Environmental Influences on Migration in Rural Ecuador

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Introduction

As the evidence for global environmental change has accumulated over the past decade, academics, policymakers, and the media have given more attention to the issue of "environmental refugees." At issue is whether environmental change will displace large numbers of vulnerable people in the developing world, particularly from rural areas where livelihoods are particularly dependent on climate and natural resources. A widely-cited article (Myers 1997) estimated that more than 25 million people had been displaced by environmental factors by 1995. Similar narratives of widespread environmental displacement have since proliferated online and in the popular press (CARE 2009; New York Times 2009). Skeptics, however, have criticized these numbers as speculation (Black 2001, Hartmann 2010) and identified important disasters in which no significant out-migration occurred (Paul 2005). In fact, despite dozens of academic publications and several international conferences on the issue, well-documented cases of environmentally-induced migration are rare and largely limited to large-scale natural disasters (e.g., Hurricane Katrina: Groen & Polivka 2008). Still unclear are the consequences of smaller-scale but more pervasive forms of environmental change, such as drought, floods and soil degradation, limiting our ability to understand the scale and nature of human displacements under accelerating global environmental change.

Fortunately, the combination of survey methods and Geographic Information Systems (GIS) offers a way forward. Modern survey methods make possible the collection of large-scale, representative data on migration, while satellite imagery and other sources have provided new measures of environmental conditions, and the use of GIS facilitates linkages between the two data sources, though notable methodological challenges remain (Fox et al. 2002). Several studies have combined these approaches to investigate tropical land use change (Walsh & Crews-Meyer 2002), but as yet few studies have examined environmental influences on migration. Exceptions include the ground-breaking study by Henry et al. (2004), and two studies by the first author (Gray 2009; Gray et al. 2009), described in detail below. As of yet, these studies have investigated only a subset of potentially important environmental factors in a few study areas.

This paper uses original survey and spatial data from three study areas in rural Ecuador to investigate the influence of multiple environmental factors on internal and international migration. Data were collected through an innovative approach that combined a flexible sampling strategy, collection of event histories at multiple scales, and derivation of community-level biophysical characteristics using

GIS. We use these data to estimate multinomial discrete-time event history models of environmental influences on migration that include area-level fixed effects and a large number of covariates. Specifically, we examine the influences of household land quality, local climate patterns, and community-level agricultural shocks on local mobility, internal migration and international migration.

All three sets of environmental factors significantly affected migration. International migration increased with land quality and decreased with agricultural shocks and annual rainfall. Local mobility and internal migration increased with the rainfall seasonality. Interaction models reveal that rainfall seasonality had greater effects on female-headed households, and wealthy households were best able to take advantage of land quality to enable international migration. These results suggest a hybrid narrative of environmentally-induced migration in which vulnerable individuals can be displaced by environmental factors, at the same time as individuals with access to natural capital can draw on it enable international migration.

Theoretical Approaches

Previous discussions of environmentally-induced migration have taken varying views of the scope of human agency in responding to environmental change. In the most common narrative, it is assumed that environmental change will displace large numbers of people and attention is focused on how many, how to respond, and the implications for national security (Myers 1997; CARE 2009). This limited view of the scope of human agency in responding to environmental change is a hallmark of neo-Malthusian, a conceptual framework that envisions strong positive feedbacks between poverty and environmental degradation (Leach & Fairhead 2000). This framework has been rejected by human-environment scholars working on a number of related issues (Leach & Fairhead 2000; Urdal 2005; Neumayer 2006). However, a number of authors have offered a more nuanced view of environmental-induced migration, one that recognizes both the human capacity to respond to environmental change as well as the significant barriers to migration for many affected individuals (Black 2001, Kniveton et al. 2008, Gray 2009). This view is consistent with a large number of studies that demonstrate the significant capability of rural households in the developing world to adapt to environmental change (e.g., Mortimore & Adams 2001), as well as the selectivity of long-distance migration for wealthier and educated individuals (White & Lindstrom 2005).

We adopt the latter view and draw in particular on three connected literatures: the sustainable livelihoods framework, studies of the determinants of migration, and studies of vulnerability. The sustainable livelihoods framework views rural households as drawing on diverse assets (e.g., human, physical, social and natural capitals) to make a living through various livelihood strategies (e.g., agriculture, wage labor and migration) in a particular social, economic and environmental context (Ellis 2000). Regarding environmentally-induced migration, this view implies that rural households are likely to be affected by environmental change but that migration is only one of multiple potential strategies to respond. Moreover, the consequences of environmental change are likely to depend on the stock of natural capital (e.g., land, soil quality) available to the household, and costly migrations are likely to be enabled by access to capital.

This view is consistent with the empirical findings of studies of the determinants of migration, which reveal that long-distance migrants are commonly young, educated adults with access to migrant networks and financial capital (White & Lindstrom 2005). Shorter-distance migrations, in contrast, are more often linked to lifecourse transitions such as marriage, entering the labor market or the continuation of schooling (Johnson & DaVanzo 1998), and can permit continued access to the resources of the origin household and continued exposure to common environmental conditions. For these reasons, short and long-distance moves are likely to respond differently to environmental and other factors (Gray 2009).

Vulnerability studies offer a complementary perspective: poor or otherwise vulnerable populations might be disproportionately affected by environmental change, including through involuntary migration (Wisner et al. 2004). A synthesis of these frameworks thus suggests that negative environmental factors can potentially reduce access to capital, hindering costly migrations, but also act as disamenities, encouraging migration (Gray 2009). As described below, we evaluate these views in the context of rural Ecuador, investigating both household and contextual factors as well as short and long-distance moves. Critically, we also control for access to physical, social and human capitals, and account for unobserved contextual factors using fixed effects.

Previous Studies

Previous demographic studies of environmentally-induced migration have investigated the consequences of large-scale natural disasters, slow-onset changes such as drought, and local environmental characteristics such as soil quality. Studies of large-scale natural disasters, particularly hurricanes in the United States, provide the most detailed previous accounts of environmentally-induced migration (e.g., Smith & McCarty 1996, Smith & McCarty 2009). Hurricane Katrina has been the focus of multiple studies, revealing that approximately 1.5 million people were displaced, with the majority leaving their state of origin and the poor more vulnerable to long-term displacement (Groen & Polivka 2008; Sastry & Gregory 2009). Much less data on natural disasters and migration is available for the developing world. Two studies have used panel data from El Salvador to show that international migration decreased after a large earthquake in 2001 (Halliday 2006; Yang 2008). Detailed information on the 2004 Indian Ocean tsunami is also available from the Study of the Tsunami Aftermath and Recovery in Indonesia, which has collected multi-wave panel data from a large, representative sample of individuals. These data reveal that most displaced individuals remained nearby their origin communities, and that indicators of vulnerability did not consistently increase displacement (Gray et al. 2009).

These studies of natural disasters provide well-documented accounts of environmental effects on migration, but do not address the experiences of the much larger populations who cope with slow-onset changes such as drought and soil degradation (Laczko & Aghazarm 2009). On this front, multiple studies have investigated the effects of rainfall, a key environmental variable in rural areas, taking advantage in variation in rainfall over both time and space. In an early descriptive study, Findley (1994) showed that migration rates did not change during a drought in Mali but that the proportion of moves made by women and children increased. Henry et al. (2004) subsequently combined demographic data on migration from Burkina Faso with time-varying spatial data on rainfall to show that rural-rural migration more was common and international migration was less common in areas with drier or more variable climates. For rural India, Badiani and Safir (2008) used panel data from six villages to show that temporary migration decreased with monsoon rainfall for farm households but increased for households dependent on wage labor. Additionally, Gray (2009, 2010), in a pilot study that preceded this one, showed that areas in the southern Ecuadorian Andes with wetter climates were less likely to send both internal and international migrants, though this effect was most important for men. These and other studies (e.g., Munshi 2003; Gutmann et al. 2005) do not yet provide a clear picture of the consequences of climate for migration (perhaps unsurprising given their distinct study areas and varying measures of climate and migration) but they do not support the idea that drought universally increases migration.

Finally, only a small number of demographic studies have investigated the consequences of local environmental conditions for migration, despite a large literature that demonstrates their importance to rural livelihoods (e.g., Sandor & Furbee 1996). Massey et al. (2007) used data from lowland Nepal to show that out-migration increased with the time to gather firewood, perceived declines in agricultural productivity, and the proportion of non-vegetated land cover in the community. However these effects were only important for local moves by low-caste individuals. Rindfuss et al. (2007) found that out-migration in rural Thailand increased with forest cover, but the study did not control for community characteristics such as accessibility that might explain this effect. Additionally, our pilot study in the southern Ecuadorian Andes (Gray 2010) revealed that internal migration increased with agricultural shocks and that international migration declined with reported soil degradation. These three studies are too few to allow generalizations about the effects of local environmental conditions on migration but indicate they are likely to be important.

Our study contributes to the second and third sets of studies above by examining how land quality, agricultural shocks and local climate patterns influence local mobility and internal and international migration in rural Ecuador. Relative to the studies cited, ours has multiple advantages. Firstly, data were collected from 107 communities in three study areas with high between-area and within-area environmental heterogeneity, allowing us to assess the effects of a large range of environmental conditions on migration. Secondly, the data include a large number of environmental characteristics, derived from both surveys and spatial analyses, permitting us to investigate various specifications of the environmental effects. Thirdly, a flexible sampling strategy allowed us to generate sufficient sample size to examine three forms of migration (local, internal and international). The study is also one of the first to examine the determinants of international migration from Ecuador.

Study Areas

Building on previous research by both authors (Bilsborrow et al. 1987; Gray 2009), the study was conducted in three study areas in rural Ecuador (Figure 1), which together contained 7% of Ecuador’s rural population in 2001. The three study areas, consisting of 5-6 contiguous cantons[1], were selected to maximize the number and diversity of out-migrants as well as within-area and between-area environmental heterogeneity. All three areas are mountainous, rural and agrarian but they differ significantly in their environmental characteristics and patterns of out-migration.

The Santo Domingo study area is centered on the city of the same name in the Andean foothills of Pichincha province west of Quito. It includes the cantons of Santo Domingo, San Miguel De Los Bancos, Pedro Vicente Maldonado, Puerto Quito and La Concordia. This area encompasses a wide range of environments from mountainous, heavily forested areas in the north to flat and intensively cultivated areas in the west. The climate is humid and tropical, key crops include heart of palm, cocoa trees and plantains, and out-migration is primarily to other coastal provinces. As an aging agricultural frontier, the region still experiences significant in-migration, and large farms and landlessness are both common.

The high-elevation Chimborazo/Cañar study area overlaps these two provinces, and includes the cantons of Biblian, Cañar, El Tambo, Suscal, Alausi, Chunchi, and Pallatanga. These areas include *paramó* grasslands and densely-settled valleys with temperate climates. Smallholder agriculture is the dominant land use and key crops include maize, beans and potatoes. Located north of Cuenca and Azogues, this area is part of Ecuador's international out-migration heartland. Migration from this region to the United States became common in the 1990s, before being superseded by the (nationwide) trend of migration to Spain in the 2000s (Jokisch 2007).

Finally, the Loja study area is located in western Loja province, and includes the cantons of Celica, Chaguarpamba, Macara, Paltas, Puyango, and Olmedo. This area is west of the area covered by our pilot study (Gray 2009). This area is located in the western Andean foothills but has an unusually dry climate with recurrent droughts. Coffee-centered agroforestry and smallholder agriculture dominated by maize are key land uses, but land use intensity and population densities are low relative to the other study areas. This region is a traditional sending region of internal migrants to the urban, coastal and Amazon destinations, though international migration (primarily to Spain) has recently become more common.

Data Collection

Sampling

Within the three study areas, respondent households were selected using a stratified, multi-stage cluster sampling methodology which included procedures to oversample households with recent out-migrants. In the first stage, a predetermined number of parishes (Ecuador's smallest administrative unit) were sampled in each study area with probabilities of selection proportional to the propensity of rural out-migration. This propensity was estimated using data from the 2001 census on place of residence five years prior. Majority urban parishes were excluded. This resulted in a sample of 29 parishes (Table 1).

[1] Cantons are roughly equivalent to US counties.

Within the selected parishes, a predetermined number of census sectors were selected randomly, with urban census sectors excluded. This resulted in a final sample of 55 census sectors (Table 1).

Beginning in June 2008, a door-to-door listing operation was conducted in each of the sample sectors to list all resident households and record (1) the age composition of household members, and (2) the number out-migrants to various destinations since January 1, 2000. The listed households were then divided into locally-recognized communities or villages. This process was informed by the spatial distribution of households, maps produced by the National Census Office, and discussions with local residents. The 55 sample census sectors contained 107 rural communities (Table 1).

Using a set of standardized rules, all listed households were subsequently classified as belonging to one of six strata based on their demographic composition and the departure and destinations of out-migrants. The six strata were Amazon-sending (i.e., sent a migrant to the Amazon), international-sending, rural-sending, urban-sending, non-migrant, and not at risk. Households which had sent a migrant to an Amazonian province were automatically included in the household sample, and those which had not sent any migrants and had no members under the age of 40 were excluded from the sample as not at risk of migration.

From the other strata, field supervisors implemented a set of standardized sampling rules in each community that took into account the total number of at-risk households in the community and the number in each of the five strata. For example, in communities with 10-19 at-risk households, up to four were to enter from each stratum with a minimum total of seven. Thus in a community with ten non-migrant households, five urban-sending households and two international-sending households, four non-migrant and four urban-sending households would be selected at random and both international-sending households would automatically enter the sample. If instead there were sixteen non-migrant households, one urban-sending household and one international-sending household, four non-migrant households would be selected at random, the urban-sending and international-sending households would automatically enter the sample, and one additional household would be selected at random, in this case from the non-migrant stratum.

This approach ensured that a diverse sample of migrant-sending households was selected in each community and that migrant-sending households were sampled with higher probability where they were rare. Overall, 2732 households were listed and 869 households were sampled, with the following composition (and sampling fractions) by strata: 22 Amazon-sending households (100%), 163 international-sending households (69%), 56 rural-sending households (98%), 247 urban-sending households (72%), and 381 non-migrant households (26%). To account for this sampling strategy, all models and descriptive statistics described below incorporate sampling weights, calculated as the inverse of the probability of selection. Among the sampled households, 843 completed the household questionnaire, with an overall response rate of 97%.

Questionnaires

Sample households were interviewed using a structured questionnaire that collected information on individual, household and farm characteristics for the years 2000-2008. An individual history was collected for each current household member over age 14 and for each member who departed beginning in 2000 if 14 or older at the time. The individual history collected annual data on place of residence, economic activities and demographic characteristics, including marital status, education level and school attendance. Limited information was also collected on migration and work experience prior to 2000. These data were reported by the interviewee, almost always the household head or spouse, who served as the proxy respondent for migrants and other household members. Recall and proxy response errors were limited by (1) the collection of information in annual time-steps, (2) the limited eight-year period of recall (short relative to other migration studies, e.g., Massey & Zenteno 2000; Schoorl et al., 2001), (3) the close relationships between the proxy respondent and target individual (most commonly parent and child), and (4) a questionnaire format that allowed for comparison of related characteristics over time, permitting internal cross-checks by the interviewer and field supervisor.

The household questionnaire collected a similar annual history on characteristics of the household and of each agricultural parcel since 2000, covering home ownership, the timing of good and bad harvests, and the size and primary use of each agricultural parcel. Additional data were also collected for the time of the survey and for 2000, such as soil quality and accessibility of the household location. Limited data were also obtained on migrants who had departed prior to 2000 in order to provide data on migrant networks beginning in that year.

Finally, a community questionnaire was implemented with a community leader to obtain cross-sectional and retrospective information about community infrastructure, accessibility, economic activities, and demographic and environmental characteristics. Information was also collected about the out-migration of entire households[2], for whom data are inevitably missing in the typical origin-area only survey (Bilsborrow et al. 1984). We plan to draw on these data in future work.

Spatial data

Global Positioning System (GPS) points were collected at community centers, the location of each household, and a subset of agricultural plots. Using Geographic Information System (GIS) software, we created 1 km buffers around the community points and extracted mean values for these areas from two existing environmental datasets. The first was a 30 m Digital Elevation Model (DEM) of Ecuador (Souris 2006), from which we extracted data on elevation and slope. The second was the global WorldClim dataset, containing interpolated climate information at 1 km resolution, estimated as a historical mean for the years 1950-2000 (Hijmans et al. 2005). We used this dataset to extract measures of mean annual precipitation and temperature for the study communities, as well as seasonal variation

[2] This information indicates that approximately 60% of internal migrants and 85% of international migrants departed as individuals and thus were part of the population sampled by our household survey.

in these values. Unfortunately, time-varying data from rainfall stations of the Ecuadorian meteorological institure were not available with sufficient spatial resolution to inform our analysis (e.g., only five of the 17 study cantons have rainfall stations). We therefore use the high-resolution WorldClim data, supplemented by community-level measures of agricultural shocks, as described below.

Census data

To provide additional contextual information at the parish level, we extracted values from the 2001 census for the sample parishes. These included the percent of population urban and the propensities of internal and international out-migration, calculated as the number of out-migrants from 1996-2001 divided by the total resident population in 1996.

Analysis

Person-year dataset

To investigate environmental influences on migration, we first use the data described above to create a person-year dataset containing information on both migrants and non-migrants. The dataset contains time-varying and time-invariant variables at individual, household, community and parish levels, with each case being one year in the life of a person at risk for out-migration, as defined below. Migration decisions (to migrate or not in year *t*) are considered to occur based on circumstances in the previous year, with the predictors thus lagged by one year (values in year *t*-1). This reduces the possibility of endogeneity with the migration decision; and means that dependent variables are available for 2001-2008 (year *t*). Following exploratory regressions, household heads and spouses and individuals under age 14 or over age 39 in year *t* were excluded from the analysis because of low propensities for out-migration. This is consistent with previous studies of migration in Ecuador (Bilsborrow et al. 1987; Barbieri & Carr 2008; Gray 2009). Following these exclusions, the analysis dataset includes 585 households and 1670 persons at risk for out-migration during the study period (Table 1). Children of the head and other non-head household members enter the dataset after 2000 when they are age 14 or older and resided in the household in year *t*-1. Individuals leave the dataset when they out-migrate after 2000, turn 40 years old, or are censored at data collection in 2008. Return migrants re-enter the dataset in each year (*i*-1) that they reside primarily in the household.

Migration is defined as a departure from the origin household for six months or longer in year *t*. Moves in which the first place of residence for six months or longer was in another country were considered to be international migration, moves within the canton were defined to be local mobility, and other moves within the country to more distant destinations were considered to be internal migration. Most internal moves were to urban areas, but all are considered here together as internal migration. Corresponding to these categories, the outcome variable is coded one to three for person-years in which migration occurred, and coded zero for person-years when migration did not occur. The dataset contains 898 non-migrants (4,231 person-years) and 772 migrants who departed their origin household one or more times (3,058 person years). Counting the moves of 15 individuals who returned to and departed from their origin household a second time during the study period, and two who returned twice and departed a third time, the dataset contains 112 local movements, 514 internal migrations, and 165 international migration movements. We refer to these three forms of movement as migration streams.

Predictors

Table 1 presents the predictors (i.e., independent variables) used in the event-history analysis, including mean person-year values by study area. Consistent with the livelihoods framework (see above and Ellis, 2000) and previous studies of the determinants of migration (e.g., Massey and Espinosa 1997), the predictors include measures of demographic characteristics, wealth and accessibility, and migration networks in addition to environmental variables. These include both time-varying and stable characteristics at individual, household, community and parish levels.

Individual-level demographic characteristics include gender, age, relationship to the household head, marital status, and level of completed education. Additional predictors at the household level include gender of the household head and the age composition of the household. Wealth is measured by home ownership and the area of agricultural lands owned or managed[3]. Accessibility is measured by distance from the dwelling to the nearest school (representing access to local services), distance to a paved road, and percent of the parish population that is urban (both representing access to urban services and to potential local destinations). Migration networks can be individual, household or contextual, and are captured, respectively, by whether the individual had previously lived outside the canton, by the number of previous local movers, internal migrants, and international migrants from the household, and by the parish-level propensities of internal and international migration from 1996-2001.

Environmental factors, the focus of this analysis, include a household index of land quality, the amount and seasonality of rainfall, and the timing of unusually good and bad harvests in the community. To create a continuous index of household land quality, we used polychoric principal components analysis (Kolenikov & Angeles 2004) to combine twelve dichotomous and positively-correlated land quality measures collected in the household survey (see Appendix 1). The results are consistent with expectations, with positive weights for the presence of flat topography, black soil, sandy soils, good soil quality, and irrigation, and negative weights for steep topography, gravel soils, yellow/red soils, and poor soil quality. The index was scaled to have a minimum of zero and a maximum of ten and was set to zero for landless households. To avoid artifacts from tying the index to a particular year, the index is time-varying and can change if the household sells or acquires land. However such transactions were rare, so for most households the index does not vary over time. With this measure included, community-level measures of topography derived from the DEM based on satellite data were consistently non-significant and therefore excluded for parsimony.

[3] Additional measures of wealth were tested in exploratory regressions but were not significant and hence were removed for parsimony. These include cattle ownership, housing quality, participation in Ecuador's cash transfer program, and infrastructure available in the community.

To control for climatic conditions at the community level, we include the historical mean annual rainfall and rainfall seasonality, crucial factors given that most households are dependent on rainfed agriculture. These variables are uncorrelated (r = 0.04, p = 0.69) and were derived from the WorldClim dataset, for which rainfall seasonality was calculated as the coefficient of variation of weekly rainfall, using the weekly means across years (Hijmans 2005). As an alternative specification, we explored the use of an index combining several measures of rainfall, temperature, and seasonality, but precipitation measures alone consistently provided a stronger explanation and were thus retained. To further capture temporal variation in climatic conditions, we also include community-level measures of the occurrence of particularly good and bad agricultural harvests, as reported by the community leader. These outcomes were most commonly attributed to insufficient/overabundant versus appropriate amounts of rainfall.

The mean values of the predictors presented in Table 2 also provide insights into differences across the three study areas. One notable difference is that Lojas has higher levels of education and an older age structure. Rates of internal out-migration are highest in Loja, rates of international out-migration are highest in Chimborazo/Cañar (see Jokisch 2007), and rates of in-migration (reflected in previous migration experience) are highest in Santo Domingo. The gender selectivity of these migration flows is reflected in the skewed sex ratios of individuals at risk for migration: they are predominantly women in Chimborazo/Cañar and predominantly men in the other two areas. Finally, important differences in environmental conditions and land tenure are also evident. Santo Domingo receives the most rainfall and has the most farms greater than 5 ha, but also the highest proportion of landlessness/near-landlessness. Chimborazo/Cañar receives much less rainfall but with low seasonality. Farms there are also much smaller, reflecting higher population densities and a longer history of settlement. Loja has intermediate-sized farms, but low rainfall and high seasonality, making it marginal for rainfed agriculture at many sites.

Statistical Model

We analyzed the data using a multinomial discrete-time event history model, which is appropriate to examine exposure over time to a mutually exclusive set of competing risks when time is measured in discrete units (Allison 1984). The model includes one equation for each multinomial outcome beyond the reference category, in this case out-migration to local, internal and international destinations. To account for baseline differences in migration across time and space, we include indicators for the year and canton (i.e., fixed effects). In this model the log odds of experiencing a migration event of type r relative to no migration (event s) are given by

$$\log\left(\frac{\pi_{rit}}{\pi_{sit}}\right) = \alpha_{rt} + \alpha_{rc} + \beta_r X_{it-1}$$

where π_{rit} are the odds of migration to destination type r for individual i in year t, π_{sit} are the odds of no migration, α_{rt} is the baseline hazard of mobility to destination type r in year t, α_{rc} is the baseline hazard of mobility to destination type r in canton c, X_{it-1} is a vector of predictor variables for individual i in year $t-1$, β_r is a vector of parameters for the effects of the independent variables on migration to destination type *r*, and the destination types, *r,* are local, internal and international destinations. Below, we present the parameters of this model in exponentiated form (e^{β}). This value is known as the odds ratio and can be interpreted as the multiplicative effect of a one unit increase in the predictor variable on the odds of that type of migration relative to the odds of no migration.

The inclusion of indicators for the year and canton accounts for overall national-scale time-varying factors and for canton-scale time-invariant factors as long as their effects are linear. Thus, the coefficients can be interpreted as comparing two individuals in the same canton who are exposed to same changing national context over time. The canton indicators are likely to absorb a large proportion of the variation in some predictors, such as rainfall, but strengthen our results by accounting for unobserved heterogeneity in other factors across cantons. All models also include corrections for clustering at the level of the parish, which accounts for the clustered sampling strategy and the multilevel nature of the predictors (Angeles et al. 2005).

Results

The results of the event history analysis are presented in Table 3, including odds ratios, significance tests, and Wald tests of joint significance across equations and across predictors. Below, we briefly discuss the effects of the control factors before turning to the environmental factors and a set of interaction models.

Control factors

Measures of demographic characteristics, wealth and accessibility, and migration networks were included in the model primarily as control variables, but the results are also of substantive interest. Overall, the results of the control variables are consistent with theory and previous studies.

As indicated by separate and joint statistical tests, *demographic characteristics* had overwhelmingly significant effects on migration. Women were much more likely than men to move within the canton but far less likely to become international migrants. This is consistent with data from the 2001 census, which show that international migrants from rural areas were predominantly male, and that internal migrants were divided nearly equally between men and women (INEC 2001). Also consistent with expectations, all forms of migration were lower for individuals under age 17 and above age 30. Internal migration peaked at ages 20-24, and international migration at ages 25-29, as found by our pilot study (Gray 2009). Children of the household head were more likely than those with other relationships to the household head to move internally, and married individuals were more likely to move locally and within Ecuador, likely in order to form new households. All three forms of migration increased with education, as expected.

Household-level demographic factors were not as consistently important but also had some significant effects. Female-headed households were less likely to send migrants to internal destinations, likely reflecting lower resources and increased labor demands. Out-migration to local destinations were less likely and internal migration more likely from households with members aged 40-59, likely reflecting lower labor needs in these households. Additionally, all forms of migration were lower in households with persons over age 60, potentially due to the need to care for these persons.

Migration was also influenced by *wealth and accessibility*. Local mobility declined with homeownership and size of the farm, reflecting satisfaction of needs for housing and land. A linear specification of land ownership (not shown) also revealed a negative effect of land area on internal migration and a positive effect on international migration, suggesting that land can also serve as a form of wealth that can be used to finance international migration. The coefficient for home ownership for international migrants also suggests such an effect. Geographic accessibility also significantly influenced out-migration to both local mobility and internal migration but not international migration. Households near paved roads were more likely to send local movers and less likely to send internal migrants, likely due to improved local employment opportunities near paved roads (see Barbieri & Carr 2008). Isolation from community services, as measured by distance to a school, also increased internal migration, consistent with the results of our pilot study (Gray 2010). Finally, individuals in urban parishes were more likely to move both locally and internally, likely reflecting better local opportunities and a preference for urban living.

Migration networks had significant effects on all three migration streams, though they were most important for internal migration and least important for international migration. At the individual level, previous migration experience (almost all within Ecuador) increased internal migration and decreased local mobility. At the household level, previous migrants mostly increased migration to the same destination type and decreased migration to competing destinations, but effects were weak for international migration. At the parish level, the effects of international migration followed the same pattern but previous internal from the parish strongly reduced subsequent internal migration, possibly due to a saturation effect following a period of national crisis from 1999-2001.

Finally, it is worth noting the importance of the *canton and year indicators* (bottom of Table 3). The canton indicators are enormously significant, particularly for international and local movements, reflecting the heterogeneity of the study cantons and the contextually-specific nature of migration decisions. The inclusion of the indicators accounts for these important differences between cantons, which would otherwise remain unobserved. Finally, the year indicators are jointly significant for local and international moves, indicating a pattern of change over time. Local mobility largely increased over time while international migration decreased, reflecting a tightening of immigration requirements to Spain, the primary post-2000 destination of international migrants (Jokisch 2007).

Overall, the significance of the control factors and consistency with theoretical expectations leaves us confident that we have accounted for the most important non-environmental influences on migration. Next we turn to the environmental factors to see if they can provide any additional explanation.

Environmental factors

Environmental factors had significant effects on all three migration streams. The joint tests reveal that environmental factors were most important for international migration, and that their overall level of significance was similar to that of migration networks and wealth or accessibility.

At the household level, land quality had a significant positive effect on international migration but not on other migration streams. For an increase in land quality equal to the mean within-canton standard deviation (1.7), the odds of international migration increased by 22%. This result suggests that land quality can act as a form of wealth that can be used to finance costly migrations. International migration from Ecuador is typically undocumented and requires a payment of US$5,000-15,000 to a smuggler or financier (Jokisch 2007). This is often financed by a loan from the same person and repaid primarily by migrant remittances. Households with lands that are high quality (and thus more valuable) may be viewed as better candidates for these loans, as well as having more capacity to finance migration directly. Land quality also had a marginally significant positive effect on local mobility, likely reflecting a similar ability to finance costs associated with local moves such as house construction.

At the community level, mean annual rainfall had a significant negative effect on international migration but, taking all three streams together, the effects were not jointly significant. However the canton indicators explain approximately 95% of the variation in mean rainfall, leaving us very little variation to explore in the model. When the canton indicators are removed (results not shown), annual rainfall has a highly significant negative effect on international migration (OR = 0.95, p = 0.001).These results taken together indicate that, conditional on farm size and other characteristics, a wet climate is linked to less international migration. Wetter areas have higher agricultural productivity which leads to higher demands for agricultural labor, particularly for men who make up the majority of both international migrants and farm laborers.

In contrast, the seasonality of rainfall significantly increased local mobility and internal migration but did not influence international migration, effects which were highly significant for all streams jointly. An increase in seasonality equal to the mean within-canton standard deviation (5.5%) leads to increase of 35% in the odds of local mobility and 14% in the odds of internal migration. High seasonality indicates the presence of distinct wet and dry seasons, which likely constrains agricultural activities and demands for agricultural labor to only a part of the year. In such a context, some household members may migrate to nearby destinations, from which they can return to assist the origin household during periods of peak labor demand, while a smaller number may be discouraged altogether and migrate away internally.

Finally, unusually good and bad harvest years *both* had the unexpected effect of reducing international migration. Poor harvests also significantly reduced local mobility. Models excluding the other environmental factors (above) produce similar results. These results suggest that there is an income effect of poor harvests on impairing the ability of the household to finance migration, particularly local and international. The additional effect of good harvests on reducing international mobility may reflect higher expectations of continued agricultural abundance and a need for household labor. Taken together with the results for rainfall seasonality, it appears that temporal fluctuations in rainfall increase local and internal migrations and decrease international migration. This is consistent with the results found by Henry et al. (2004) for Burkina Faso, where drought and dry climates increased rural-rural migration but decreased international migration.

In light of the particular importance of land quality and rainfall seasonality, we separately test for interactions between these factors and a subset of the other predictors, including gender, education, female headship, farm size, and the other environmental factors (Table 4). These models allow us to test predictions from the literature on vulnerability, and to observe interactions between agrarian and environmental characteristics. Both sets of interactions, with land quality (Model 2) and rainfall seasonality (Model 3), were jointly significant, and key results are described below.

Interactions with land quality were most important for international migration, including significant interactions with gender, education, and farm size (Model 2). The positive effects of land quality on international migration were significantly higher for women, individuals with a primary education, and households with a large farm, and lower for female-headed households and those with a medium-sized farm. These results suggest that women, the educated, and landed households are best able to take advantage of land quality to facilitate international migration. Educated and landed households with high-quality lands are unusually wealthy and are better able to finance international migrants. Given their high-quality lands, these households might also prefer to send female migrants and retain men to work as agricultural laborers (Radcliffe 1986, Gray 2010). In contrast, female-headed households and those with medium-sized farms appear to prefer to retain potential international migrants despite high land quality, perhaps due to greater labor demands by these households.

Among the interactions with rainfall seasonality (Model 3), those with female headship and annual rainfall are most significant and of interest. Relative to male-headed households, the positive effects of rainfall seasonality on local mobility are larger for female-headed households and the effects of rainfall seasonality on international migration become negative. This suggests that female-headed households, with less access to male labor and perhaps to credit, are pushed by seasonal climates to send local migrants (predominantly female) and are less able or willing to send international migrants (predominantly male). The effects of rainfall seasonality were also mediated by annual rainfall. Where annual rainfall is higher, the positive effect of seasonality on local mobility is reduced and the positive effect on internal migration is increased. This may reflect greater resources in wetter areas, enabling longer-distance migrations, or more environmental heterogeneity in dryer areas, allowing suitable destinations to be found nearby.

Conclusions

These results have important implications for migration theory, research methods and development practice. Regarding theory, the results do not support the common Neo-Malthusian narrative that views environmental factors as driving long-distance migration by vulnerable individuals. Instead, the results support a hybrid narrative that recognizes both the importance of both environmental structure and the agency of affected households. In rural Ecuador, well-positioned households are able to take advantage of land quality to send international migrants. At the same time, lack of security in rainfall increases local and internal movements and reduces international migration. The former effect is most important for women and latter effect is most important for female-headed households, underlining the central role of gender in the migration process. Together with the results of previous studies (e.g., Henry et al. 2004; Massey et al. 2007), this study indicates that Neo-Malthusian narrative of environmentally-induced migration should be set aside. Future authors should instead recognize the significant flexibility of individuals and households in their response to environmental conditions, as well as the existence of substantial barriers to long-distance migration

Regarding research methods, this study applied a novel combination of methods that could be drawn upon in future studies. Key elements of the methodology include the use of a special sampling strategy to oversample households with a diversity of out-migrants, the collection of structured event histories at various scales, linkages of communities to spatial datasets of environmental characteristics, and multivariate analysis incorporating area-level fixed effects. This approach enabled cost-effective data collection from a diverse set of migrant-sending household across a wide range of environmental conditions, which in turn made it possible to draw plausible conclusions about environmental influences on migration while taking into account a wealth of non-environmental factors.

This study represents an important step forward in methodology but many future improvements are possible. Key environmental measures are not included in this study, including soil samples and time-varying rainfall measurements. The former is due to budget limitations and the latter to the paucity of rainfall stations in Ecuador. Migration studies based upon retrospective data can also suffer from recall and proxy response errors, as well as missing data on entire departed households, both issues we took steps to address. A promising path forward is to collect or use panel datasets that interview the same respondents over time, and to link these individuals to environmental conditions at baseline. However, few current panel datasets in developing countries contain detailed data on both migration and the environment, as well as sufficient geographic coverage to offer wide variation in environmental conditions (for partial exceptions, see Massey et al. 2007; Rindfuss et al. 2007).

Regarding development practice, this study has implications for ongoing international discussions about "climate refugees". Discussions among policy-makers and in the media commonly assume that climate change will displace large numbers of people across international boundaries, and much attention has focused on how to provide legal protection for these "refugees" (EJF 2009). In contrast, this and other studies (Henry et al. 2004; Gray et al. 2009) suggest that climate-related displacement will often be local, occurring within nations or smaller areas. Referring to so many of the international migrants as "environmental refugees" unfortunately contributes to the "invisibility" of the much larger number of short-distance movers, who are also much more likely to be vulnerable and in need of assistance. A useful path forward for practitioners would be to focus on detecting areas affected by climate change (e.g., though remote sensing; Brown 2008) and consistently delivering aid in a timely fashion (e.g., though in-country purchases or cash transfers; Del Ninno et al. 2007), taking into account that some but all not affected people are likely to have been displaced.

In Ecuador, future climate changes are projected to include increased temperatures, particularly at higher altitudes, and increases in annual rainfall and rainfall seasonality (Urrutia & Vuille 2009). Our results suggest that, net of other factors, these changes might lead to decreased international migration and increased local and international migration from rural areas. Much will also depend on concurrent changes in the social and economic contexts of migration. Nonetheless, our findings support a renewed emphasis on rural livelihoods in Ecuadorian development policy as a buffer against future environmental change. Many of our study participants have benefited from Ecuador's cash transfer program (the Human Development Bond; Paxson & Schady 2007), but the accessibility and quality of state services and infrastructure continue to suffer from a pervasive urban bias (World Bank 2004). Agricultural extension (Howden et al. 2007) and crop insurance (Meze-Hausken et al. 2009) are both areas where few services are currently available and expansion could increase resilience to future climate change, reduce rural poverty, and limit the extent of future climate-related displacements.

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Figure 1. Map of the study areas.

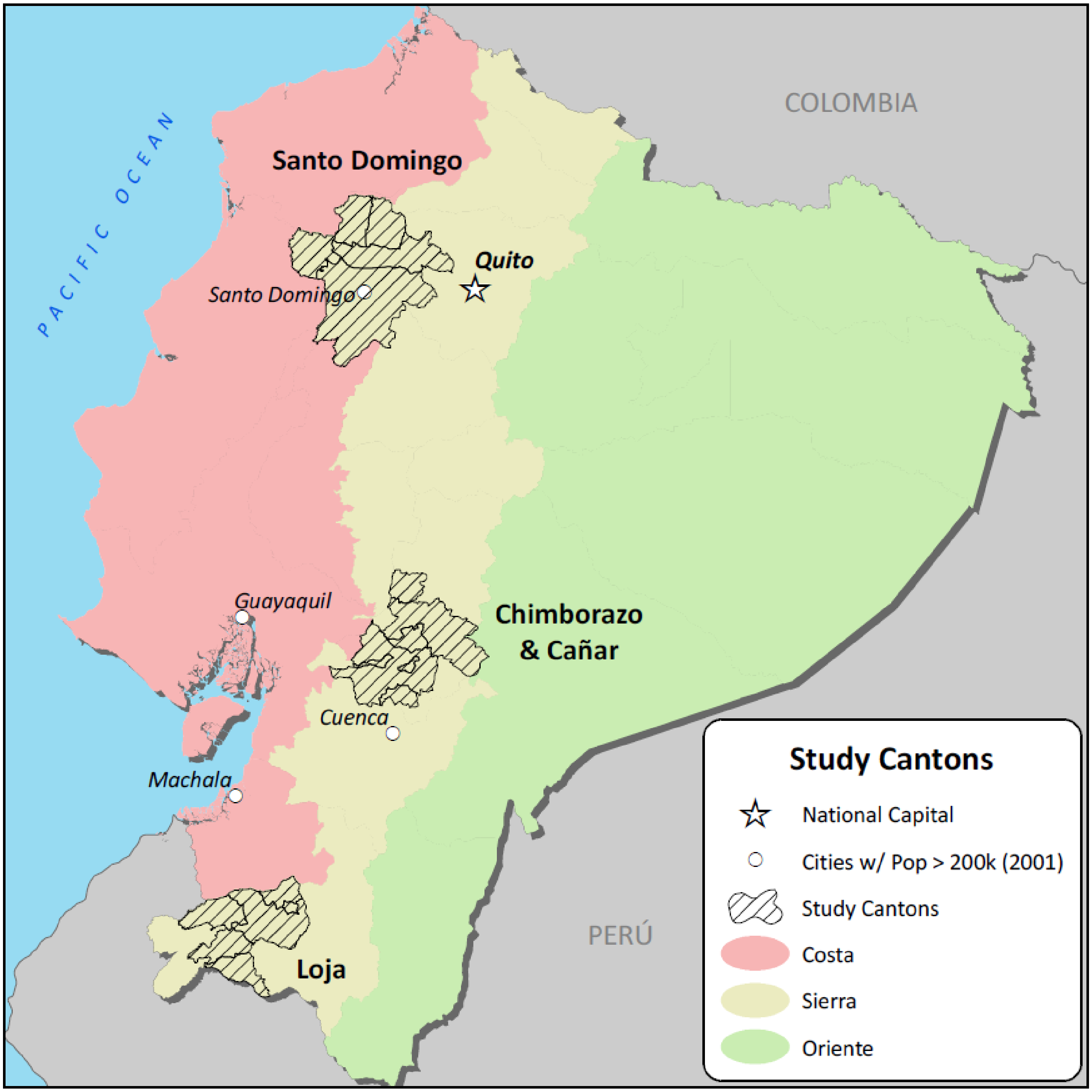

Table 1. Characteristics of the person-year dataset.

	Full	**Santo Domingo**	**Chimborazo /Cañar**	**Loja**
Cantons	17	5	6	6
Parishes	29	5	14	10
Sectors	55	15	21	19
Communities	107	27	35	44
Households	585	134	215	236
Individuals	1670	398	577	695
Person-years	7289	1624	2452	3213
Local moves	112	52	22	38
Internal moves	514	142	111	261
International moves	165	17	115	33

Table 2. Definitions and mean person-year values of the independent variables for the full sample and the three study areas.

Predictor	Unit	Level	Time-varying	Full sample	Santo Domingo	Chimborazo /Cañar	Loja
Demographic characteristics							
Female	1/0	Indiv	No	46%	39%	57%	36%
Age 14-16	1/0	Indiv	Yes	32%	33%	35%	27%
Age 17-19	1/0	Indiv	Yes	24%	25%	24%	21%
Age 20-24	1/0	Indiv	Reference	22%	24%	21%	22%
Age 25-29	1/0	Indiv	Yes	11%	11%	10%	14%
Age 30-39	1/0	Indiv	Yes	10%	7%	9%	17%
Child of head	1/0	Indiv	Yes	86%	87%	86%	85%
Married or partnered	1/0	Indiv	Yes	12%	12%	15%	7%
Less than primary education	1/0	Indiv	Reference	14%	19%	16%	5%
Primary education	1/0	Indiv	Yes	77%	74%	76%	81%
Secondary education	1/0	Indiv	Yes	9%	7%	8%	14%
Female head	1/0	HH	Yes	22%	10%	31%	19%
HH members age <15	#	HH	Yes	2.01	1.97	2.30	1.57
HH members age 15-39	#	HH	Yes	2.79	3.03	2.59	2.90
HH members age 40-59	#	HH	Yes	1.11	1.28	1.01	1.11
HH members age 60+	#	HH	Yes	0.46	0.28	0.47	0.64
Wealth and accessibility							
Owns home	1/0	HH	Yes	88%	80%	90%	93%
Small or no farm (<1 ha)	1/0	HH	Reference	46%	55%	50%	31%
Medium farm (1-5 ha)	1/0	HH	Yes	32%	13%	36%	43%
Large farm (>= 5 ha)	1/0	HH	Yes	22%	32%	14%	26%
Distance to school	km	HH	No	1.07	1.42	0.76	1.23
Distance to paved road	km	HH	No	1.09	0.74	1.19	1.30
Parish percent urban	%	Parish	No	13%	23%	8%	11%
Migration networks							
Personal migration experience	1/0	Indiv	Yes	18%	35%	10%	13%
HH local movers	#	HH	Yes	0.83	0.92	0.71	0.92
HH internal migrants	#	HH	Yes	1.05	1.31	0.60	1.55
HH international migrants	#	HH	Yes	0.41	0.04	0.77	0.19
Parish internal propensity	%	Parish	No	8%	8%	7%	12%
Parish international propensity	%	Parish	No	6%	3%	9%	4%
Environmental factors							
Land quality index	1-10	HH	Yes	4.03	3.73	4.14	4.17
Annual rainfall	dm/year	Com	No	15.1	28.1	8.4	12.8
Rainfall seasonality	%	Com	No	71%	80%	52%	94%
Poor harvest year	1/0	Com	Yes	14%	16%	15%	12%
Good harvest year	1/0	Com	Yes	31%	32%	31%	30%

a 1/0 indicates a dichotomous variable; # indicates a count.

Table 3. Multinomial event history analysis of migration to local, internal and international destinations (odds ratios and significance tests).

	Model 1			
Predictor	**Local**	**Internal**	**International**	**Joint test** [1]
Demographic characteristics				
Female	3.21 ***	1.29	0.30 ***	***
Age 14-16	0.26 ***	0.46 **	0.19 ***	***
Age 17-19	1.33	0.72 +	0.61	*
Age 25-29	1.31	0.55 +	1.49 +	*
Age 30-39	0.54	0.72	0.21 *	*
Child of head	2.55	1.94 **	0.50	*
Married or partnered	6.42 **	1.63 +	1.39	*
Primary education	1.70 *	1.36 *	2.02 +	+
Secondary education	2.60 **	1.79 **	3.38 *	**
Female HH head	1.13	0.65 *	0.74	+
HH members age <15	1.04	1.03	0.87	
HH members age 15-39	1.01	0.98	1.05	
HH members age 40-59	0.58 ***	1.30 *	0.77	**
HH members age 60+	0.65 *	0.78 +	0.56 *	**
Wealth and accessibility				
Owns home	0.18 ***	1.08	4.18 +	**
Medium farm (1-5 ha)	0.55 +	0.87	0.69	
Large farm (>= 5 ha)	0.32 **	0.69	1.07	*
Distance to school	0.83	1.15 **	1.06	*
Distance to paved road	1.23 ***	0.93 **	1.05	***
Parish percent urban	1.06 **	1.03 ***	0.99	***
Migration networks				
Personal migration experience	0.57 *	2.04 *	1.17	*
HH local movers	1.25 *	0.77 **	0.89	***
HH internal migrants	0.79 *	1.19 **	0.84 +	***
HH international migrants	0.70	0.74 *	1.13	**
Parish internal propensity	0.97	0.91 ***	1.03	*
Parish international propensity	0.70 *	0.93 *	1.27 *	***
Environmental factors				
Land quality index	1.15 +	0.99	1.12 **	**
Annual rainfall	1.00	1.01	0.82 *	
Rainfall seasonality	1.06 **	1.02 ***	0.99	***
Poor harvest year	0.37 *	0.95	0.48 **	*
Good harvest year	1.76	0.85	0.53 **	*
Joint tests [1]				
Demographic characteristics	281.23 ***	204.86 ***	241.97 ***	7677.3 ***
Wealth and accessibility	54.62 ***	54.95 ***	6.96	238.9 ***
Migration networks	15.70 *	50.73 ***	11.25 *	145.8 ***
Environmental factors	20.2 *	33.9 ***	62.4 ***	255.4 ***
Canton indicators	1463.8 ***	207.7 ***	4059.9 ***	26742.7 ***
Year indicators	58.5 ***	9.8	23.8 *	931.9 ***

Reference categories are male, age 20-24, less than primary education, and small or no farm.
Model also includes indicators for the canton and year, not shown.
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[1] Results of Wald tests of the joint significance of selected groups of coefficients as indicated.

Table 4. Interactions between land quality/precipitation seasonality and selected predictors (odds ratios and significance tests).

Predictor	Local	Internal	International	Joint test [1]
Model 2: Interactions with Land Quality				
Female	0.970	0.958	1.334 **	+
Primary education	1.031	1.033	1.432 ***	*
Secondary education	0.942	1.050	1.254	
Female HH head	0.922	0.910 +	0.870 +	+
Medium farm (1-5 ha)	0.742 +	1.003	0.744 **	*
Large farm (>= 5 ha)	0.782	1.100	1.762 **	*
Annual rainfall	0.997	0.992 *	1.006	*
Rainfall seasonality	0.993 *	1.000	1.001	
Poor harvest year	1.036	1.036	0.889	
Good harvest year	1.007	1.053	0.941	
Joint test [1]	29.8 **	26.8 *	81.6 ***	6828.0 ***
Model 3: Interactions with Rainfall Seasonality				
Female	1.009	0.999	1.018 *	
Primary education	1.000	0.999	0.982	
Secondary education	1.035	0.996	0.966	
Female HH head	1.057 **	1.000	0.977 ***	***
Medium farm (1-5 ha)	0.982	1.000	0.990	
Large farm (>= 5 ha)	0.994	1.007	1.016	
Land quality index	0.989 *	1.000	1.001	+
Annual rainfall	0.995 *	1.003 **	0.998	*
Poor harvest year	1.019	0.992	0.998	
Good harvest year	1.015	1.010 +	1.005	
Joint test [1]	33.1 **	20.2 *	76.9 ***	8700.7 ***

Models include main effects and indicators for the canton and year, not shown.
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[1] Results of Wald tests of the joint significance of selected groups of coefficients as indicated.

Appendix 1. Results of the polychoric principle components analysis of land quality.

Category	Indicator	Mean	Value	Coefficient
Topography	Flat land	0.16	0	-0.10
			1	0.52
	Hilly land	0.27	0	-0.08
			1	0.21
	Steep land	0.41	0	0.24
			1	-0.34
Soil type	Black soil	0.38	0	-0.24
			1	0.40
	Samdy soil	0.08	0	-0.02
			1	0.22
	Gravel soil	0.21	0	0.16
			1	-0.59
	Clay soil	0.03	0	0.00
			1	0.03
	Yellow/red soil	0.12	0	0.04
			1	-0.30
Soil quality	Good soil	0.36	0	-0.23
			1	0.40
	Regular soil	0.40	0	0.12
			1	-0.18
	Poor soil	0.07	0	0.05
			1	-0.73
Irrigation	Irrigation	0.28	0	-0.04
			1	0.09

Note: Indicators are based on ownership of a parcel with the characteristic, and are thus not mutually exclusive for households owning multiple parcels.