizer and attain relatively high yields and attractive gross margins. The economic importance of maize in the area becomes apparent when one considers that it generates about three-quarters of farm households' agricultural cash income and two-thirds of their total cash income. High levels of fertilizer use and maize yields in the northern uplands of Vietnam are confirmed by Thanh Ha et al. (2004). Farmers are well aware of adverse environmental consequences of maize cultivation on sloping land: they know that soil erosion occurs on their maize land, and they perceive this to be a moderately severe problem. 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, such as vegetative barriers either along contour lines or as cover crops or mulch, remain very low. The only practice which is relatively widespread (34% of respondent households) is the digging of small ditches across sloping fields, aimed at channelling run-off water off the plot; however, the effectiveness of this method in reducing soil erosion is questionable since water is merely diverted onto neighboring fields. Lack of effectiveness is also the reason most frequently cited for not adopting this technique (cf. Table 2). The fact that maize is a highly profitable cash crop under the current economic 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. Consequently, both loss of land and direct negative effects on the maize crop, e.g. through shading, were the most frequently cited reasons for not practising any soil conservation techniques on the upland plots. Moreover, the fact that soil erosion entails a loss in soil fertility with negative consequences

[11] The critical χ^2 value for a total of seven restrictions and an error probability of 5% (14.07) is exceeded by the test value λ (16.31).

on maize yields may (still) be masked by the high amounts of mineral fertilizer applied (cf. Table 1).

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 0.46 percentage points. On the other hand, if *Paddy share* increases by one percentage point, *Maize share* is reduced by 0.34 percentage points. This conforms to our expectations, since maize is typically grown on sloping upland fields. A different specification of the upland share variable was also tested, which comprised all the cultivable area apart from paddy land and fish ponds. This variable had far less explanatory power than the specification finally used, which is based on the official land classification system. This means that farmers indeed adhere to this classification, i.e., they tend not to grow maize on land classified as ‘garden’ or ‘perennial crop’ land. The highly significant negative coefficient on *Paddy share* shows that, although maize has become a very profitable cash crop, farmers continue to have a clear priority to use irrigable land not for maize but for the cultivation of rice, which is mostly home-consumed. This suggests that – apart from food taste and cultural preferences- farmers view it as too risky to rely on local, national, and global rice markets for the acquisition of their major food crop and are willing to pay a considerable risk premium (in terms of foregone gross margin on the more lucrative crop maize) for ensuring food security through home-produced rice. Regarding the regression coefficient on *Farm size* we conclude that, irrespective of the lack of statistical significance, its economic significance is negligible, indicating that for a one-hectare increase in cultivable area (the mean of *Farm size* being 1.6 hectares) the share devoted to maize increases by 1.1 percentage points.

Concerning human capital, the model results confirm that the characteristics of the household head have important implications on in the area allocation to maize. The age of the household head does not seem to play a role. Contrary to our expectation, illiterate household heads allocate six percentage points more land to maize than literate household heads. Based on the current analysis we cannot make statements about possible differences regarding the appropriateness of crop management between the two groups, however. Qualitative research conducted by CIMMYT in the uplands of northern Vietnam (Thanh Ha et al. 2004) indicates that there are significant deficiencies in farmers’ knowledge on proper maize management. Surprisingly, we find that the area share devoted to maize is almost 15 percentage points higher for female-headed households. However, probably due to more pronounced capital and labor constraints, they attain maize yields that are on the average 1,130 Mg ha^{-1} (18%) lower than those of male-headed households. The difference is statistically significant at the 1% level of error probability (Mann-Whitney test). Therefore, regarding the share of agricultural income derived from maize there is no significant difference between the two. The greater area share allocation can be explained by differences in land endowment between the two household types: 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 $P < 0.01$) leading to a smaller area share being fallowed (0.9 versus 4.3%, Mann-Whitney test significant at $P < 0.1$). Second, female-headed households are less endowed with paddy land (269 versus 382 m^2 per person, Mann-Whitney test significant at $P < 0.1$). Therefore, the need to allocate land to a profitable cash crop is particularly pronounced in order to generate income for the satisfaction of food needs. Regarding ethnicity, we find that compared to the reference group of Thai households the share of cultivable area allocated to maize production is 16 percentage points smaller in the case of the H'mong and 12 percentage points larger in the case of the Kinh. Both effects are likely to be related to market access and consumption preferences: the H'mong live at high elevations in relatively remote villages where irrigation is often not available, and the cultivation of paddy rice limited. They tend to plant more upland rice for own consumption because transaction costs for the purchase of rice or the sale of maize in lowland markets are relatively high. The opposite is true in the case of the Kinh who typically occupy the lowland areas, are much more market-oriented (cf. Neef et al. 2002), and also have much lower transaction costs in agricultural markets. The sign of the regression coefficient on *Dependency ratio* is negative, which conforms to our hypothesis. However, the size of the coefficient is very small, indicating a 1.5 percentage point reduction in *Maize share* for a 0.1 point increase in the dependency ratio. As stated in Section 3, we assume this effect to be attributable to reduced labor availability and/or a preference for food crops with an increasing number of dependent household members.

Contrary to our expectation, the coefficient on *Wealth index* is negative, implying that poorer households devote a larger share of their cultivable area to maize than wealthier households[12], although this typically entails considerable cash input, especially in terms of fertilizer. This result may be attributable to data limitations: in our analysis we cannot differentiate between area devoted to hybrid maize and area devoted to local maize varieties. The latter are grown with little cash inputs and also for purposes of home-consumption, especially if paddy land is not available. The regression coefficient on *Off-farm income* is not statistically significantly

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[12] A quantitative interpretation of the coefficient is not possible since *Wealth index* is a relative measure of wealth among the sample households.

different from zero. 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 3.6 percentage points. This is a rather large effect which emphasizes the importance of rural credit to finance the high amounts of inputs that are commonly applied to maize (cf. Table 1). Hereby, 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 interest rates paid by the wealthiest tercile among our sample households, which rely less on informal lenders, average 0.85% per month, they amount to 1.10% in the medium tercile, and 1.69% in the poorest tercile[13]. Hence, for the poorest tercile credit is on the average 54% more expensive than for the medium and 99% more expensive than for the wealthiest tercile. All differences are statistically significant at $P < 0.01$ (Kruskal-Wallis test followed by individual Mann-Whitney tests, correcting for family-wise alpha error).

With regard to the infrastructural environment that farmers operate in, an influence of the maize price received in the cropping season 2006 on the area share devoted to the crop in 2007 is not supported by our household-level data, although they exhibit a considerable degree of variation, ranging from 1,150 to 3,000 VND kg^{-1}. This can be explained by a lack of alternative cash crops that are able to compete with maize, even if the price received in a particular location and under a specific marketing arrangement (see below) may be comparatively low. Furthermore, neither an influence of access to agricultural extension nor the distance to the closest fertilizer outlet is supported by the data. In contrast to our expectation, the area share devoted to maize increases with increasing distance to the nearest paved road. The explanation of this effect may in part be related to the lack of differentiation between hybrid maize, which is exclusively grown as a cash crop, and local maize, which may also serve home-consumption purposes especially in remote mountainous areas that lack access to irrigable land for rice cultivation. More importantly, however, some 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, hence explaining why neither the physical distance to the closest fertilizer store nor the distance to the nearest paved road discourage farmers from engaging in maize production. These 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, less

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[13] These data are based on different recall periods (two months to five years) for different loan amounts (10,000 VND to > 2 million VND) in order to obtain meaningful information. Informal loans received from relatives or friends are excluded.

remote 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. Another important source of agricultural inputs as in-kind 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.

6 Conclusions and recommendations

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. Although farmers are well aware of soil erosion on their maize plots, effective soil conservation measures are rarely practiced. The fact that maize is a highly profitable cash crop under the current economic conditions means that the establishment of soil conservation measures incurs high opportunity costs in terms of land lost for maize production. Moreover, the negative effect of erosion on soil fertility may (still) be masked by the high amounts of mineral fertilizer applied. Our analysis shows that, 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 to not play a significant role, which is probably due to marketing and input supply arrangements with maize traders who collect the produce in the village. Maize is attractive to farmers from all social strata, notably the poor and illiterate.

Although formal credit programs do not directly target credit to maize, it is comparatively easy to obtain in-kind credit for maize production in terms of seed and fertilizer from maize traders or via village-level institutions. Although the interest rates charged are typically high, this is an attractive option particularly for the poorest farmers living in remote places who lack adequate access to formal credit at much more moderate interest rates. We thus conclude that enhancing the access of the poor to low-interest formal rural credit would make it easier for them to diversify their crop portfolio and reduce the risk of becoming indebted and caught in a poverty trap. Given the currently extremely high shares of maize in overall production and cash income this can easily happen when revenues plummet due to maize pests or diseases, price fluctuations, or adverse climatic conditions. As emphasized earlier, in concert with climate change, the latter can be expected to become a more severe problem in the future, both in terms of prolonged drought spells and periods of excessive – and therefore particularly erosive – rainfall leading to localized flooding.

In order to address the crucial issue of soil erosion and degradation on the maize-dominated upland areas in and beyond north-western Vietnam, more interdisciplinary research is needed on land use options that are economically attractive - and thus competitive with maize – while at the same time serving a soil conservation purpose. The experience in Yen Chau shows that measures that have the sole purpose of reducing soil erosion are not adopted at any significant scale. Since the livestock sector in Vietnam is rapidly growing, research priority may be given to soil conserving land use options that produce feed and/or are easily combined with the current production of maize, such as contour strips of fodder grasses, for instance. In order to ensure the practical relevance and adoptability of these land use options these research activities should be conducted in close collaboration with farmers and other stakeholders, such as the agricultural extension service and policy-makers involved in land use planning and environmental protection.

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